Role of Magnetic Resonance Imaging Diffusion Weighted and Apparent Diffusion Coefficient Evaluation in Brain Infarction

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ABSTRACT
BACKGROUND- Cerebral infarction is a leading cause of mortality and long-term neurological disability worldwide. Early and accurate diagnosis is crucial for timely therapeutic intervention and improved clinical outcomes. Diffusion-Weighted Imaging (DWI) and Apparent Diffusion Coefficient (ADC) mapping on Magnetic Resonance Imaging (MRI) have emerged as highly sensitive tools for the early detection and characterization of ischemic brain lesions.
MATERIAL AND METHOD- This prospective observational study was conducted in the Department of Radio-Diagnosis at a tertiary care hospital. About 50 clinically suspected patients of ischemic stroke underwent MRI brain including DWI and ADC sequences at 1.5 Tesla Philips MRI machine. The distribution of infarcts, vascular territory involvement, and ADC values were analyzed and correlated with the clinical stage of infarction.
RESULT- DWI demonstrated high sensitivity in detecting acute cerebral infarcts, showing hyperintense signals within minutes of symptom onset. Corresponding ADC maps revealed reduced ADC values in acute infarction, with pseudo-normalization in subacute stages and increased values in chronic infarcts. Middle cerebral artery territory was the most commonly involved. ADC quantification aided in differentiating acute from subacute and chronic infarctions.
CONCLUSION- Diffusion-Weighted Imaging combined with ADC mapping is a reliable, non-invasive, and highly sensitive modality for early diagnosis and staging of cerebral infarction. It plays a pivotal role in guiding clinical decision-making and improving patient management. This study reinforce the essential role of diffusion imaging and ADC in modern neuroimaging and advocate its use in evaluation and early management of patients with suspected ischemic stroke.

Keywords- Cerebral infarction, Diffusion-weighted imaging, Apparent diffusion coefficient, MRI, Stroke

Introduction

Globally, stroke remains a major cause of mortality and long-term disability. Stroke is a medical emergency that demands prompt diagnosis and management to minimize long-term neurological damage[1]. It is currently recognized as the second leading cause of death worldwide and a leading contributor to adult neurological morbidity. In India, stroke poses a significant and growing public health challenge, with incidence rates rising due to increasing life expectancy, urbanization, and prevalence of risk factors such as hypertension, diabetes mellitus, smoking, and sedentary lifestyle. The disease affects both rural and urban populations, often striking individuals in their most productive years, thereby imposing a considerable social and economic burden [2].

The magnitude of the disease in India has shown a concerning rise over the past few decades, reflecting changes in lifestyle, aging population, and the growing prevalence of vascular risk factors such as hypertension, diabetes mellitus, dyslipidemia, smoking, and sedentary habits [3]. Patients may present with dysarthria, characterized by slurred or indistinct speech due to impaired motor control, or aphasia, which includes difficulty in comprehension or expression of language [4].

From a clinical perspective, stroke constitutes a neurological emergency requiring rapid recognition and intervention within the critical "golden period," typically the first three to six hours after symptom onset. Early detection allows for prompt initiation of reperfusion therapy, such as thrombolysis or thrombectomy, which can significantly improve functional outcomes. From a radiological standpoint, accurate imaging is indispensable for differentiating ischemic from hemorrhagic stroke, localizing the lesion, and assessing its extent. While computed tomography (CT) remains the initial modality of choice for excluding hemorrhage, magnetic resonance imaging (MRI), particularly diffusion-weighted imaging (DWI) and apparent diffusion coefficient (ADC) mapping, has proven to be highly sensitive in detecting early ischemic changes within minutes of onset, making it invaluable in modern stroke diagnosis and management [5].

MRI provides multimodal visualization—structural, vascular, and perfusion-based—enabling comprehensive assessment of cerebral ischemia [6].

