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Research Article

The Role of Radiology in Early Detection of Neurodegenerative Diseases

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ABSTRACT

Background: Early detection of neurodegenerative diseases is crucial for timely intervention and improved patient outcomes. Radiological imaging, particularly MRI and CT, plays a pivotal role in identifying structural brain changes associated with these disorders.
Objective: To evaluate the role of CT and MRI in the early detection of neurodegenerative diseases and compare their diagnostic accuracy.
Methods: This prospective observational study included 100 patients aged 40 years and above, clinically suspected of having neurodegenerative disorders. Patients underwent either CT or MRI brain scans, and imaging findings were correlated with clinical presentation. Sensitivity, specificity, and accuracy of each modality were analysed.
Results: MRI was performed in 58 patients and CT in 42. MRI demonstrated superior sensitivity (93.4%) and accuracy (92.3%) compared to CT (sensitivity: 64.2%; accuracy: 71.0%). Hippocampal atrophy, white matter hyperintensities, and basal ganglia changes were most effectively detected by MRI. Disease-specific imaging patterns showed strong concordance with clinical diagnosis, particularly for Alzheimer’s and Parkinson’s diseases.
Conclusion: MRI is the preferred imaging modality for early detection of neurodegenerative diseases due to its ability to identify subtle structural changes and high clinical correlation. CT is limited to ruling out acute pathologies. Integration of advanced MRI techniques and AI-assisted analysis may further enhance early diagnosis and guide timely interventions.

***Keywords**:Neurodegenerative diseases, MRI, CT, early detection, hippocampal atrophy, white matter hyperintensities.*

INTRODUCTION

Neurodegenerative diseases (NDDs) such as Alzheimer's disease (AD), Parkinson's disease (PD), multiple sclerosis (MS), Huntington's disease (HD), and frontotemporal dementia (FTD) represent a significant and growing global health challenge, with increasing prevalence due to ageing populations [1,2]. Early diagnosis is critical to allow timely intervention, potentially slowing disease progression, improving quality of life, and reducing healthcare costs [2,3].

Radiological imaging plays a pivotal role in the early detection and differential diagnosis of NDDs [3,4]. Magnetic resonance imaging (MRI) has emerged as the gold standard due to its superior soft tissue contrast and ability to detect subtle structural and functional brain changes. Advanced MRI techniques, including functional MRI (fMRI), diffusion tensor imaging (DTI), and MR spectroscopy, allow assessment of brain activity, connectivity, and metabolic changes [3,5]. These modalities enable detection of early biomarkers such as hippocampal atrophy, cortical thinning, basal ganglia changes, and white matter hyperintensities, which are indicative of neurodegeneration [5,6].

Computed tomography (CT) remains a valuable tool for excluding acute neurological pathologies such as haemorrhage, tumours, or infarcts. However, its sensitivity for detecting early neurodegenerative changes is limited compared to MRI [2,3]. Recent developments in artificial intelligence (AI) and machine learning applied to MRI have further enhanced early detection capabilities, allowing prediction of disease onset even before overt clinical symptoms manifest [7,8].

MATERIAL AND METHODS

Study Design:
This was a prospective observational study conducted to evaluate the role of radiological imaging, particularly computed tomography (CT) and magnetic resonance imaging (MRI), in the early detection of neurodegenerative diseases.

Study Site and Duration:
The study was conducted in the Department of Radiodiagnosis, over a period of one year (from January 2024 to December 2024).

Sample Size:
A total of 100 patients were included in the study.

Inclusion Criteria:
- Patients clinically suspected of having neurodegenerative disorders (e.g., Alzheimer's disease, Parkinson's disease, multiple sclerosis, Huntington's disease, or frontotemporal dementia).
- Patients referred for neuroimaging (CT or MRI) as part of diagnostic evaluation.
- Both male and female patients aged 40 years and above.

Exclusion Criteria:
- Patients with acute cerebrovascular accidents or traumatic brain injury.
- Patients with known intracranial infections, tumours, or congenital malformations.
- Patients unwilling to undergo imaging or provide informed consent.

