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DIAGNOSTIC ACCURACY OF APPARENT DIFFUSION COEFFICIENT FOR THE DIAGNOSIS OF ACUTE ARTERIAL STROKE KEEPING DIFFUSION WEIGHTED IMAGING AS GOLD STANDARD

PRECISÃO DIAGNÓSTICA DO COEFICIENTE DE DIFUSÃO APARENTE NO DIAGNÓSTICO DE AVC ARTERIAL AGUDO, TOMANDO A IMAGEM PONDERADA POR DIFUSÃO COMO PADRÃO-OURO

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Abstract
Objective To determine the diagnostic accuracy of apparent diffusion coefficient for diagnosis of acute arterial stroke taking diffusion weighted imaging as gold standard. Study Design Cross sectional validation study. Duration and Place of Study Conducted from December 2025 to March 2026 at Radiology Department, Ittefaq Hospital Trust, Lahore. Methodology A total of 166 patients aged 30–70 years with clinical diagnosis of acute arterial stroke were included. Magnetic resonance imaging was performed and apparent diffusion coefficient and diffusion weighted imaging findings were recorded. Mean and standard deviation was calculated for quantitative variables while frequency and percentage were used for qualitative variables. Diagnostic accuracy parameters including sensitivity, specificity, positive predictive value and negative predictive value was calculated by

Resumo
Objetivo Determinar a precisão diagnóstica do coeficiente de difusão aparente no diagnóstico de acidente vascular cerebral arterial agudo, utilizando a imagem ponderada por difusão como padrão-ouro. Desenho do estudo Estudo de validação transversal. Duração e local do estudo Realizado de dezembro de 2025 a março de 2026 no Departamento de Radiologia do Ittefaq Hospital Trust, em Lahore. Metodologia Foram incluídos 166 pacientes com idades entre 30 e 70 anos com diagnóstico clínico de acidente vascular cerebral arterial agudo. Foi realizada ressonância magnética, e os resultados do coeficiente de difusão aparente e da imagem ponderada por difusão foram registrados. A média e o desvio padrão foram calculados para as variáveis quantitativas, enquanto a frequência e a porcentagem foram utilizadas para as variáveis qualitativas. Os parâmetros de

2×2 table. Results Mean age was 53.89 ± 8.52 years and mean body mass index was 28.11 ± 3.12 kg/m². Males were 53.6% and females 46.4%. Apparent diffusion coefficient showed sensitivity 70%, specificity 80% and overall diagnostic accuracy 73%. Positive predictive value was 86% while negative predictive value was 59%. Conclusion Apparent diffusion coefficient is moderately accurate for diagnosis of acute arterial stroke but cannot be used alone as compared to diffusion weighted imaging.
Short Running Title: Diagnostic accuracy of apparent diffusion coefficient in acute arterial stroke

Keywords: Diffusion Magnetic Resonance Imaging. Ischemic Stroke. Magnetic Resonance Imaging. Sensitivity and Specificity. Stroke.

precisão diagnóstica, incluindo sensibilidade, especificidade, valor preditivo positivo e valor preditivo negativo, foram calculados por meio de tabela 2×2. Resultados A idade média foi de 53,89 ± 8,52 anos e o índice de massa corporal médio foi de 28,11 ± 3,12 kg/m². Os homens representaram 53,6% e as mulheres, 46,4%. O coeficiente de difusão aparente apresentou sensibilidade de 70%, especificidade de 80% e precisão diagnóstica geral de 73%. O valor preditivo positivo foi de 86%, enquanto o valor preditivo negativo foi de 59%. Conclusão O coeficiente de difusão aparente é moderadamente preciso para o diagnóstico de acidente vascular cerebral arterial agudo, mas não pode ser utilizado isoladamente em comparação com a imagem ponderada por difusão. Título abreviado Precisão diagnóstica do coeficiente de difusão aparente no acidente vascular cerebral arterial agudo.