Diffusion-weighted MRI can detect cerebral infarction within minutes of onset, while ADC mapping allows objective quantification and temporal characterization of ischemic injury. Systematic evaluation of DWI and ADC in cerebral infarction is particularly important in the Indian population, where delayed presentation is common. Assessing diffusion characteristics across different stages of infarction can aid in early diagnosis, lesion localization, and clinical decision-making. There is limited regional data on standardised ADC thresholds for infarct staging . Therefore, systematic evaluation of DWI and ADC parameters in different stages of cerebral infarction is essential for improving diagnostic accuracy and guiding therapeutic decision- making.

Technical and Clinical Considerations

Accurate measurement and interpretation of the Apparent Diffusion Coefficient (ADC) depend on multiple technical and physiological factors. As a quantitative biomarker, ADC is sensitive to sequence design, scanner calibration, and patient-related variables, all of which must be optimized to ensure reproducibility and diagnostic reliability [7].

MATERIAL AND METHOD

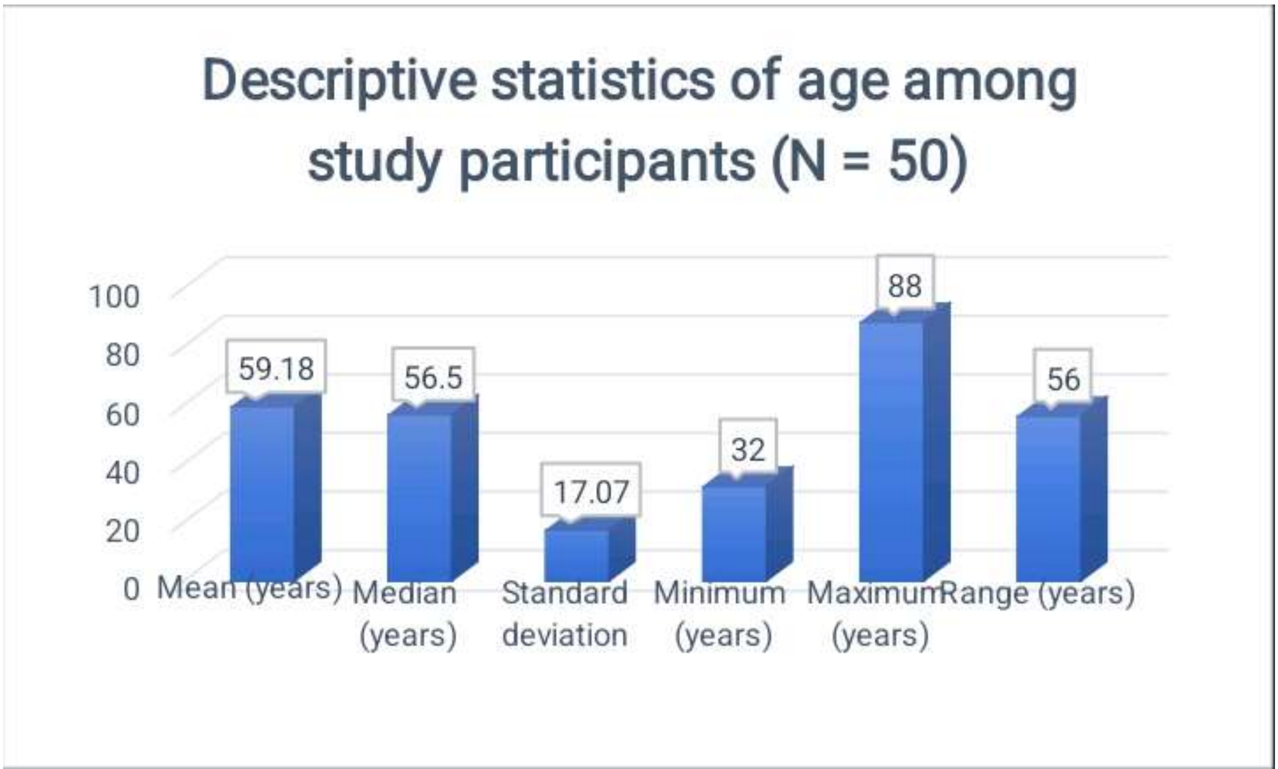
This hospital based cross-sectional observational study was conducted at a tertiary care hospital, involving two key departments over 18 months. The Department of Radio-Diagnosis performed all MRI brain scans, including conventional sequences, diffusion-weighted imaging (DWI), and apparent diffusion coefficient (ADC) mapping using a Philips 1.5 Tesla MRI system, and also carried out image interpretation and ROI-based ADC analysis in about 50 clinically suspected ischemic stroke patients. The Department of General Medicine served as the clinical referral unit, where patients presenting with symptoms of stroke were evaluated, diagnosed, and subsequently referred for neuroimaging. Together, these departments ensured appropriate clinical assessment, imaging, and data collection for all enrolled stroke patients.

