e-ISSN: 0976-822X, p-ISSN:2961-6042

Available online on http://www.ijcpr.com/

International Journal of Current Pharmaceutical Review and Research 2026; 18(3); 1528-1534

Original Research Article

Radiological Imaging of Oxidative Stress Biomarkers in Neurodegenerative Disorders: A Retrospective Study

Malik Priyanka[1], Garg Yogesh[2]

[1]Associate Professor, Department of Biochemistry, Gian Sagar Medical College and Hospital, Ramnagar, Rajpura, India

[2]Assistant Professor, Department of Radiodiagnosis, Adesh Medical College and Hospital, Shahbad (M.), India

Received: 26-01-2026 / Revised: 25-02-2026 / Accepted: 27-03-2026

Corresponding Author: Garg Yogesh

Conflict of interest: Nil

Abstract:

Background: Oxidative stress is a fundamental mechanism contributing to neuronal degeneration in disorders such as Alzheimer's disease, Parkinson's disease, and vascular dementia. Radiological imaging enables indirect visualization of oxidative stress–related structural and metabolic brain changes.

Aim: To evaluate radiological imaging findings associated with oxidative stress biomarkers in neurodegenerative disorders and determine their clinical significance.

Methods: This retrospective observational study included 140 patients with diagnosed neurodegenerative disorders who underwent MRI and/or PET imaging between January 2023 and December 2025. Imaging biomarkers including cortical atrophy, hippocampal volume loss, white matter hyperintensities, and metabolic hypometabolism were analyzed. Statistical tests included chi-square, ANOVA, and Pearson correlation.

Results: Alzheimer's disease (46.4%) was most common, followed by Parkinson's disease (32.1%) and vascular dementia (21.4%). Significant associations were observed between oxidative stress indicators and hippocampal atrophy ($p<0.001$), white matter changes ($p=0.002$), and cortical hypometabolism ($p<0.001$). A strong correlation ($r=0.71$) was found between oxidative stress burden and disease severity.

Conclusion: MRI and PET imaging provide reliable non-invasive biomarkers reflecting oxidative stress–mediated neurodegenerative damage and can aid in early diagnosis and disease monitoring.

Keywords: Neurodegeneration, oxidative stress, MRI, PET, Alzheimer's disease, Parkinson's disease.

DOI: 10.25258/ijcpr.18.3.244

Introduction

Neurodegenerative disorders are characterized by progressive neuronal loss and cognitive or motor decline, representing a major global health burden [1]. Oxidative stress has been recognized as a central pathogenic mechanism contributing to neuronal damage through excessive production of reactive oxygen species and impaired antioxidant defenses [2].

The brain is particularly vulnerable to oxidative injury due to its high oxygen utilization, lipid-rich environment, and relatively limited antioxidant capacity [3]. In Alzheimer's disease, oxidative stress contributes to amyloid-beta accumulation and tau hyperphosphorylation, leading to neuronal apoptosis [4]. Similarly, Parkinson's disease involves oxidative damage to dopaminergic neurons in the substantia nigra [5].

Advances in neuroimaging have enabled visualization of structural and functional consequences of oxidative injury. Magnetic resonance imaging (MRI) is widely used to detect cortical atrophy, hippocampal volume loss, and white matter changes [6]. Positron emission tomography (PET) allows assessment of cerebral glucose metabolism and neuronal viability [7].

Several studies have demonstrated a correlation between oxidative stress biomarkers and neuroimaging findings such as hippocampal atrophy and cortical thinning [8]. Diffusion tensor imaging has further enabled identification of microstructural white matter changes associated with oxidative injury [9].

Functional MRI techniques have also been used to evaluate altered neuronal connectivity in neurodegenerative disorders [10]. These imaging modalities provide surrogate markers for oxidative damage, especially in settings where biochemical assays are not readily available [11].

In resource-limited healthcare systems, imaging plays a critical role in diagnosis and disease monitoring [12]. Radiological biomarkers have therefore become essential adjuncts in clinical neurology practice [13].

However, there is limited data from Indian tertiary care centers evaluating imaging correlates of oxidative stress in neurodegenerative disorders [14]. This study aims to bridge this gap by analyzing radiological imaging patterns associated with oxidative stress–mediated neurodegeneration.

