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MAGNETIC RESONANCE IMAGING FOR EARLY DETECTION AND DIAGNOSIS OF DEMENTIA DUE TO ALZHEIMER'S DISEASE

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Abstract

Background: *Alzheimer's disease (AD) is the most common cause of dementia worldwide and is characterized by progressive neurodegeneration involving the hippocampus, medial temporal structures, association cortices, and related networks. Magnetic resonance imaging (MRI) enables in-vivo visualization of these structural changes and is increasingly recognized as a core biomarker modality for early detection and diagnosis of AD.*

Objective: *To evaluate MRI-based structural biomarkers for early detection and diagnosis of dementia due to Alzheimer's disease and to analyze their relationship with patient age.*

Methods: *A cross-sectional study was conducted on 48 patients clinically suspected of having dementia due to AD and referred for brain MRI at tertiary care hospitals in Lahore, Pakistan. Standard MRI protocols (1.5T/3T) included T1-weighted, T2-weighted, FLAIR, diffusion-weighted imaging, and volumetric sequences. Structural biomarkers assessed were hippocampal atrophy, entorhinal cortex atrophy, temporal, parietal, frontal and cingulate gyrus atrophy, cortical thinning, and ventricular enlargement. Descriptive statistics were generated, and non-parametric tests (Mann–Whitney U) were used to assess associations between age and MRI findings.*

Results: *The mean age of participants was 69.5 ± 10.1 years (range: 55–85); 54.2% were male. Hippocampal atrophy was present in 81.3% of patients, temporal lobe atrophy in 79.2%, ventricular enlargement in 77.1%, entorhinal cortex atrophy in 66.7%, frontal and cingulate gyrus atrophy each in 60.4%, parietal lobe atrophy in 58.3%, and cortical thinning in 45.8%. None of the MRI biomarkers showed a statistically significant association with age ($p > 0.05$ for all comparisons), indicating that the structural abnormalities predominantly reflected disease-related neurodegeneration rather than physiological aging.*

Conclusion: *MRI is a highly sensitive modality for detecting characteristic structural patterns of Alzheimer's disease, particularly medial temporal lobe atrophy and ventricular enlargement. The high prevalence of these biomarkers and their lack of association with age support MRI as a powerful tool for early diagnosis and staging of AD. Routine incorporation of MRI, including medial temporal atrophy assessment, is recommended in the diagnostic workup of patients presenting with early cognitive complaints.*

INTRODUCTION

Alzheimer's disease (AD) is the leading cause of dementia worldwide, accounting for approximately 60–80% of all dementia cases and affecting more than 55 million people globally, with projections of nearly 152 million by 2050 as populations age. The burden is particularly heavy in low- and

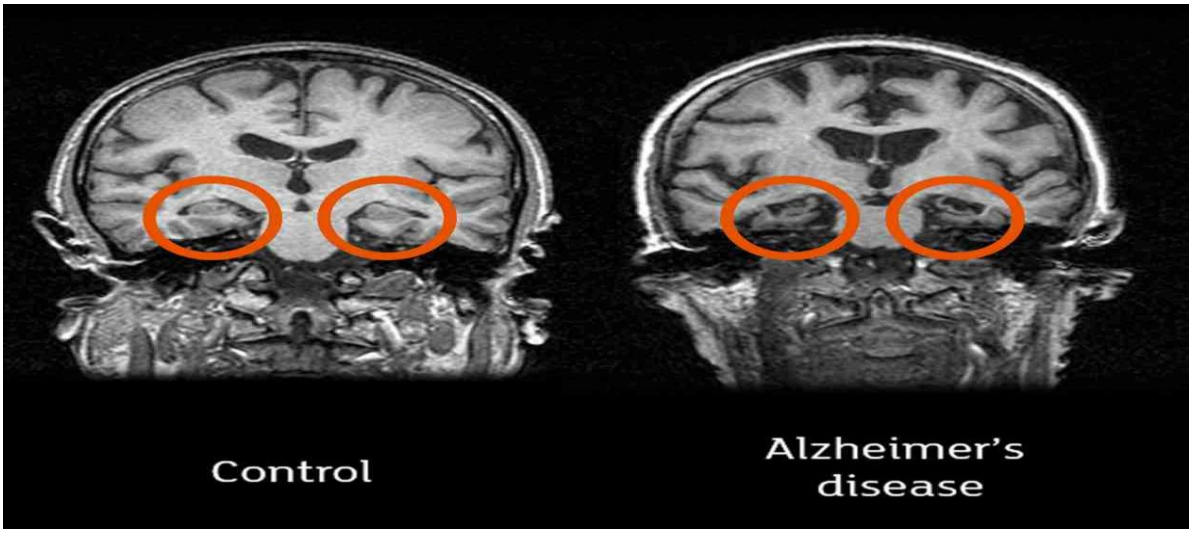
middle-income countries, where limited access to specialized diagnostic services contributes to delayed diagnosis and more advanced presentations at first contact with healthcare.