RESULT

1. The age of the study population ranged from 32 to 88 years. The mean age was 59.18 years with a standard deviation of 17.07 years, and the median age was 56.5 years. The age distribution demonstrated a predominance of middle-aged and elderly individuals. Descriptive statistics of age are presented in Table 1.

Table 1 Descriptive statistics of age among study participants (N = 50)

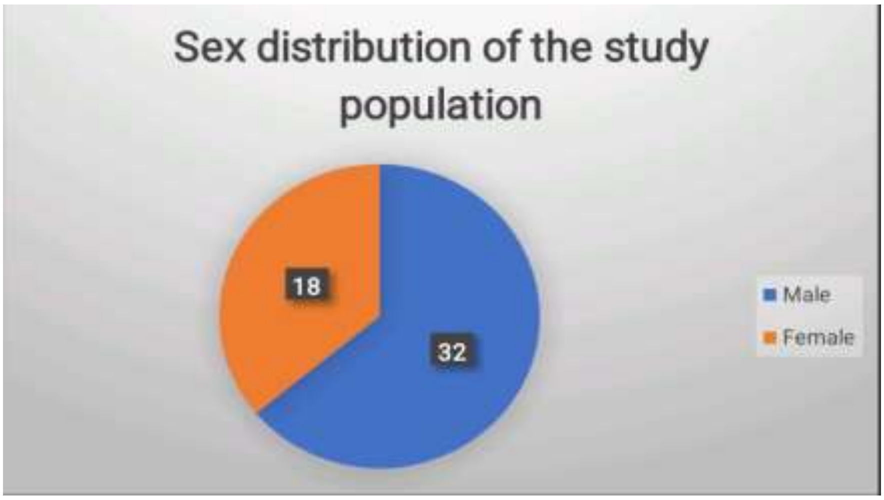
Statistics	Value
Mean (years)	59.18
Median (years)	56.50
Standard deviation	17.07
Minimum (years)	32
Maximum (years)	88
Range (years)	56



2. With respect to sex distribution, males constituted the majority of the study population. Of the 50 patients, 32 (64%) were male and 18 (36%) were female, yielding a male-to-female ratio of approximately 1.8:1. The sex distribution is shown in Table 2.

Table 2. Sex distribution of the study population

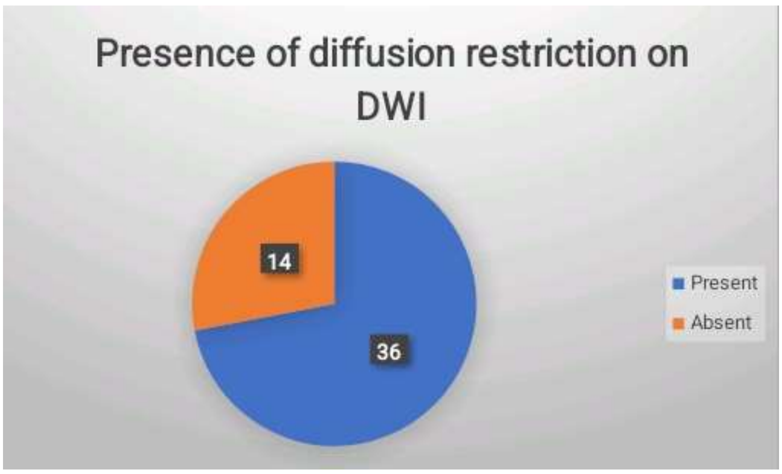
Sex	Frequency	Percentage
Male	32	64.0
Female	18	36.0
Total	50	100.0