Palavras-chave: *Imagem por Ressonância Magnética de Difusão. Acidente Vascular Cerebral Isquêmico. Imagem por Ressonância Magnética. Sensibilidade e Especificidade. Acidente Vascular Cerebral.*

1 INTRODUCTION

Acute arterial stroke refers to a significant neurological disorder characterized by the sudden onset of reduced or completely blocked cerebral circulation, usually caused by the formation of a thrombus or embolus.[1] Acute arterial stroke is considered one of the major factors of mortality and disability worldwide. Early detection of acute arterial stroke is essential in preventing permanent cerebral damage. Ischemia occurs within minutes of the onset of acute arterial stroke, causing cellular hypoxia, cellular energy depletion, and eventually cell death if not treated in time.[2] Clinically, acute arterial stroke presents with sudden weakness, dysarthria or aphasia, facial asymmetry, or decreased consciousness depending on the area of the brain involved.[3] Although computed tomography scans are commonly used in the detection of acute arterial stroke, they are often unable to display early ischemic changes in the first hours of onset; thus, advanced imaging techniques are often necessary in the early detection of acute arterial stroke.[4]

The apparent diffusion coefficient (ADC) is a quantitative measurement obtained from magnetic resonance imaging (MRI).[5] It calculates the amount of water molecule diffusion in the body. In acute arterial strokes, cytotoxic edema impairs intracellular water movement, causing decreased ADC values in the affected areas of the brain.[6] This decrease in ADC values can be observed in the early stages of the stroke, including minutes after the onset of the stroke. This makes ADC a significant tool in the early diagnosis of acute arterial strokes. In addition, ADC maps can differentiate between restricted diffusion and the T2 shine-through phenomenon.[7]

Diffusion-weighted imaging (DWI) is an advanced magnetic resonance imaging technique that is highly sensitive in detecting early signs of ischemia in the brain by detecting restricted diffusion of water.[8] In acute arterial stroke, it is highly sensitive in detecting restricted diffusion in the affected area of the brain, as indicated by a hyperintense signal on the image.[9] It is therefore superior in comparison to conventional imaging techniques, as it detects restricted diffusion within minutes of onset of stroke. Its application in acute arterial stroke is attributed to its sensitivity and fast imaging times. It is particularly beneficial in detecting small infarcts and lesions in the posterior circulation of the brain, which is often difficult using conventional imaging techniques.[10]

Early and accurate detection of acute arterial stroke is critical since it has been proven that early intervention significantly reduces morbidity and mortality. Although Diffusion-Weighted Imaging has high sensitivity, false positives may also occur through the T2 shine-through effect. However, the Apparent Diffusion Coefficient provides quantitative confirmation of stroke, though it is also subject to change depending on the temporal evolution and stage of stroke. It is in light of this fact that this study was conducted, with the main goal of evaluating and comparing the effectiveness of Diffusion-Weighted Imaging and Apparent Diffusion Coefficient in the early detection of acute arterial stroke, so as to provide more accurate and reliable imaging for better patient outcomes.

2 METHODOLOGY

This cross sectional validation study was conducted at Radiology Department of Ittefaq Hospital Trust, Lahore from December 2025 to March 2026. Ethical approval was

obtained from institutional review committee before start of study and confidentiality of patient data was maintained throughout. Sample size was calculated by using WHO sensitivity and specificity calculator for diagnostic test studies. Taking sensitivity 69%, specificity 78% and prevalence 60.2%,[11] with confidence interval 95% and precision 10% for both sensitivity and specificity, the calculated sample size was 166 patients.

3 INCLUSION CRITERIA

Patients of both genders having age 30–70 years, presenting within 24 hours of onset of symptoms and having clinical diagnosis of acute arterial stroke were included. Clinical diagnosis of acute arterial stroke was taken as sudden onset focal neurological deficit lasting ≥24 hours with features including motor deficit with NIHSS score ≥4, speech disturbance like aphasia or dysarthria, visual loss such as hemianopia or monocular blindness, sensory deficit or altered level of consciousness with Glasgow Coma Scale <15.