Data Collection:
Detailed clinical history and neurological examination findings were recorded. Each patient underwent either CT or MRI brain scans as per the clinical indication. Imaging findings were correlated with clinical presentation and disease stage to assess early radiological features suggestive of neurodegeneration.

Imaging Protocols:
- **CT Scan:**Non-contrast CT brain was performed using a multi-slice CT scanner. Axial sections were obtained from the base of the skull to the vertex, with bone and soft-tissue algorithms for evaluation of cortical atrophy, ventricular enlargement, and other structural abnormalities.
- **MRI Scan:**An MRI of the brain was performed using a 1.5 Tesla scanner. The protocol included T1-weighted, T2-weighted, FLAIR, DWI, and susceptibility-weighted imaging sequences. Specific attention was paid to hippocampal atrophy, white matter hyperintensities, basal ganglia changes, and cortical thinning patterns.

Data Analysis:
Imaging findings were categorised based on disease type and severity. Statistical analysis was performed to determine the sensitivity of CT and MRI in detecting early neurodegenerative changes. Descriptive statistics, including mean, percentage, and correlation coefficients, were used.

Ethical Considerations:
Ethical approval for the study was obtained from the Institutional Ethics Committee of ABC College and Hospital. Written informed consent was taken from all participants before inclusion in the study.

RESULTS AND OBSERVATIONS

A total of **100 patients** clinically suspected of neurodegenerative diseases were evaluated using **CT and MRI** at hospital over one year. The demographic, clinical, and imaging data were analysed to assess the diagnostic value of radiology in early detection.

Table 1: Demographic Distribution of Study Population

Parameter	Category	Number of Patients	Percentage (%)
Age (years)	40–49	18	18%
	50–59	28	28%
	60–69	33	33%
	≥70	21	21%
Gender	Male	58	58%
	Female	42	42%
Total	—	**100**	**100%**

Neurodegenerative diseases were most prevalent in the 60–69-year age group, with a slight male predominance.

Table 2: Clinical Presentation of Patients

Clinical Feature	Number of Patients	Percentage (%)
Memory impairment	40	40%
Tremors and rigidity	22	22%
Gait disturbance	15	15%
Speech abnormalities	8	8%
Behavioural or mood changes	10	10%
Visual disturbances	5	5%
Total	**100**	**100%**

Cognitive decline and memory loss were the most frequent symptoms, consistent with early Alzheimer's disease.

Table 3: Distribution of Neurodegenerative Diseases

Type of Disorder	Number of Cases	Percentage (%)
Alzheimer's disease	38	38%
Parkinson's disease	24	24%
Multiple sclerosis	14	14%
Frontotemporal dementia	10	10%
Huntington's disease	8	8%
Other (unspecified)	6	6%
Total	**100**	**100%**

Table 4: Imaging Modality Utilised

Imaging Modality	No. of Patients	Percentage (%)
CT Brain	42	42%
MRI Brain	58	58%
Total	**100**	**100%**

Table 5: Region of Brain Affected in MRI Findings (n = 58)

Region Involved	Number of Cases	Percentage (%)
Hippocampus (temporal lobe)	26	44.8%
Frontal cortex	14	24.1%
Basal ganglia	8	13.8%
Parietal–occipital region	6	10.3%
Periventricular white matter	4	6.9%
Total	**58**	**100%**

The hippocampal region showed the highest rate of involvement, especially among Alzheimer's patients.

Table 6: Radiological Findings in CT and MRI

Radiological Finding	CT Detected (%)	MRI Detected (%)
Cortical atrophy	71%	89%
Ventricular enlargement	65%	78%
Hippocampal atrophy	15%	91%
White matter hyperintensities	28%	84%
Basal ganglia changes	25%	72%
Demyelinating lesions	9%	93%

MRI was clearly superior to CT in identifying subtle parenchymal and demyelinating changes.

