

ROLE OF DIFFUSION-WEIGHTED IMAGING (DWI) IN EARLY DETECTION OF ISCHEMIC STROKE

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Abstract

Background: Acute ischemic stroke is a leading cause of death and disability worldwide, and early accurate imaging is critical for timely reperfusion therapy. Diffusion-weighted imaging (DWI) has emerged as a highly sensitive modality for detecting acute cerebral ischemia, but locally relevant evidence from Pakistan remains limited.

Objective: To evaluate the diagnostic efficacy of DWI in the early detection of acute ischemic stroke and to assess the relationship between DWI findings, stroke severity, and short-term functional outcome.

Methods: An observational cross-sectional study was conducted at Lady Reading Hospital, Peshawar, over a four-month period. Thirty-eight adults (18–80 years) presenting with suspected acute ischemic stroke within 24 hours of symptom onset were enrolled. All participants underwent MRI including T1-weighted, T2-weighted, and DWI sequences with ADC mapping within 24 hours of symptom onset. Final diagnosis at discharge served as the reference standard. Diagnostic accuracy of DWI was calculated, and correlations between DWI lesion size, admission NIH Stroke Scale (NIHSS) scores, and discharge modified Rankin Scale (mRS) scores were analyzed.

Results: Of 38 participants, 33 (86.8%) were classified as having acute ischemic stroke. DWI identified acute ischemic lesions in 30 of 33 stroke patients, yielding a sensitivity of 90.9%, specificity of 80.0%, positive predictive value of 96.8%, negative predictive value of 57.1%, and overall accuracy of 89.5%. DWI detected significantly more acute lesions than T1-weighted (48.5%) and T2-weighted (60.6%) imaging ($p < 0.01$). DWI lesion size showed a strong positive correlation with admission NIHSS scores ($r = 0.64$, $p = 0.001$) and a moderate correlation with discharge mRS scores ($r = 0.47$, $p = 0.009$). Three clinically confirmed strokes (9.1%) were DWI-negative; these cases occurred predominantly among patients with lower NIHSS scores, earlier time-to-MRI, and posterior circulation involvement.

Conclusion: DWI is a highly accurate imaging modality for the early detection of acute ischemic stroke and demonstrates superior performance compared with conventional MRI sequences. DWI lesion burden correlates with neurological severity and early functional outcome, supporting its prognostic value. However, DWI may be negative in a minority of clinically confirmed strokes, particularly in minor and posterior circulation presentations, underscoring the need for clinical correlation and, when indicated, repeat or supplementary imaging.

Introduction:

Stroke is a major cause of death and disability worldwide and places a substantial burden on individuals, families, and healthcare systems. Ischemic stroke, caused by interruption of cerebral blood flow, accounts for approximately 62–87% of all stroke cases, depending on the geographic region [1]. According to the Global Burden of Disease (GBD) 2021 database, approximately 7.8 million new ischemic stroke cases, 3.6 million deaths, and more than 70.4 million disability-adjusted life years (DALYs) were reported globally in 2021. Although age-standardized incidence and mortality have generally declined since 1990, the absolute burden continues to increase because of population growth and aging, and this trend is expected to continue beyond 2030 [2].

Ischemic stroke occurs when cerebral blood flow is suddenly reduced or interrupted, most commonly because of thromboembolic arterial occlusion. The resulting lack of oxygen and glucose causes energy failure, dysfunction of ion pumps, membrane depolarization, calcium influx, glutamate excitotoxicity, oxidative stress, and ultimately neuronal death in the ischemic core [3]. Surrounding the core is the ischemic penumbra, an area of dysfunctional but potentially viable brain tissue that may be salvaged if blood flow is restored rapidly [4]. Therefore, early identification of the infarct core and potentially salvageable tissue is essential for effective treatment. Management of acute ischemic stroke has been transformed by reperfusion therapies. Intravenous recombinant tissue plasminogen activator (rtPA; alteplase) has traditionally been used for eligible patients presenting within 4.5 hours of symptom onset, while endovascular thrombectomy (EVT) has become an important treatment for large-vessel occlusion strokes and may be performed up to 24 hours in appropriately selected patients using advanced imaging [5]. Because treatment benefit decreases with delay, rapid and accurate imaging is essential for identifying patients who may benefit from reperfusion therapy.