3. Diffusion restriction was observed in 36 patients (72%), while 14 patients (28%) showed no restriction. The distribution of diffusion restriction is shown in Table 3.

Table 3. Presence of diffusion restriction on DWI.

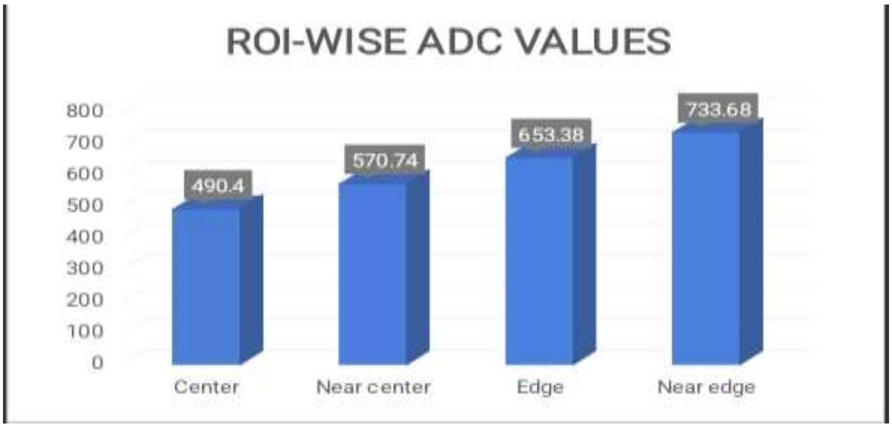
DWI Restriction	Frequency	Percentage
Present	**36**	**72.0**
Absent	**14**	**28.0**



4. ROI-wise analysis revealed progressively increasing ADC values from the center of the infarct toward its periphery. Mean ADC values for each region of interest are shown in Table 4.

Table 4. ROI-wise ADC values

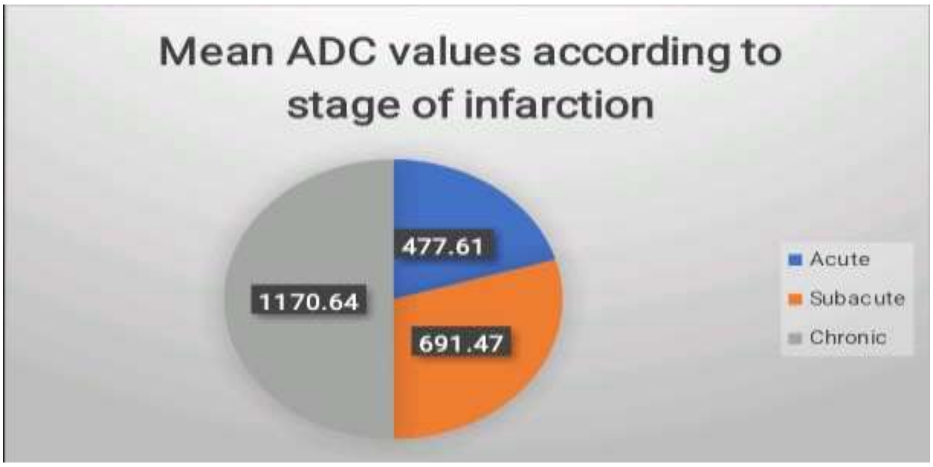
ROI	Mean ADC ± SD (10^{-6} mm^2/ sec)
Center	490.40 ± 99.33
Near center	570.74 ± 103.50
Edge	653.38 ± 121.23
Near edge	733.68 ± 142.89



5. ADC values also demonstrated significant variation across different stages of infarction. Acute infarcts showed the lowest ADC values, while chronic infarcts demonstrated the highest values. The stage-wise ADC distribution is presented in Table 5.