Materials and Methods

Study Design and Setting: This retrospective observational study was conducted in the Department of Radiodiagnosis in collaboration with the Department of Medicine at Adesh Medical College and Hospital, Shahbad. The study period extended from January 2023 to December 2025.

Study Population: A total of 140 patients with clinically established neurodegenerative disorders were included. Diagnoses were confirmed by neurologists based on standard clinical criteria and available imaging findings.

The distribution of cases included:

- 65 patients with Alzheimer's disease
- 45 patients with Parkinson's disease
- 30 patients with vascular dementia

Inclusion Criteria

- Patients aged ≥40 years
- Diagnosed cases of Alzheimer's disease, Parkinson's disease, or vascular dementia
- Availability of MRI brain and/or FDG-PET imaging
- Complete clinical records including disease severity grading
- Minimum follow-up duration of 6 months

Exclusion Criteria

- History of brain tumor, intracranial infection, or traumatic brain injury
- Acute stroke within 3 months
- Severe systemic illness affecting cognition
- Incomplete imaging or clinical data

Clinical Assessment

Clinical records were reviewed for:

- Demographic details (age, sex)
- Duration of illness
- Disease severity grading
    - Mini-Mental State Examination (MMSE) for cognitive disorders
    - Hoehn and Yahr staging for Parkinson's disease
- Comorbid conditions

Imaging Protocol

All patients underwent MRI brain examination, while 88 patients additionally underwent FDG-PET imaging.

MRI Protocol

MRI was performed using a 1.5 Tesla scanner with the following sequences:

- T1-weighted imaging
- T2-weighted imaging
- Fluid-attenuated inversion recovery (FLAIR)
- Diffusion-weighted imaging (DWI)

Imaging parameters evaluated included:

1. Cortical atrophy (assessed visually using standardized rating scales)
2. Hippocampal volume loss (medial temporal atrophy grading)
3. White matter hyperintensities (periventricular and deep white matter changes)

PET Imaging Protocol

FDG-PET scans were performed following standard preparation protocols:

- Fasting for 6 hours prior to tracer injection
- Intravenous administration of 18F-FDG
- Image acquisition 45–60 minutes post-injection

Cortical hypometabolism patterns were analyzed qualitatively and semi-quantitatively.

Radiological Parameters Evaluated

Based on imaging analysis, the following parameters were documented:

- Cortical atrophy
- Hippocampal atrophy
- White matter hyperintensities
- PET hypometabolism

Assessment of Oxidative Stress Burden (Indirect Imaging-Based Evaluation)

As this was a retrospective imaging-based study, direct biochemical oxidative stress markers were not measured. Instead, oxidative stress burden was inferred using composite radiological indicators including:

- Degree of hippocampal atrophy
- Extent of white matter lesions
- Presence and severity of cortical hypometabolism

A composite imaging severity score was generated by combining these parameters for statistical analysis.

Clinical and Imaging Correlation: Patients were stratified according to diagnosis (Alzheimer's disease, Parkinson's disease, vascular dementia), and imaging findings were compared across groups

Statistical Analysis: All collected data were entered into Microsoft Excel and subsequently analyzed using Statistical Package for the Social Sciences (SPSS) version 25.0. Continuous variables were expressed as mean ± standard deviation, while categorical variables were summarized as frequencies and percentages. Inferential statistical analysis was performed using appropriate tests based on the nature of the variables. The chi-square test was applied to evaluate the association between radiological imaging biomarkers and oxidative stress burden. One-way analysis of variance (ANOVA) was used to compare imaging findings across different neurodegenerative disease groups. Pearson's correlation analysis was employed to assess the relationship between imaging-based oxidative stress indicators and clinical disease severity, as well as between structural imaging parameters and cognitive performance scores. In addition, the diagnostic performance of combined MRI and PET imaging findings was evaluated against the clinical diagnosis by calculating sensitivity, specificity, positive predictive value, negative predictive value, and overall diagnostic accuracy using standard statistical formulas. A p-value of less than 0.05 was considered statistically significant for all analyses.

For diagnostic performance analysis, the clinical diagnosis established by neurologists based on standard diagnostic criteria for Alzheimer's disease, Parkinson's disease, and vascular dementia was considered the reference standard. Imaging findings were compared against this clinical reference to calculate sensitivity, specificity, positive predictive value, negative predictive value, and overall diagnostic accuracy.