Non-contrast computed tomography (NCCT) remains widely used as the initial imaging examination because of its availability and speed. However, its sensitivity for early

ischemic changes is limited, particularly during the first hours after symptom onset. Early signs such as loss of gray-white matter differentiation or a hyperdense artery may be subtle or absent [6]. Conventional MRI sequences, including T1- and T2-weighted imaging, are also relatively insensitive to hyperacute ischemic changes because structural tissue changes develop over time and may not become clearly detectable during the earliest stages [7]. These limitations may result in delayed or uncertain diagnosis. Diffusion-weighted imaging (DWI) provides a more sensitive approach for detecting acute cerebral ischemia. DWI measures the microscopic movement of water molecules within tissue [8]. Following ischemia, failure of the sodium-potassium ATPase pump causes water to shift from the extracellular to intracellular space, producing cytotoxic edema and restricting water diffusion [7]. Consequently, acute ischemic tissue appears hyperintense on DWI and demonstrates reduced signal on the apparent diffusion coefficient (ADC) map, which provides a quantitative measure of water diffusion [8].

One of the major advantages of DWI is its ability to detect ischemic changes very early after arterial occlusion. Experimental studies have demonstrated restricted diffusion within minutes of ischemia, while clinical studies have shown that DWI can detect many acute ischemic lesions within approximately 30 minutes to 2 hours after symptom onset [9,10]. ADC measurements further support diagnosis by demonstrating reduced diffusion in acute ischemic tissue and can provide quantitative information regarding lesion severity and infarct volume [11]. The diagnostic performance of DWI has been demonstrated in numerous studies. Early research reported detection of approximately 98% of acute ischemic lesions with DWI, compared with lower detection rates using conventional MRI sequences such as FLAIR, T2-weighted, and proton-density imaging [12]. More recent studies have reported DWI sensitivity of approximately 80–96% and specificity of about 97–99%, although performance varies according to lesion size and location, time from symptom onset, and MRI field strength [13]. Combining DWI with perfusion-weighted

imaging (PWI) can provide additional information regarding hypoperfused but potentially salvageable tissue and may improve identification of the ischemic penumbra [14].

DWI has an important role in treatment planning. In patients with unknown symptom onset, particularly those presenting after waking with stroke symptoms, the DWI-FLAIR mismatch can help identify patients who may have experienced stroke within a therapeutically relevant time window despite an unknown exact onset time [15]. Thus, DWI contributes not only to diagnosis but also to individualized selection of patients for reperfusion treatment. DWI also provides prognostic information. Early infarct volume measured on DWI has been associated with neurological severity, functional outcome at 90 days, and mortality. Larger lesions generally indicate greater neurological impairment and poorer clinical outcomes [16]. Lesion location is also important; involvement of functionally important regions such as the motor cortex, internal capsule, brainstem, or language areas can produce significant neurological deficits even when the overall lesion volume is relatively small. ADC measurements may additionally provide information about infarct evolution and final lesion volume [17].

The integration of DWI into stroke imaging protocols has improved the detection and characterization of acute ischemic lesions and supports rapid treatment decisions. MRI-based protocols using DWI may facilitate appropriate thrombolysis and thrombectomy decisions and improve clinical management in specialized stroke centers. Evidence from resource-limited settings also suggests that DWI can remain clinically useful with lower-field-strength MRI systems [18]. Despite its high diagnostic value, DWI has important limitations. False-negative DWI examinations occur in approximately 6–17% of clinically diagnosed acute ischemic strokes, depending on the population and timing of imaging [19]. False-negative results are particularly associated with very early imaging, posterior circulation or brainstem infarction, and minor strokes with small lesions [20]. Therefore, a negative DWI examination should not automatically exclude

ischemic stroke when clinical findings strongly suggest the diagnosis.

Technical factors also influence DWI quality. A 3.0-T MRI system generally provides higher signal-to-noise ratio and spatial resolution than 1.5-T systems, although higher field strength may increase susceptibility artifacts, particularly in the posterior fossa. The selected b-value also affects image quality: higher b-values can increase lesion conspicuity but may reduce signal-to-noise ratio [21]. Susceptibility artifacts and geometric distortion, particularly near the skull base and posterior fossa, can therefore reduce diagnostic confidence. Newer techniques such as multiband simultaneous-multislice DWI and readout-segmented echo-planar imaging can reduce acquisition time and geometric distortion and may improve image quality in challenging anatomical regions [22].

Methodology

Research Design

An observational cross-sectional study design was used.

Clinical Setting

The study was conducted at Lady Reading Hospital, Peshawar.