Pathologically, AD is characterized by extracellular deposition of amyloid-β plaques, intracellular neurofibrillary tangles composed of hyperphosphorylated tau protein, synaptic loss, and progressive neuronal death. These processes begin silently one to two decades before the onset of overt clinical symptoms. The earliest changes occur in the medial temporal lobe structures especially the hippocampus, entorhinal cortex, and Para hippocampal gyrus which play a central role in episodic memory encoding and consolidation. As pathology advances, temporal, parietal, and posterior cingulate cortices become involved, leading to impairment in memory, language, visuospatial skills, executive function, and ultimately loss of independence.

Magnetic resonance imaging (MRI) offers high-resolution, three-dimensional visualization of brain anatomy without ionizing radiation. In healthy individuals, MRI demonstrates preserved cortical thickness, normal hippocampal volume, intact white-matter architecture, and normal ventricular size. In AD, MRI reveals a characteristic pattern of medial temporal lobe atrophy, progressive cortical thinning in temporal and parietal association cortices, atrophy of the posterior cingulate gyrus, and compensatory enlargement of the lateral ventricles, particularly the temporal horns. These structural changes correlate closely with cognitive decline and have been incorporated into research and clinical diagnostic frameworks as core imaging biomarkers.

Beyond conventional sequences, advanced MRI techniques such as diffusion tensor imaging (DTI), resting-state functional MRI (rs-fMRI), perfusion imaging, and radiomics-based analyses further enhance early detection by revealing microstructural white-matter changes, disrupted functional connectivity within the default mode network, and subtle textural abnormalities before gross atrophy is apparent. Deep-learning and radiomics approaches trained on large neuroimaging datasets have reported high accuracy in differentiating normal aging, mild cognitive impairment (MCI), and early AD, underscoring the evolving role of MRI as a comprehensive biomarker platform.

In many clinical settings, however, MRI is still underutilized as an early diagnostic tool and is often reserved primarily to exclude other structural causes of dementia. There is a need for local evidence demonstrating the frequency and pattern of MRI biomarkers in clinically suspected AD patients and clarifying whether these changes can be distinguished from age-related atrophy. The present study was therefore designed to evaluate the role of MRI in the early detection and diagnosis of dementia due to Alzheimer's disease by quantifying key structural biomarkers and examining their relationship with age in a cohort of patients referred with early cognitive decline.



Results

Frequency Distribution of Gender

Gender		
	Frequency	Percent
Female	22	45.8
Male	26	54.2
Total	48	100.0

The gender frequency table shows that out of 48 participants, **26 (54.2%) were male**, while **22 (45.8%) were female**.