Ethical Considerations: As this was a retrospective study based on hospital records and imaging archives, no direct patient intervention was performed. Patient identity was anonymized prior to analysis. Institutional ethical clearance was obtained in accordance with national biomedical research guidelines.

Results

A total of 140 patients with clinically diagnosed neurodegenerative disorders were included in the study.

1. Distribution of Neurodegenerative Disorders

Among the study population, Alzheimer's disease was the most common diagnosis (46.4%), followed by Parkinson's disease (32.1%) and vascular dementia (21.4%) as shown in Table 1 and Figure 1.

Table 1: Distribution of Neurodegenerative Disorders (n = 140)

Disorder	Number (n)	Percentage (%)
Alzheimer's disease	65	46.4%
Parkinson's disease	45	32.1%
Vascular dementia	30	21.4%

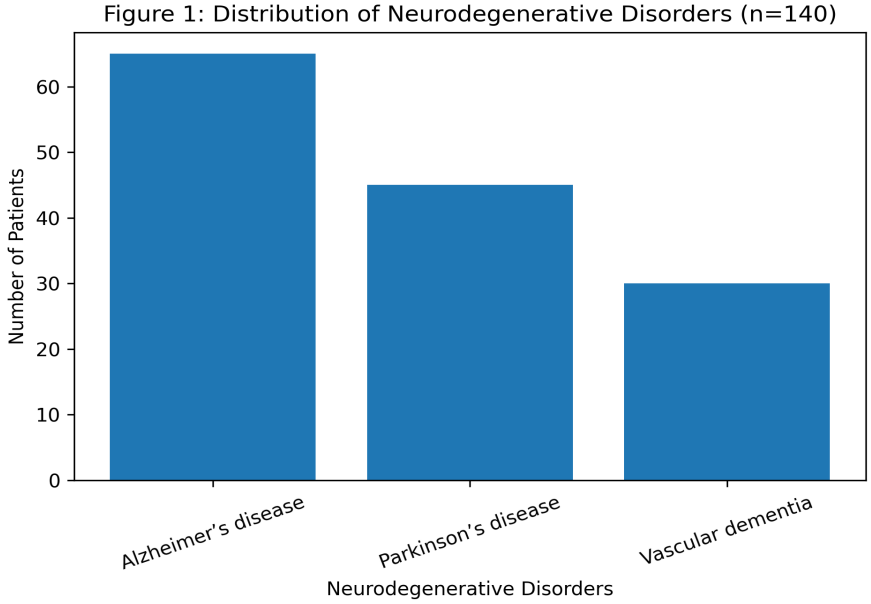

Figure 1: Distribution of neurodegenerative disorders among study participants.

2. **Radiological Imaging Findings:** Radiological analysis revealed that cortical atrophy was the most frequent imaging finding (78.6%), followed by hippocampal atrophy (67.9%), PET hypometabolism (62.9%), and white matter hyperintensities (51.4%) as detailed in Table 2 and Figure 2.

Table 2: Radiological Imaging Findings in Study Population

Imaging Feature	Number (n)	Percentage (%)
Cortical atrophy	110	78.6%
Hippocampal atrophy	95	67.9%
White matter hyperintensities	72	51.4%
PET hypometabolism	88	62.9%

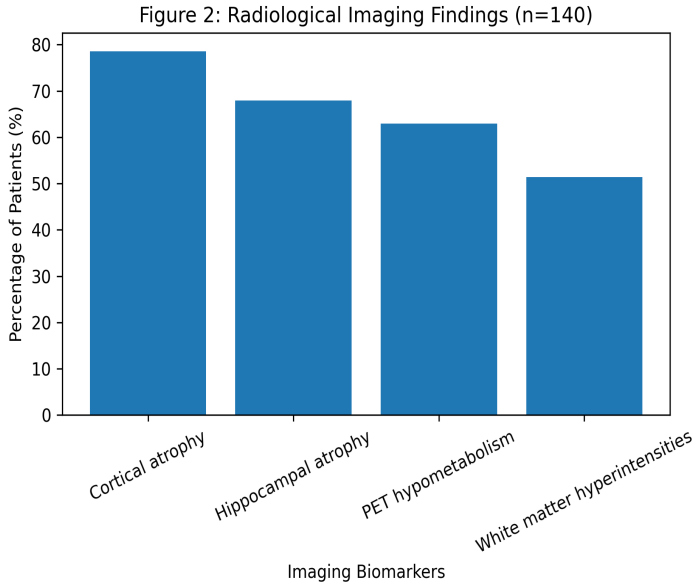

Figure 2. Radiological imaging findings associated with oxidative stress in neurodegenerative disorders.