Table 5. Mean ADC values according to stage of infarction

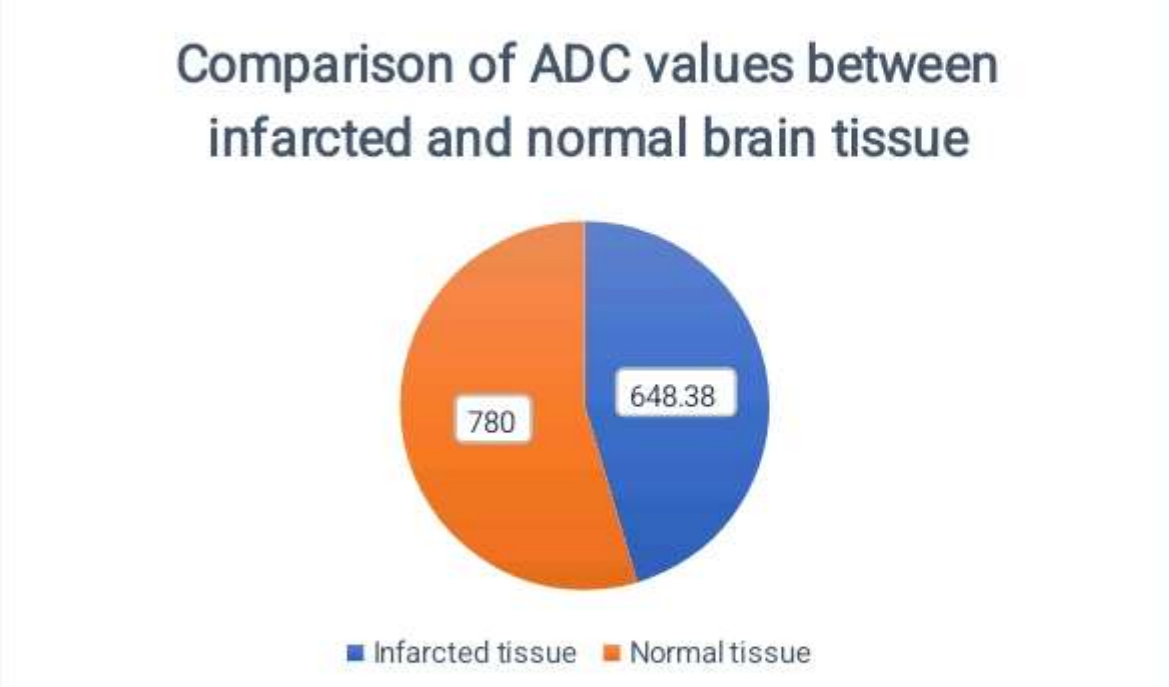
Stage	Mean ADC ± SD (10^{-6} mm^2/ sec)
Acute	477.61 ± 24.81
Subacute	691.47 ± 33.42
Chronic	1170.64 ± 41.19



6. Mean ADC values in infarcted tissue were significantly lower than those in contralateral normal brain tissue. The paired comparison of ADC values is presented in Table 6.

Table 6. Comparison of ADC values between infarcted and normal brain tissu

Region	**Mean ADC ± SD (×10⁻⁶ mm²/s)**
Infarcted tissue	**648.38 ± 249.99**
Normal tissue	**780.00 ± 0.00**



DISCUSSION

Demographic Profile in Context of Existing Literature

The mean age of patients in the present study was 59.18 ± 17.07 years, with the majority of cases occurring in the fifth and sixth decades of life. This age distribution is consistent with several Indian and international studies, which have reported a predominance of ischemic stroke in middle-aged and elderly populations. The relatively wide age range observed in this study reflects the heterogeneous nature of stroke epidemiology in the Indian subcontinent, where younger patients may be affected due to poorly controlled vascular risk factors and delayed preventive care.