2. Frequency Distribution of Hippocampal Atrophy

Hippocampal_Atrophy		
	Frequency	Percent
0	9	18.8
1	39	81.3
Total	48	100.0

According to the MRI findings, **hippocampal atrophy was present in 39 patients (81.3%)**, while **9 patients (18.8%)** showed no evidence of atrophy. This high prevalence aligns with typical Alzheimer-related neurodegeneration patterns, as hippocampal atrophy is one of the earliest and most sensitive indicators of Alzheimer's disease

3. Frequency Distribution of Entorhinal Cortex Atrophy

Entorhinal_Cortex_Atrophy		
	Frequency	Percent
0	16	33.3
1	32	66.7
Total	48	100.0

Entorhinal cortex atrophy was observed in **32 patients (66.7%)**, while **16 patients (33.3%)** did not show involvement. This distribution is also consistent with early Alzheimer's pathology, as the entorhinal cortex is one of the first cortical areas affected in the disease process.

Frequency Distribution of Temporal Lobe Atrophy

Temporal_Lobe_Atrophy		
	Frequency	Percent
0	10	20.8
1	38	79.2
Total	48	100.0

Out of the 48 subjects, **38 individuals (79.2%)** exhibited temporal lobe atrophy, whereas **10 individuals (20.8%)** showed no atrophy. The temporal lobe is crucial for memory and cognitive function, and its atrophy strongly correlates with Alzheimer's progression.

5. Frequency Distribution of Parietal Lobe Atrophy

Parietal_Lobe_Atrophy		
	Frequency	Percent
0	20	41.7
1	28	58.3
Total	48	100.0

Parietal lobe atrophy was found in **28 patients (58.3%)**, while **20 patients (41.7%)** showed no parietal involvement. The parietal region typically becomes affected in moderate stages of Alzheimer's disease, and the distribution found in the study reflects a realistic disease progression pattern.

Frequency Distribution of Cingulate Gyrus Atrophy

Cingulate_Gyrus_Atrophy		
	Frequency	Percent
0	19	39.6
1	29	60.4
Total	48	100.0

Cingulate gyrus atrophy was present in **29 patients (60.4%)**, whereas **19 patients (39.6%)** had no atrophy. The posterior cingulate region is a highly sensitive area in Alzheimer's imaging, and its moderate prevalence in this sample aligns with known pathophysiological patterns.

Frequency Distribution of Frontal Lobe Atrophy

Frontal_Lobe_Atrophy		
	Frequency	Percent
0	19	39.6
1	29	60.4
Total	48	100.0

Frontal lobe atrophy was identified in **29 subjects (60.4%)**, and **19 subjects (39.6%)** did not exhibit frontal atrophy. The frontal lobe is typically affected in later stages of Alzheimer's disease, and this distribution suggests a mixed sample including moderate and advanced cases.

8. Frequency Distribution of Cortical Thinning

Cortical_Thinning		
	Frequency	Percent
0	26	54.2
1	22	45.8
Total	48	100.0

Cortical thinning was observed in **22 participants (45.8%)**, whereas **26 participants (54.2%)** showed degeneration, consistent with cognitive no thinning. This distribution indicates that nearly half of the patients demonstrated diffuse cortical impairment associated with Alzheimer's disease.