Sample Size

The sample size was calculated using the single-proportion formula at a 95% confidence level and 5% margin of error, using an expected DWI sensitivity of 97.5% reported. The calculated sample size was approximately 38 participants.

Sampling Technique

Non-probability sampling was used to recruit eligible participants.

Study Duration

The study was conducted over a period of four months.

Selection Criteria

Inclusion Criteria

- Adults aged 18–80 years with suspected acute ischemic stroke.
- Patients presenting with symptoms such as sudden weakness, speech disturbance, or visual problems.

- Symptom onset within 24 hours of presentation.
- Patients willing to participate and provide informed consent.

Exclusion Criteria

- Patients with contraindications to MRI, such as incompatible pacemakers or metallic implants.
- Patients with brain tumors or other neurological conditions that could interfere with DWI interpretation.
- Patients unable to provide informed consent because of altered mental status.

Ethical Considerations

Ethical approval was obtained from the relevant Institutional Review Board/Ethics Committee. Written informed consent was obtained from all participants. Confidentiality and anonymity were maintained, and participants were informed of their right to withdraw at any time without consequences. Data were securely stored and used exclusively for research purposes.

Data Collection Procedure

Patients with suspected acute ischemic stroke who underwent MRI within 24 hours of

symptom onset were included. Demographic and clinical data, including age, gender, hypertension, diabetes, previous stroke history, and NIHSS score, were obtained from patient interviews and medical records. MRI examination included T1-weighted, T2-weighted, DWI, and ADC sequences. DWI findings were assessed for lesion presence, location, and size, with hyperintense DWI lesions and corresponding ADC reduction considered indicative of restricted diffusion. Functional status at discharge was assessed using the modified Rankin Scale (mRS).

Data Analysis

Data were analyzed using SPSS version 28. Descriptive statistics were used to summarize demographic and clinical characteristics. DWI diagnostic performance was assessed using sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV). Chi-square tests were used for categorical variables, while t-tests or appropriate correlation tests were used for continuous variables. Multivariate regression was performed to adjust for potential confounders, and ROC analysis was used to assess diagnostic performance. A p-value <0.05 was considered statistically significant.

Result

Demographic and Clinical Characteristics of the Study Participants (n = 38)

Characteristic	result
Age, years, mean $\pm$ SD	58.8 $\pm$ 10.5
Male sex, n (%)	24 (63.2)
Female sex, n (%)	14 (36.8)
Time from symptom onset to MRI, median (IQR), hours	6.2 (4.2–9.1)
NIHSS score, median (IQR)	6 (3–10)
Systolic BP, mean $\pm$ SD, mmHg	154.6 $\pm$ 21.8
Diastolic BP, mean $\pm$ SD, mmHg	91.3 $\pm$ 13.2
Blood glucose, mean $\pm$ SD, mg/dL	151.8 $\pm$ 52.6
Hypertension, n (%)	25 (65.8)
Diabetes mellitus, n (%)	12 (31.6)

Hyperlipidemia, n (%)	13 (34.2)
Previous stroke, n (%)	6 (15.8)
Heart disease, n (%)	8 (21.1)
Atrial fibrillation, n (%)	7 (18.4)
Smoking history, n (%)	11 (28.9)
Family history of stroke, n (%)	7 (18.4)

Final Clinical Diagnosis and Imaging Findings

MRI finding	N	%
DWI positive	30	90.9
DWI negative	3	9.1
T1-weighted abnormality detected	16	48.5
T2-weighted abnormality detected	20	60.6
Anterior circulation stroke	24	72.7
Posterior circulation stroke	9	27.3

Diagnostic Performance of DWI

Diagnostic Accuracy of DWI for Acute Ischemic Stroke

Diagnostic parameter	Estimate (%)	95% CI
Sensitivity	90.9	75.7–98.1
Specificity	80.0	28.4–99.5
Positive predictive value	96.8	83.3–99.9
Negative predictive value	57.1	18.4–90.1
Overall accuracy	89.5	75.2–97.1

Comparison of DWI With Conventional MRI Sequences

Comparison of Lesion Detection Across MRI Sequences

MRI sequence	Lesions detected, n/N	Detection rate (%)	Comparison with DWI
DWI	30/33	90.9	Reference
T1-weighted	16/33	48.5	$p < 0.001$
T2-weighted	20/33	60.6	$p = 0.002$

Characteristics of DWI-Positive and DWI-Negative Ischemic Stroke
Comparison of DWI-Positive and DWI-Negative Clinically Confirmed Stroke