4 EXCLUSION CRITERIA

Patients with history of previous ischemic stroke, intracranial hemorrhage on CT scan, contraindication to MRI like pacemaker, metallic implants or severe claustrophobia, patients having stroke mimics such as brain tumor, abscess, demyelinating disease or encephalitis and patients with pregnancy on HCG were excluded.

Written informed consent was taken from all patients before inclusion in study. Detailed history and clinical examination was performed in all patients at presentation. All patients then underwent MRI brain on 1.5 Tesla machine using standard stroke protocol including T1, T2, FLAIR sequences along with apparent diffusion coefficient mapping and diffusion weighted imaging. Regions of interest were drawn on ADC map in suspected ischemic areas while avoiding CSF, hemorrhage and artifacts, and mean ADC values were recorded in $\times 10^{-6}$ mm²/s. After that diffusion weighted imaging was performed using standard b values and images were assessed by trained radiologist by comparing suspected area with opposite normal brain side. On apparent diffusion coefficient, stroke was labeled present when ADC value was $\leq 620 \times 10^{-6}$ mm²/s in

affected region. On diffusion weighted imaging, stroke was labeled present when there was hyperintense signal in comparison to contralateral normal brain parenchyma.

All data was entered and analyzed by using IBM SPSS version 27. Quantitative variables like age, BMI and duration of complaints were expressed as mean ± standard deviation. Qualitative variables like gender, socioeconomic status, residential status and imaging findings were presented as frequency and percentage. Diagnostic accuracy parameters including sensitivity, specificity, positive predictive value, negative predictive value and overall diagnostic accuracy were calculated using 2×2 table. Effect modifiers like age, gender and BMI were controlled by stratification and post stratification diagnostic accuracy test was applied.

5 RESULTS

The study was including a total of 166 patients, with mean age was found to be 53.89 ± 8.52 years and mean BMI was 28.11 ± 3.12 kg/m². The mean duration of symptoms at presentation was 15.48 ± 6.98 hours. Regarding gender distribution, majority of patients was males 89 (53.6%) while females was 77 (46.4%). In terms of socioeconomic status, low- and middle-income groups was equally distributed, each comprising 64 patients (38.6%), whereas high socioeconomic class was represented by 38 patients (22.9%). Most of the patients belongs to rural areas 95 (57.2%) as compared to urban areas 71 (42.8%) (Table 1).

Table 1

Patient Demographics

Demographics	**Mean ± SD / n (%)**
Age (years)	53.89 ± 8.52
BMI (kg/m²)	28.11 ± 3.12
Duration (hours)	15.48 ± 6.98
Gender	
Male n (%)	89 (53.6%)
Female n (%)	77 (46.4%)
Socioeconomic Status	
Low n (%)	64 (38.6%)
Middle n (%)	64 (38.6%)
High n (%)	38 (22.9%)
Residential Area	
Rural n (%)	95 (57.2%)

Urban n (%)	71 (42.8%)

When the overall diagnostic results were evaluated, ADC was identified acute arterial stroke as positive in 87 patients (52.4%) and negative in 79 patients (47.6%). In comparison, DWI which was used as gold standard, detected positive cases in 107 patients (64.5%) and negative in 59 patients (35.5%) (Table 2).

Table 2

Overall Results of ADC and DWI in Diagnosis of Acute Arterial Stroke

Acute Arterial Stroke	ADC	DWI
Positive	87 (52.4%)	107 (64.5%)
Negative	79 (47.6%)	59 (35.5%)
Total	166 (100%)	166 (100%)

In the comparison of ADC against DWI, ADC correctly identify 75 true positive cases and 47 true negative cases. However, 12 cases were falsely identified as positive by ADC (false positives), and 32 cases was missed by ADC which was actually positive on DWI (false negatives) (Table 3).