Male predominance was observed, with males constituting 64% of the study population. This finding aligns with previous studies that have consistently demonstrated a higher incidence of ischemic stroke among males, potentially attributable to higher prevalence of modifiable risk factors such as smoking, alcohol consumption, and occupational stress. However, it is noteworthy that the proportion of female patients remains substantial, underscoring the need for gender-inclusive preventive strategies.

Diffusion-Weighted Imaging: Diagnostic and Temporal Significance

Diffusion restriction was observed in 72% of patients overall and in all cases of acute infarction. This reinforces the high sensitivity of DWI in detecting acute ischemic changes, a finding that has been repeatedly demonstrated in the literature . The absence of diffusion restriction in the majority of chronic infarcts further supports the specificity of DWI for acute ischemia.

Apparent Diffusion Coefficient: Core Findings and Comparisons

One of the most significant findings of the present study was the marked reduction in ADC values within infarcted tissue compared to contralateral normal brain. The mean ADC value of infarcted regions was significantly lower than that of normal brain tissue, a finding that is consistent with other indian and international studies.

Spatial ADC Variation: Core and Peripheral Differences

The present study demonstrated a clear spatial gradient of ADC values within infarcts, with the lowest values observed at the infarct center and progressively higher values toward the periphery. This spatial heterogeneity has been described previously and reflects the coexistence of irreversibly damaged core tissue and potentially salvageable penumbral regions .

The significant difference between central and peripheral ADC values observed in this study supports the concept that ADC mapping can provide insights into infarct heterogeneity and tissue viability. Although perfusion imaging was not performed in the present study, the observed spatial ADC gradients are consistent with perfusion-diffusion mismatch concepts described in earlier literature.

Temporal Evolution of ADC values

A progressive increase in ADC values with advancing infarct stage was one of the most striking findings of the present study. Acute infarcts demonstrated the lowest ADC values, while chronic infarcts exhibited markedly elevated values. This temporal evolution is consistent with the biphasic pattern described in experimental and clinical studies, wherein cytotoxic edema dominates the acute phase, followed by vasogenic edema and tissue necrosis in later stages.

The magnitude of ADC increase observed in chronic infarcts further highlights the irreversible nature of tissue damage at this stage.

CONCLUSION

The present study demonstrates that diffusion-weighted magnetic resonance imaging, in conjunction with apparent diffusion coefficient analysis, plays a crucial and indispensable role in the evaluation of cerebral infarction. Diffusion-weighted imaging provides high sensitivity for the detection of acute ischemic changes, often before abnormalities become evident on conventional magnetic resonance imaging sequences. This early detection capability is particularly valuable in the hyperacute and acute phases of stroke, where timely diagnosis directly influences therapeutic decision-making.

Quantitative analysis of ADC values offers objective insight into the pathophysiological evolution of ischemic brain injury. The study confirms that ADC values are significantly reduced in acute infarction due to cytotoxic edema, show pseudonormalization during the subacute phase, and become markedly elevated in chronic infarction as a result of tissue necrosis and gliosis. These predictable temporal changes in ADC values allow reliable differentiation between acute, subacute, and chronic infarcts, even in cases where clinical history is unclear or incomplete.

The demonstration of spatial variation in ADC values within infarcted regions further enhances the diagnostic utility of diffusion imaging. Lower ADC values at the infarct core and progressively higher values toward the periphery reflect the heterogeneous nature of ischemic injury. This spatial information provides indirect insight into tissue viability and complements conventional imaging in assessing the extent and severity of infarction.

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