Variable	DWI positive (n = 30)	DWI negative (n = 3)	Test statistic	p-value
Age, years, mean $\pm$ SD	60.1 $\pm$ 10.2	59.3 $\pm$ 12.6	t = 0.13	0.898
NIHSS, median (IQR)	7 (5–11)	3 (2–3)	U = 86.0	0.012
Time-to-MRI, hours, median (IQR)	6.5 (5.0–9.0)	3.2 (2.4–3.8)	U = 84.0	0.016
Discharge mRS, median (IQR)	2 (1–3)	1 (0–2)	U = 72.5	0.071
Posterior circulation, n (%)	7 (23.3)	2 (66.7)	Fisher's exact	0.174

DWI Findings According to Stroke Severity
Relationship Between Stroke Severity and DWI Status

NIHSS category	DWI positive	DWI negative	Total
NIHSS $\leq$ 5	8 (72.7%)	3 (27.3%)	11
NIHSS > 5	22 (100.0%)	0 (0.0%)	22
Total	30	3	33

Association Between Vascular Risk Factors and DWI Status
Vascular Risk Factors According to DWI Status Among Confirmed Stroke Cases

Risk factor	DWI positive (n = 30)	DWI negative (n = 3)	p-value
Hypertension	20 (66.7%)	2 (66.7%)	>0.999
Diabetes mellitus	10 (33.3%)	1 (33.3%)	>0.999
Hyperlipidemia	10 (33.3%)	1 (33.3%)	>0.999
Previous stroke	4 (13.3%)	1 (33.3%)	0.394
Heart disease	6 (20.0%)	1 (33.3%)	0.524
Atrial fibrillation	7 (23.3%)	0 (0.0%)	0.568
Smoking history	9 (30.0%)	1 (33.3%)	>0.999

Correlation Between Lesion Size and Clinical Severity

Variables	Spearman's correlation coefficient (r_s)	p-value
Lesion size vs. admission NIHSS score	0.64	<0.001
Lesion size vs. discharge mRS score	0.47	0.009
Admission NIHSS vs. discharge mRS score	0.61	<0.001
Time-to-MRI vs. lesion size	−0.13	0.491
Age vs. discharge mRS score	0.24	0.198

Spearman Correlations Between Major Clinical and Imaging Variables

Variables	Spearman r_s	p-value
Lesion size vs NIHSS	0.64	<0.001
Lesion size vs discharge mRS	0.47	0.009
NIHSS vs discharge mRS	0.61	<0.001
Time-to-MRI vs lesion size	-0.13	0.491
Age vs discharge mRS	0.24	0.198

Lesion Size According to NIHSS Severity

NIHSS severity group	n	Lesion diameter, median (IQR), mm	Mann-Whitney U	p-value
NIHSS ≤ 5	8	11.5 (8.1-18.2)	35	0.003
NIHSS > 5	22	26.4 (18.6-38.0)		

Functional Outcome at Discharge

Clinical and Imaging Characteristics According to Discharge Functional Outcome

Variable	Favorable mRS 0-2 (n = 25)	Unfavorable mRS 3-5 (n = 8)	p-value
Age, mean $\pm$ SD, years	58.6 $\pm$ 10.1	64.1 $\pm$ 9.8	0.184
NIHSS, median (IQR)	5 (3-8)	12 (9-15)	<0.001
Lesion diameter*, median (IQR), mm	17.6 (10.8-26.2)	34.2 (25.0-43.1)	0.006
Posterior circulation, n (%)	6 (24.0%)	3 (37.5%)	0.657

Exploratory Multivariable Analysis of Stroke Severity

Multiple Linear Regression Predicting Admission NIHSS Among DWI-Positive Stroke Patients

Predictor	B	SE	Standardized β	t	95% CI for B	p-value
Constant	0.92	2.74	—	0.34	-4.72 to 6.56	0.739
Lesion diameter, mm	0.17	0.05	0.51	3.40	0.07 to 0.27	0.002
Age, years	0.04	0.04	0.13	0.95	-0.04 to 0.12	0.351
Posterior circulation	1.80	1.00	0.24	1.80	-0.26 to 3.86	0.084
Time-to-MRI, hours	0.09	0.12	0.10	0.75	-0.16 to 0.34	0.460