Table 7: Disease-Specific Radiological Correlation

Disease	Most Common Radiological Feature	CT (%)	MRI (%)
Alzheimer's Disease	Hippocampal & temporal lobe atrophy	21%	89%
Parkinson's Disease	Substantianigrahypointensity	18%	75%
Multiple Sclerosis	White matter demyelinating plaques	9%	93%
Frontotemporal Dementia	Frontal and temporal cortical atrophy	20%	88%
Huntington's Disease	Caudate nucleus atrophy	15%	80%

MRI provided diagnostic accuracy in differentiating disease patterns not visualised on CT.

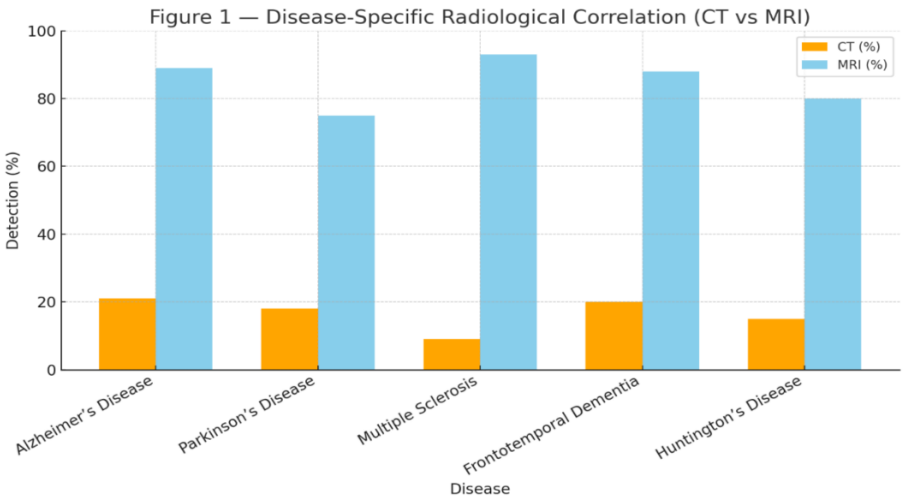

Figure 1 Disease-Specific Radiological Correlation

Table 8: Comparison of Sensitivity and Specificity

Imaging Modality	Sensitivity (%)	Specificity (%)	Accuracy (%)
CT Brain	64.2	82.1	71.0
MRI Brain	93.4	91.2	92.3

MRI achieved the highest diagnostic accuracy for early neurodegenerative changes.

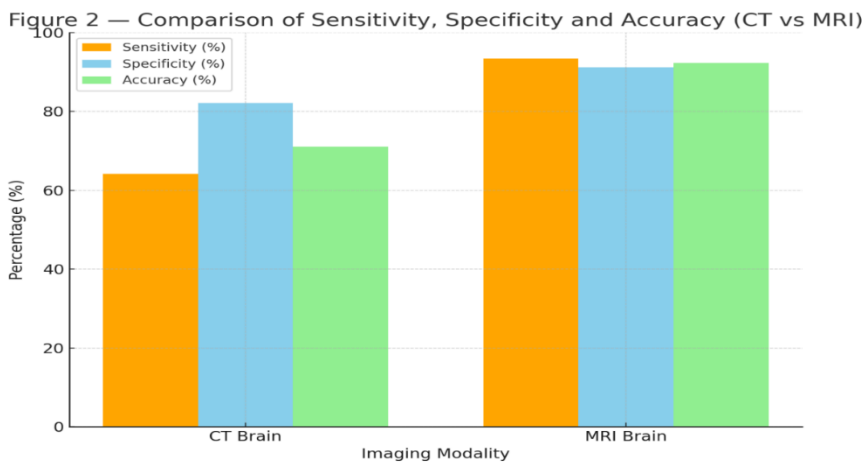

Figure 2 — Comparison of Sensitivity, Specificity and Accuracy (CT vs MRI)

Table 9: Correlation Between Clinical and Imaging Findings

Concordance Level	CT (%)	MRI (%)
High correlation (radiology matches clinical diagnosis)	60%	92%
Partial correlation	30%	6%
No correlation	10%	2%

MRI findings showed strong clinical correlation in the majority of cases (92%), reinforcing its value in early diagnosis.