Table 3

Comparison of ADC versus DWI in Diagnosis of Acute Arterial Stroke

ADC	DWI		Total
	Positive	Negative	
Positive	75 (TP)	12 (FP)	87
Negative	32 (FN)	47 (TN)	79
Total	107	59	166

Key: TP = True positive, FP = False positive, FN = False negative, TN = True negative

The diagnostic performance parameters of ADC were then calculated, sensitivity was found to be 70% and specificity was 80%. The overall diagnostic accuracy was estimated at 73%. The positive predictive value (PPV) was 86% while negative predictive value (NPV) was relatively lower at 59% (Table 4).

Table 4

Sensitivity, Specificity, Diagnostic Accuracy, PPV and NPV of ADC in Diagnosis of Acute Arterial Stroke

Diagnostic Parameter	Result
Sensitivity	70%
Specificity	80%
Diagnostic Accuracy	73%
PPV	86%
NPV	59%

In the stratified analysis by age, patients of age 50 years or below was showing sensitivity of 71%, specificity of 84%, diagnostic accuracy of 76%, PPV of 88%, and NPV of 65%. For patients above 50 years of age, sensitivity was slightly lower at 69%, specificity was 75%, diagnostic accuracy was 71%, PPV was 85%, and NPV was 54%. When analysis was stratified by gender, in male patients' sensitivity was 66%, specificity was 77%, diagnostic accuracy was 70%, PPV was 84%, and NPV was 55%. Female patients were showing comparatively better performance with sensitivity of 76%, specificity of 82%, diagnostic accuracy of 78%, PPV of 88%, and NPV of 66%. For BMI stratification, patients with BMI of 25 kg/m² or below was having sensitivity of 78%, specificity of 71%, diagnostic accuracy of 76%, PPV of 88%, and NPV of 56%. In patients with BMI above 25 kg/m², sensitivity was 69%, specificity was 81%, diagnostic accuracy was 73%, PPV was 86%, and NPV was 60% (Table 5).

Table 5

Stratified Analysis of Sensitivity, Specificity, Diagnostic Accuracy, PPV and NPV of ADC in Diagnosis of Acute Arterial Stroke with Age, Gender and BMI

Variables	Groups	Diagnostic Parameter	Result
Age (years)	≤50	Sen	71%
		Spec	84%
		DA	76%
		PPV	88%
		NPV	65%
	>50	Sen	69%
		Spec	75%
		DA	71%
		PPV	85%
		NPV	54%
Gender	Male	Sen	66%
		Spec	77%
		DA	70%
		PPV	84%
		NPV	55%

	Female	Sen	76%
		Spec	82%
		DA	78%
		PPV	88%
		NPV	66%
BMI (kg/m²)	≤25	Sen	78%
		Spec	71%
		DA	76%
		PPV	88%
		NPV	56%
	>25	Sen	69%
		Spec	81%
		DA	73%
		PPV	86%
		NPV	60%

6 DISCUSSION

The mean age of patients was 53.89 ± 8.52 years, which is consistent with the known fact that ischemic stroke is more commonly affecting middle aged and older population due to progressive atherosclerosis and accumulation of vascular risk factors over time. Mean BMI was 28.11 ± 3.12 kg/m², indicating that most of the patients was in overweight category, which is a well-established risk factor for stroke as excess adipose tissue is contributing to hypertension, dyslipidemia and endothelial dysfunction. Male patients were slightly more in numbers 89 (53.6%) as compared to females 77 (46.4%), this can be explained by the fact that males is having higher tendency for smoking, hypertension and other cardiovascular risk factors at earlier age as compared to females. ADC showed a sensitivity of 70%, specificity of 80%, and a diagnostic accuracy of 73%. This lower sensitivity implies that ADC might not identify a certain number of true positive stroke cases in the early phase of stroke because of the failure of ADC values to decrease below a predetermined level in cases of ischemic stroke. This leads to false negative results because of the failure of ADC to identify stroke in the early phase. The PPV of ADC was found to be high at 86%, which indicates that a positive result on ADC is likely to be true. However, NPV of ADC was found to be low at 59%.