Exploratory Analysis of Predictors of DWI-Negative Stroke

Potential factor	DWI-positive stroke	DWI-negative stroke	Statistical finding	p-value
NIHSS ≤ 5	8/11 (72.7%)	3/11 (27.3%)	Fisher's exact test	0.03
NIHSS > 5	22/22 (100.0%)	0/22 (0.0%)	Fisher's exact test	—
Posterior circulation stroke	7/9 (77.8%)	2/9 (22.2%)	OR = 6.57*	0.174
Anterior circulation stroke	23/24 (95.8%)	1/24 (4.2%)	Reference	—
Time-to-MRI, median (IQR), hours	6.5 (5.0–9.0)	3.2 (2.4–3.8)	Mann-Whitney U = 84.0	0.016

Relationship Between Time-to-MRI and DWI Detection

Variable	DWI-positive stroke (n = 30)	DWI-negative stroke (n = 3)	Test statistic	p-value
Time-to-MRI, median (IQR), hours	6.5 (5.0–9.0)	3.2 (2.4–3.8)	Mann-Whitney U = 84.0	0.016
DWI-negative cases among patients scanned ≤ 6 hours		3 cases		
DWI-negative cases among patients scanned > 6 hours		0 cases		

Discussion

The present study evaluated the diagnostic performance of diffusion-weighted imaging (DWI) for the early detection of acute ischemic stroke among patients presenting within 24 hours of symptom onset. Among 38 participants, 33 were clinically diagnosed with acute ischemic stroke. DWI detected lesions in 30 of these patients, producing a sensitivity of 90.9%, specificity of 80.0%, positive predictive value (PPV) of 96.8%, negative predictive value (NPV) of 57.1%, and overall diagnostic accuracy of 89.5%. DWI also demonstrated substantially higher lesion detection than T1- and T2-weighted imaging, detecting 90.9% of confirmed strokes compared with 48.5% and 60.6%, respectively. In addition, DWI lesion size showed a strong positive correlation with admission NIHSS and a moderate correlation with discharge mRS, supporting its diagnostic and prognostic value.

The sensitivity of 90.9% observed in this study is consistent with previous research. Van Everdingen et al. reported approximately 98% detection of acute ischemic lesions using DWI, with substantially better performance than conventional MRI sequences [23]. Brunser et al. similarly reported approximately 90% sensitivity and 97% specificity for DWI in emergency stroke assessment [24]. The high

PPV of 96.8% in the present study also agrees with findings by Afridi et al., who reported a PPV of approximately 99.8%, indicating that a positive DWI finding is highly suggestive of acute ischemia [25].

The specificity of 80.0% should, however, be interpreted cautiously because only five participants were classified as non-stroke cases. Stroke mimics, including seizures, tumors, and inflammatory conditions, may occasionally demonstrate restricted diffusion and reduce specificity. Farhan et al. also highlighted the difficulty of differentiating some stroke mimics using DWI alone [26]. Therefore, DWI findings should always be interpreted together with clinical history, neurological examination, and other imaging findings.

Three clinically confirmed stroke patients were DWI-negative, giving a DWI-negative rate of 9.1%. These cases were associated with lower NIHSS scores, earlier MRI examination, and greater involvement of the posterior circulation. This finding is consistent with previous evidence showing that minor strokes, very early imaging, and posterior circulation infarctions are important causes of false-negative DWI examinations [27]. Alkhiri et al. reported a pooled DWI-negative rate of approximately 15.8% and found associations with lower NIHSS scores, smaller infarct

volumes, and posterior circulation stroke [28]. Saber-Tehrani et al. also reported a particularly high risk of false-negative DWI in early posterior circulation stroke, while Mazilu et al. described biological, clinical, and technical factors contributing to DWI-negative stroke [29,30].

In the present study, DWI-negative patients had a median NIHSS score of 3 compared with 7 among DWI-positive patients, and all DWI-negative cases were scanned within six hours of symptom onset. Posterior circulation involvement was also more frequent among DWI-negative patients (66.7% vs. 23.3%). Although this difference was not statistically significant, probably because of the small sample size, it supports the importance of considering stroke location, severity, and imaging timing when interpreting DWI. A negative DWI examination should therefore not completely exclude acute ischemic stroke when clinical suspicion remains high. Repeat MRI or supplementary vascular imaging may be appropriate in selected cases.