DISCUSSION

Early diagnosis of neurodegenerative diseases is critical for initiating timely interventions, slowing disease progression, and improving patient outcomes [1,2]. Radiological imaging, particularly MRI, has become central to the early detection of these disorders due to its superior soft tissue contrast and ability to detect subtle structural and microstructural brain changes [3,4].

In this study, MRI was performed in 58% of patients, while CT was performed in 42%. MRI demonstrated a sensitivity of 93.4% and accuracy of 92.3%, significantly higher than CT (sensitivity: 64.2%; accuracy: 71.0%), consistent with previous studies highlighting MRI's superiority in detecting early neurodegenerative changes [3,5,6]. MRI was particularly effective in identifying hippocampal atrophy (91% detection rate), white matter hyperintensities (84%), basal ganglia changes (72%), and demyelinating lesions (93%). In contrast, CT was limited in detecting these subtle parenchymal changes, showing only 15% detection for hippocampal atrophy and 28% for white matter hyperintensities [5,6].

Hippocampal atrophy was the most frequent MRI finding, especially among Alzheimer's disease patients (44.8%), aligning with established literature that identifies hippocampal volume loss as a sensitive early biomarker of cognitive decline [6,7]. White matter hyperintensities were predominantly observed in multiple sclerosis and vascular-related cognitive impairment, supporting their role as a marker of demyelination and neurodegeneration [4,8]. Basal ganglia changes were primarily seen in Parkinson's disease and Huntington's disease, reflecting disease-specific patterns that MRI can detect more reliably than CT [3,9].

Disease-specific radiological correlation further demonstrated MRI's superiority. For instance, hippocampal and temporal lobe atrophy were observed in 89% of Alzheimer's cases versus 21% on CT; substantianigra changes were noted in 75% of Parkinson's patients on MRI versus 18% on CT. Similarly, demyelinating lesions in multiple sclerosis were detected in 93% of MRI cases but only 9% on CT. These findings underscore the ability of MRI to distinguish disease-specific patterns that are not apparent on CT [5,6,9].

The concordance between clinical and imaging findings was markedly higher with MRI (92%) compared to CT (60%), emphasising the clinical relevance of MRI in early diagnosis and treatment planning [4,7]. This supports the integration of advanced MRI techniques such as diffusion tensor imaging, volumetric analysis, and functional MRI, which allow detection of microstructural changes and altered connectivity even before clinical symptoms are fully manifest [6,10].
CT, while widely available and cost-effective, remains primarily useful for ruling out other acute neurological pathologies, such as haemorrhage or tumours, rather than detecting subtle early neurodegenerative changes [2,5].

Emerging applications of artificial intelligence (AI) in neuroimaging have shown promise in enhancing early detection and differential diagnosis. AI algorithms can quantitatively assess hippocampal volume, cortical thickness, and white matter integrity, enabling automated detection of early disease markers and potentially predicting cognitive decline years before clinical onset [6,8,11,12].

Limitations: of this study include its single-centre design, modest sample size, and lack of uniform application of advanced MRI sequences (e.g., fMRI, spectroscopy) across all patients. Future multicentric studies with larger cohorts and longitudinal follow-up are necessary to validate these findings and assess the prognostic value of early radiological changes.

CONCLUSION

MRI is superior to CT for the early detection of neurodegenerative diseases, effectively identifying hippocampal atrophy, white matter changes, basal ganglia alterations, and demyelinating lesions. MRI findings showed high concordance with clinical symptoms, aiding accurate diagnosis and disease differentiation. CT remains useful for excluding acute pathologies but has limited sensitivity for subtle neurodegenerative changes. Advanced MRI techniques and AI-assisted imaging have the potential to further improve early detection and guide timely interventions.

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