Arafat *et al.* [12] was reporting diagnostic accuracy of DWI as 96.3% with low ADC values found in 90% of their patients, which is considerably higher than present study findings, this difference may be because Arafat *et al.* [12] was using DWI itself as the modality being evaluated rather than ADC values alone, and their study population had

mean age 65.2 ± 7.83 years which is older than present study mean age of 53.89 ± 8.52 years, and older patients usually is having more established infarct changes making ADC changes more obvious and detectable. Similarly Babar *et al.* [13] reported sensitivity of 91.67%, specificity of 93.18% and diagnostic accuracy of 92.27% for DWI, which is also much higher than present study, again reflecting that DWI as complete sequence is performing better than ADC map evaluation alone. Regarding gender distribution, male patients were 89 (53.6%) and females were 77 (46.4%) in present study, which is comparable to Mollah *et al.* [14] who also reported 60% male predominance in their cross-sectional study.

The sensitivity of ADC in present study was 70%, which is somewhat lower than what was reported by Engelter *et al.* [15] who noted DWI detection rate of more than 95% in stroke patients with ADC decrease of 40–50% in acute phase. This lower sensitivity in present study can be related to the fact that ADC changes is time dependent, and mean symptom duration in present study was 15.48 ± 6.98 hours, which is suggesting that some patients may have presented in subacute phase where ADC values is starting to pseudo-normalize, reducing the ability of ADC to correctly identify all positive cases. Okorie *et al.* [16] also emphasized that DWI is most sensitive within therapeutic window of 3–4.5 hours, further supporting this explanation.

Jin *et al.* [17] was reporting diagnostic AUC of 0.949 for ADC which is reflecting very high diagnostic capability, higher than present study findings, their study was also demonstrating that lower ADC values is significantly associated with poorer neurological outcomes as measured by NIHSS and mRS scores, this is providing additional scientific basis that ADC is not only a diagnostic tool but also carry prognostic value which was not evaluated in present study. Tong *et al.* [18] further highlighted that proportion of low ADC pixels was significantly higher in lesions with hemorrhagic transformation 47% versus 19% ($P<0.001$), indicating that very low ADC values may also be helping in identifying patients at risk of hemorrhagic complications, which is a clinically important consideration.

When stratified analysis is considered, female patients in present study was showing better diagnostic accuracy of 78% as compared to males 70%, and patients with age 50 years or below was having accuracy of 76% versus 71% in older age group. Chaturvedi *et al.* [19] and Iftikhar *et al.*[20] both was demonstrating that younger patients and

those with supratentorial lesions is showing better imaging diagnostic performance, which is partially consistent with present study age-stratified findings.

The present study had a few limitations too. This study was conducted at a single institution and had a small sample size of 166 patients. Also, standardization of apparent diffusion coefficient (ADC) values was not done, and the settings used for the MRI machines may have affected the results. Also, clinical follow-up was not done for the patients, which would have helped in assessing the prognostic value of ADC values for the patients.

7 CONCLUSION

The present study concluded that the apparent diffusion coefficient (ADC) can be regarded as a moderately effective tool in the diagnosis of acute arterial strokes; however, its effectiveness in the diagnosis of acute arterial strokes was found to be slightly lower than that of diffusion-weighted imaging (DWI), which is considered the golden standard in the diagnosis of strokes. The sensitivity and specificity of ADC were found to be acceptable but not sufficient to be considered as a standalone tool in the diagnosis of strokes.

DISCLAIMER

Not any.

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CONFLICT OF INTEREST

Author declare that they have no any conflict of interest regarding this study.

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Authors' Contribution

All authors contributed equally to the development of this article.

Data availability

All datasets relevant to this study's findings are fully available within the article.

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