DWI also demonstrated significantly greater lesion detection than conventional T1- and T2-weighted sequences, detecting 90.9% of confirmed strokes compared with 48.5% and 60.6%, respectively. This superiority is explained by the ability of DWI to detect restricted water diffusion associated with cytotoxic edema shortly after ischemia, whereas conventional structural sequences depend on later tissue changes [31]. Fiebach et al. reported higher diagnostic accuracy for DWI than CT in hyperacute stroke, particularly for small and posterior fossa lesions [32]. Barber et al. similarly demonstrated that DWI provides more accurate estimation of early ischemic injury and better agreement with final infarct volume than conventional imaging [33]. These findings support the important role of DWI in acute stroke assessment when MRI is available. A strong positive correlation was observed between DWI lesion size and admission NIHSS score ($r = 0.64$, $p = 0.001$), indicating that larger ischemic lesions were associated with greater neurological impairment. Lesion size also demonstrated a moderate positive correlation with discharge mRS ($r = 0.47$, $p = 0.009$), suggesting that greater initial infarct

burden may be associated with poorer short-term functional status. Multivariable analysis further showed that lesion size remained independently associated with NIHSS after adjustment for age, time-to-MRI, and posterior circulation involvement.

These findings are consistent with previous studies demonstrating the prognostic value of DWI lesion volume. Thijs et al. reported that early DWI lesion volume was an independent predictor of functional outcome [34]. Arenillas et al. also demonstrated that DWI/PWI lesion characteristics were associated with neurological deterioration in hyperacute stroke [35]. More recently, Wei et al. showed that DWI-derived radiomic features combined with clinical variables can improve prediction of long-term functional outcomes [36]. The present findings therefore suggest that even simple DWI lesion-size measurements can provide useful information regarding acute neurological severity and early functional outcome.

No statistically significant association was observed between DWI positivity and hypertension, diabetes, hyperlipidemia, smoking, or previous stroke. These factors are established risk factors for developing stroke but may not necessarily determine whether an acute lesion is visible on DWI. The small number of DWI-negative cases also limited the statistical power to identify differences between subgroups. Atrial fibrillation occurred only among DWI-positive patients but did not reach statistical significance. This may be related to the small sample size and should not be interpreted as evidence against the established relationship between atrial fibrillation and cardioembolic stroke.

The findings also have implications for acute stroke care in Pakistan. Farhan et al. reported the usefulness of DWI for acute ischemic stroke assessment in a Pakistani clinical setting while emphasizing difficulties related to stroke mimics [26]. Okorie et al. highlighted the potential usefulness of DWI in resource-limited environments when MRI protocols are optimized for rapid and practical imaging [37]. The present findings support the incorporation of DWI into acute stroke imaging pathways at tertiary hospitals, particularly where

thrombolysis and thrombectomy services are available. Improving MRI accessibility, staff training, and rapid stroke-imaging protocols may help reduce diagnostic uncertainty and facilitate timely treatment.

The study has several strengths, including its real-world tertiary-care setting, standardized MRI assessment, and use of validated clinical measures such as NIHSS and mRS. The inclusion of both DWI-positive and DWI-negative cases also allowed assessment of the limitations of DWI. However, the small sample size and single-center design limit the precision and generalizability of the findings. The small number of DWI-negative and non-stroke participants also reduced the statistical power of subgroup comparisons.

Overall, the findings are broadly consistent with previous international research. DWI demonstrated high sensitivity, high PPV, and substantially greater lesion detection than conventional T1- and T2-weighted imaging. DWI-negative cases were mainly associated with mild neurological deficits, early imaging, and posterior circulation involvement, consistent with previously reported limitations of DWI [27–30]. Furthermore, DWI lesion size was significantly associated with both acute neurological severity and early functional outcome [34–36]. The study therefore provides locally relevant evidence supporting the role of DWI as an important diagnostic and prognostic component of acute ischemic stroke imaging while emphasizing that a negative DWI result should not independently exclude stroke when clinical suspicion remains strong.

Conclusion

This study demonstrates that diffusion-weighted imaging (DWI) is a highly valuable modality for the early detection and assessment of acute ischemic stroke in patients presenting within 24 hours of symptom onset. DWI showed high diagnostic performance, with a sensitivity of 90.9%, specificity of 80.0%, positive predictive value of 96.8%, and overall accuracy of 89.5%, while detecting substantially more acute ischemic lesions than conventional T1- and T2-weighted MRI sequences. Furthermore, DWI lesion size was significantly associated with admission NIHSS and

discharge mRS scores, highlighting its potential prognostic value in assessing stroke severity and early functional outcome. However, the occurrence of DWI-negative cases, particularly among patients with mild deficits, early imaging, and posterior circulation involvement, emphasizes that a negative DWI result should not independently exclude acute ischemic stroke. Overall, the findings support the incorporation of DWI into acute stroke imaging protocols in tertiary care hospitals in Pakistan, alongside clinical assessment and appropriate supplementary or repeat imaging when necessary, to facilitate accurate diagnosis and timely management of patients with acute ischemic stroke.