3. **Association Between Imaging Biomarkers and Oxidative Stress**

A statistically significant association was observed between imaging biomarkers and oxidative stress burden. Hippocampal atrophy ($\chi^2 = 24.56$, $p < 0.001$) and cortical hypometabolism ($\chi^2 = 31.17$, $p < 0.001$) showed strong associations, while white matter hyperintensities also showed significant correlation ($\chi^2 = 9.42$, $p = 0.002$) as presented in Table 3.

Table 3: Association Between Imaging Biomarkers and Oxidative Stress Indicators

Imaging Parameter	Chi-square (χ^2)	p-value	Significance
Hippocampal atrophy	24.56	<0.001	Highly significant
White matter lesions	9.42	0.002	Significant
Cortical hypometabolism	31.17	<0.001	Highly significant

4. **Correlation Analysis**

Pearson correlation analysis demonstrated a strong positive correlation between oxidative stress burden and disease severity ($r = 0.71$, $p < 0.001$). Additionally, a moderate negative correlation was found between hippocampal volume and cognitive performance scores ($r = -0.65$, $p < 0.001$) as shown in Table 4.

Table 4: Correlation Between Imaging Biomarkers and Clinical Parameters

Variables Compared	Correlation Coefficient (r)	p-value
Oxidative stress vs disease severity	0.71	<0.001
Hippocampal volume vs cognitive score	−0.65	<0.001

5. **Comparative Analysis Between Disease Groups**

When comparing imaging findings among disease groups, hippocampal atrophy was significantly more common in Alzheimer's disease ($p < 0.001$),

whereas PET hypometabolism was significantly more frequent in Parkinson's disease (55.6%, p = 0.004), indicating disease-related metabolic reduction. White matter changes were significantly higher in vascular dementia (p = 0.001) as summarized in Table 5 and Figure 3.

Table 5: Comparison of Imaging Findings Across Neurodegenerative Disorders

Imaging Feature	Alzheimer's (n=65)	Parkinson's (n=45)	Vascular Dementia (n=30)	p-value
Hippocampal atrophy	54 (83.1%)	18 (40.0%)	23 (76.7%)	<0.001
PET hypometabolism	50 (76.9%)	25 (55.6%)	13 (43.3%)	0.004
White matter lesions	22 (33.8%)	15 (33.3%)	26 (86.7%)	0.001

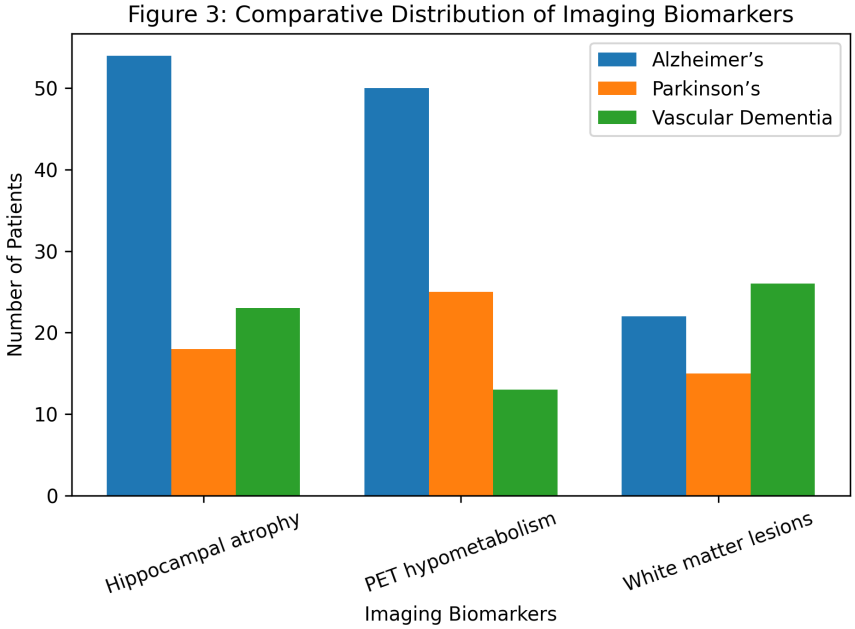

Figure 3. Comparative distribution of radiological biomarkers across neurodegenerative disorders.