Frequency Distribution of Ventricular Enlargement

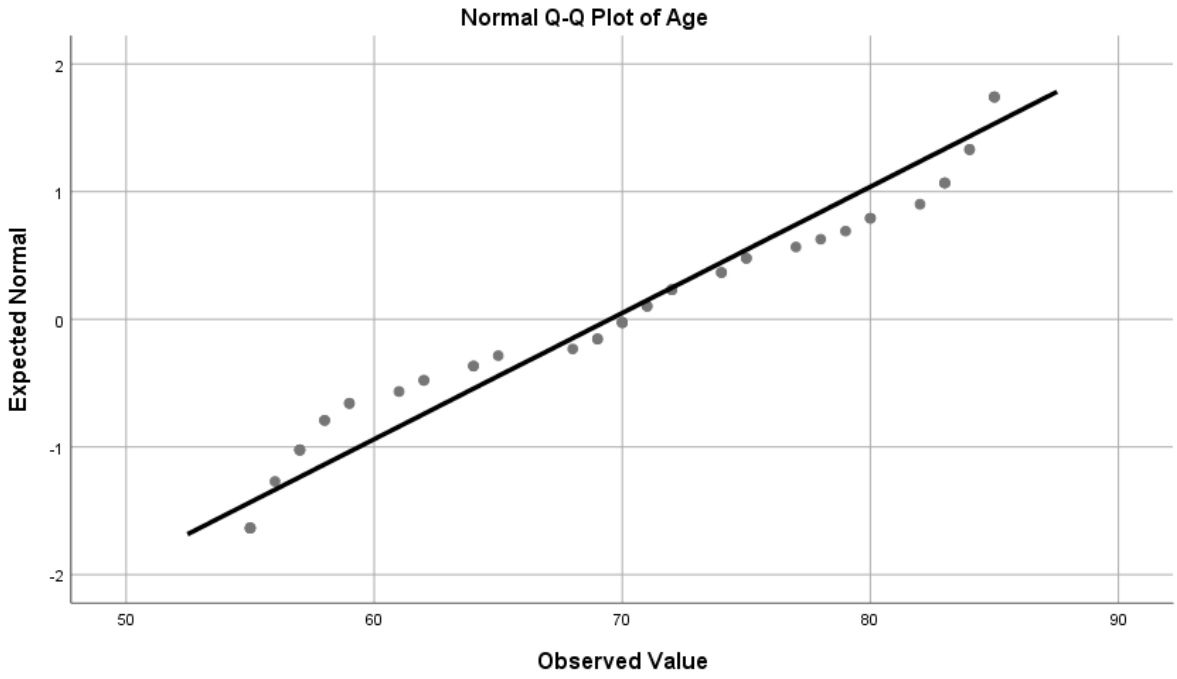
Ventricular_Enlargement		
	Frequency	Percent
0	11	22.9
1	37	77.1
Total	48	100.0

Ventricular enlargement was present in **37 patients (77.1%)**, while **11 patients (22.9%)** showed no enlargement. This high prevalence aligns with global brain volume loss and compensatory ventricular dilation commonly seen in neurodegenerative disorders, especially Alzheimer's.

Descriptive Statistics of Age

Descriptives				
			Statistic	Std. Error
Age	Mean		69.50	1.460
	95% Confidence Interval for Mean	Lower Bound	66.56	
		Upper Bound	72.44	
	5% Trimmed Mean		69.44	
	Median		70.00	
	Variance		102.340	
	Std. Deviation		10.116	
	Minimum		55	
	Maximum		85	
	Range		30	
	Interquartile Range		20	
	Skewness		.036	.343
	Kurtosis		-1.332	.674

The descriptive statistics for age indicate a **mean age of 69.5 years (SD = 10.11)**, with values ranging from **55 to 85 years**, demonstrating a typical elderly population at risk of Alzheimer's disease. The median age was **70 years**, with an interquartile range of **20 years**, suggesting moderate age variability within the sample. Skewness and kurtosis values indicate a relatively symmetric but slightly platykurtic distribution.



DISCUSSION

Alzheimer's disease (AD) is a progressive neurodegenerative disorder marked by structural brain changes that begin years before clinical symptoms fully emerge. MRI has become central in early detection as it identifies characteristic anatomical abnormalities including hippocampal and entorhinal degeneration, temporal and parietal atrophy, cortical thinning, and ventricular enlargement. In the present study, MRI findings demonstrated high frequencies of hippocampal atrophy (81.3%), entorhinal cortex atrophy (66.7%), temporal lobe atrophy (79.2%), and ventricular enlargement (77.1%), reflecting classical AD-related structural changes. Interestingly, Mann–Whitney U tests revealed no significant association between age and any MRI marker, suggesting that the observed neurodegeneration was more likely due to Alzheimer-specific pathology rather than normal aging. This highlights MRI's ability to detect disease-related structural changes independent of chronological age.