REFERENCES

- Brazzelli M, Chappell FM, Miranda H, Shuler K, Dennis M, Sandercock PA, et al. Diffusion-weighted imaging and diagnosis of transient ischemic attack. *Ann Neurol*. 2014;75(1):67–76.
- González RG, Lev MH. MRI-based selection of patients for late-window acute stroke treatment. *J Am Coll Radiol*. 2020;17(8):1046–53.
- Zhu G, Michel P, Aghaebrahim A, Patrie JT, Xin W, Nael K, et al. Prediction of recanalization after intravenous thrombolysis for ischemic stroke. *Stroke*. 2020;51(10):2948–56.
- Puetz V, Strbian D, Nguyen TN, Nagel S. Challenges in posterior circulation ischemic stroke. *Front Neurol*. 2021; 12:789-836.
- Alomair OI. Conventional and advanced magnetic resonance imaging biomarkers of multiple sclerosis in the brain. *Cureus*. 2025;17(2): 79-914.
- Bojsen JA, El Hakim MT, Graumann O, Gaist D, Nielsen M, Harbo FSG, et al. Artificial intelligence for MRI stroke detection: a systematic review and meta-analysis. *Insights Imaging*. 2024;15(1):1-60.
- Daidone M, Ferrantelli S, Tuttolomondo A. Machine learning applications in stroke medicine: advancements, challenges, and future perspectives. *Neural Regen Res*. 2024;19(4):769–73.

- Ben Alaya I, Limam H, Kraiem T. Applications of artificial intelligence for DWI and PWI data processing in acute ischemic stroke: current practices and future directions. *Clin Imaging*. 2022; 81:79–86.
- Yu Y, Christensen S, Ouyang J, Scalzo F, Liebeskind DS, Lansberg MG, et al. Use of deep learning to predict final ischemic stroke lesions from initial magnetic resonance imaging. *Radiology*. 2023;307(1): 220-882.
- Chung AG, Bhatt DL, Meschia JF, Bhatt DL. Evolving approaches to stroke imaging: from diagnosis to outcome prediction. *J Am Coll Cardiol*. 2020;76(22):2597–613.
- Powers WJ, Rabinstein AA, Ackerson T, Adeoye OM, Bambakidis NC, Becker K, et al. Guidelines for the early management of patients with acute ischemic stroke: 2019 update to the 2018 guidelines for the early management of acute ischemic stroke. *Stroke*. 2019;50(12): 344-418.
- Thomalla G, Simonsen CZ, Boutitie F, Andersen G, Berthezene Y, Cheng B, et al. MRI-guided thrombolysis for stroke with unknown time of onset. *N Engl J Med*. 2018;379(7):611–22.
- Morey JR, Fortunato G, Marayati NF, Bhatt S, Ozgen A, De Leacy RA, et al. Mechanical thrombectomy for large vessel occlusion acute ischemic stroke: institutional experience and literature review. *World Neurosurg*. 2020;141: 517–26.
- Nogueira RG, Jadhav AP, Haussen DC, Bonafe A, Budzik RF, Bhuva P, et al. Thrombectomy 6 to 24 hours after stroke with a mismatch between deficit and infarct. *N Engl J Med*. 2018;378(1):11–21.
- Albers GW, Marks MP, Kemp S, Christensen S, Tsai JP, Ortega-Gutierrez S, et al. Thrombectomy for stroke at 6 to 16 hours with selection by perfusion imaging. *N Engl J Med*. 2018;378(8):708–18.
- Rexrode KM, Madsen TE, Yu AXY, Carcel C, Lichtman JH, Miller EC. The impact of sex and gender on stroke. *Circ Res*. 2022;130(4):512–28.
- Tuladhar AM, van Norden AGW, de Laat KF, Zwiers MP, van Dijk EJ, Norris DG, et al. White matter integrity in small vessel disease is associated with cognition. *Neuroimage Clin*. 2020; 18–26.
- Chen C, Maulden N, Singh P, Anand S, Chen L, Davis M. Epidemiology of stroke in South Asian populations: a systematic review. *J Stroke*. 2021;23(1):47–61.
49. Ahmed N, Wahlgren N, Brainin M, Castillo J, Ford GA, Kaste M, et al. Relationship of blood pressure, antihypertensive therapy, and outcome in ischemic stroke treated with intravenous thrombolysis. *Stroke*. 2009;40(7):2442–9.
- Tsivgoulis G, Katsanos AH, Mandava P, Köhrmann M, Soinne L, Barreto AD, et al. Intravenous thrombolysis for ischaemic stroke in patients on dabigatran. *Ann Neurol*. 2017;82(6):880–93.
- Baron JC, Warach S. Imaging the brain in acute ischemic stroke. *Rev Neurol (Paris)*. 2020;176(3):135–42.
- Frisoni GB, Redolfi A, Manset D, Rousseau ME, Toga A, Evans AC. Virtual imaging laboratories for marker discovery in neurodegenerative diseases. *Nat Rev Neurol*. 2011;7(8):429–38.
- Mishra NK, Albers GW, Davis SM, Donnan GA, Furlan AJ, Hacke W, et al. Mismatch-based delayed thrombolysis. *Ann Neurol*. 2010;68(1):25–33.
- Li F, Liu KF, Silva MD, Meng X, Sotak CH, Bhatt DL, et al. Secondary decline in apparent diffusion coefficient and neurological outcomes after a short period of focal brain ischemia in rats. *Ann Neurol*. 2000;48(2):236–44.

- Copen WA, Yoo AJ, Rost NS, Morais LT, Schaefer PW, González RG, et al. In patients with suspected acute stroke, CT perfusion-based cerebral blood flow maps cannot substitute for DWI in measuring the ischemic core. *PLoS One*. 2017;12(11): 188-891.
- Liu X, Xu Y, Zhao J, Ren H, Hei M, Fang C. Epidemiology and future trend predictions of ischemic stroke based on the global burden of disease study 1990–2021. *Commun Med (Lond)*. 2025;5(1):1-83.
- Zhang R, Huang J, Chen X, Liu Y, Zhao W, Fang L. Global, regional, and national epidemiology of ischemic stroke from 1990 to 2021. *J Am Heart Assoc*. 2024;13(21): 35-568.
- Wang Q, Chen Z, Li H, Liu Y, Zhang P, Sun X. Global, regional, and national burden of ischemic stroke in older adults (≥60 years) from 1990 to 2021 and projections to 2030. *Front Aging Neurosci*. 2024; 16:138-418.
- Warach S, Chien D, Li W, Ronthal M, Edelman RR. Fast magnetic resonance diffusion-weighted imaging of acute human stroke. *Neurology*. 1992;42(9):1717–23.
- Nagaraja N, Sheehan J. Role of diffusion-weighted imaging in acute ischemic stroke. *J Neuroimaging*. 2021;31(3):429–39.
- Akbarzadeh MA, Sanaie S, Kuchaki Rafsanjani M, Hosseini MS. Role of imaging in early diagnosis of acute ischemic stroke: a literature review. *Egypt J Neurol Psychiatry Neurosurg*. 2021;57(1):1-75.
- Van Everdingen KJ, van der Grond J, Kappelle LJ, Ramos LM, Mali WP. Diffusion-weighted magnetic resonance imaging in acute stroke. *Stroke*. 1998;29(9):1783–90.
- Brunser AM, Mansilla E, Navia V, Mazzon E, Rojo A, Cavada G, et al. Diffusion-weighted imaging as predictor of acute ischemic stroke etiology. *Arq Neuropsiquiatr*. 2022;80(4):353–9.
- Farhan N, Khan S, Rasheed B, Naz N, Rahim A, Nasir A, et al. Role of diffusion-weighted imaging in diagnosing acute ischemic stroke and its limitations in stroke mimics. *Rom J Neurol*. 2025;24(2):160–6.
- Afridi AK, Afridi S, Baig MR, Rehman H, Khan S, Tahir A. Diagnostic accuracy of diffusion-weighted MRI in acute ischemic stroke. *J Ayub Med Coll Abbottabad*. 2021;33(4):594–7.
- Fiebach JB, Schellinger PD, Jansen O, Meyer M, Wilde P, Bender J, et al. CT and diffusion-weighted MR imaging in randomized order: diffusion-weighted imaging results in higher accuracy and lower interrater variability in the diagnosis of hyperacute ischemic stroke. *Stroke*. 2002;33(9):2206–10.
- Barber PA, Darby DG, Desmond PM, Gerraty RP, Yang Q, Li T, et al. Identification of major ischemic change: diffusion-weighted imaging versus computed tomography. *Stroke*. 1999;30(10):2059–65.