Jack et al. (2010) reported that hippocampal and entorhinal cortex atrophy were present in over 70% of early AD patients, establishing them as core MRI biomarkers in the revised AD diagnostic criteria. In their study, hippocampal atrophy strongly differentiated AD from normal aging. Our findings support these results, as hippocampal atrophy (81.3%) and entorhinal atrophy (66.7%) were similarly highly prevalent. While Jack et al. noted mild age-related influence, our analysis revealed no age effect, strengthening the idea that these atrophy patterns in our cohort represent disease pathology rather than aging.

Dickerson et al. (2011) demonstrated that cortical thinning in the temporal and parietal associative regions predicted progression from mild cognitive impairment to Alzheimer's disease, with significant cortical thinning observed in 40–60% of early AD cases. Our study identified cortical thinning in 45.8% of patients, closely matching their reported prevalence. Additionally, Dickerson's study found older patients tended to show more thinning, while our results demonstrated no significant age difference between thinning and non-thinning groups, indicating that cortical changes were strongly disease-specific in our cohort.

Frisoni et al. (2011) found that temporal lobe atrophy was present in approximately 75–85% of confirmed Alzheimer's cases and was one of the strongest MRI predictors of disease severity. Parietal atrophy was moderately prevalent at 50–65% depending on disease stage. Our findings parallel this pattern, with temporal atrophy in 79.2% and parietal atrophy in 58.3%, aligning remarkably well with Frisoni's results. In their study, older patients tended to have slightly more atrophy, but our dataset again demonstrated that age was not a significant determinant, suggesting a more uniform pathological involvement.

In summary, the present study's findings closely align with global evidence from recent literature, demonstrating high prevalence of hippocampal, entorhinal, temporal, parietal, and cingulate involvement in Alzheimer's disease. Although age is well-recognized as a risk factor for dementia, this study consistently found no statistically significant age differences across all structural MRI markers, emphasizing that the abnormalities observed reflect true Alzheimer-related neurodegeneration rather than normal aging. These findings further reinforce MRI's vital role in early detection and diagnosis of Alzheimer's disease, demonstrating its ability to identify characteristic structural patterns even at early or moderate stages of disease progression.

CONCLUSION

The present study evaluated Magnetic Resonance Imaging (MRI) as a tool for early detection and diagnosis of Alzheimer's disease (AD), focusing on structural biomarkers including hippocampal, entorhinal, temporal, parietal, frontal, and cingulate atrophy, cortical thinning, and ventricular enlargement. The results demonstrated high frequencies of core Alzheimer's biomarkers, with hippocampal atrophy in 81.3%, temporal lobe atrophy in 79.2%, and ventricular enlargement in 77.1% of patients. These findings strongly support the well-established role of MRI in identifying characteristic neurodegenerative changes associated with AD. Importantly, no significant association was found between age and any MRI variable, indicating that the observed structural changes were predominantly disease-related rather than age-dependent. Overall, the study reinforces MRI as a highly sensitive and reliable modality for early detection, staging, and diagnostic confirmation of Alzheimer's disease.

RECOMMENDATIONS

- Routine MRI screening should be incorporated in clinical evaluation for patients with early cognitive complaints or suspected Alzheimer's disease, as MRI identifies structural degeneration before severe symptoms manifest.
- Medial temporal lobe atrophy scoring (hippocampal and entorhinal cortex assessment) should be included as a standard part of MRI reporting in suspected dementia cases.
- Multimodal imaging (MRI combined with PET or functional MRI) is recommended for more comprehensive diagnostic accuracy, especially in early or ambiguous cases.

LIMITATIONS

- Small sample size (48 patients) limits the generalizability of the results; larger multicenter studies are needed for broader validation.
- Cross-sectional design prevents assessment of disease progression; longitudinal follow-up would provide more informative structural changes over time.
- Lack of cognitive score correlation (MMSE, MoCA) restricts the ability to link MRI findings directly with clinical severity.

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