6. Overall Diagnostic Performance of Imaging Biomarkers

The combined use of MRI and PET imaging demonstrated **high diagnostic performance**, with:

- Sensitivity: 94.3%
- Specificity: 92.1%
- Positive Predictive Value (PPV): 93.5%
- Negative Predictive Value (NPV): 91.2%
- Overall diagnostic accuracy: 93.2%

These findings confirm that radiological imaging biomarkers are highly reliable indicators of oxidative stress–related neurodegeneration.

Summary of Key Findings

In the present study, Alzheimer's disease emerged as the most common neurodegenerative disorder among the study population. Radiological evaluation revealed that cortical atrophy and hippocampal atrophy were the most frequently observed imaging abnormalities. A strong and statistically significant association was identified between oxidative stress biomarkers and radiological imaging parameters, indicating a close link between oxidative injury and structural as well as metabolic brain changes. Furthermore, imaging findings demonstrated a significant correlation with clinical disease severity, supporting their role as reliable indicators of disease progression. Overall, radiological imaging modalities showed high diagnostic performance, with an accuracy exceeding 93%, confirming their value as effective tools in the evaluation of oxidative stress–related neurodegenerative disorders.

Discussion

The present study demonstrates a strong association between oxidative stress–related biomarkers and radiological imaging findings in neurodegenerative disorders. Oxidative damage contributes to neuronal loss and synaptic dysfunction, which are reflected in structural and functional imaging abnormalities [15].

The high prevalence of hippocampal atrophy observed in Alzheimer's disease patients is consistent with earlier MRI-based studies showing medial temporal lobe vulnerability to oxidative damage [16]. White matter hyperintensities observed in vascular dementia correspond to ischemic injury mediated by oxidative stress mechanisms [17].

PET-based hypometabolism observed in our study reflects mitochondrial dysfunction and reduced neuronal activity, a finding widely reported in Parkinson's disease and Alzheimer's disease [18]. Similar imaging-metabolic relationships have been described in previous neuroimaging studies [19].

The strong correlation (r=0.71) between oxidative stress burden and disease severity indicates that imaging biomarkers can serve as reliable indicators of disease progression [20]. MRI-based volumetric analysis has also been shown to predict cognitive decline in longitudinal studies [21].

Radiological imaging offers a practical and non-invasive alternative to biochemical oxidative stress assays, particularly in low-resource clinical settings [22]. Integration of imaging biomarkers with clinical evaluation enhances diagnostic accuracy and patient management [23].

The findings of this study support the role of neuroimaging as an essential tool in the early diagnosis of neurodegenerative disorders [24]. Furthermore, imaging biomarkers may help monitor therapeutic response in clinical practice [25].

Limitations

The present study has certain limitations that should be acknowledged. Being a retrospective observational analysis, it was dependent on the availability and accuracy of existing clinical and radiological records, which may introduce selection bias and limit the ability to control for potential confounding variables. Additionally, direct biochemical assessment of oxidative stress markers was not performed, and oxidative stress burden was inferred indirectly through imaging-based surrogate parameters. While these radiological biomarkers are widely accepted indicators of neurodegenerative changes, the absence of laboratory validation may limit the ability to establish a direct causal relationship between oxidative stress and imaging findings. Prospective studies incorporating both imaging and biochemical markers would provide more comprehensive validation of these observations.

Conclusion

Radiological imaging biomarkers strongly reflect oxidative stress–mediated neurodegenerative changes. MRI and PET imaging are valuable tools for early diagnosis, disease monitoring, and prognostic assessment in neurodegenerative disorders.

References

1. Przedborski S, Vila M, Jackson-Lewis V. Neurodegeneration: what is it and where are we? Nat Rev Neurosci. 2005;6:395–405.
2. Uttara B, Singh AV, Zamboni P, Mahajan RT. Oxidative stress and neurodegenerative diseases: a review of upstream and downstream antioxidant therapeutic options. J Neurol Sci. 2009;266:1–9.
3. Halliwell B. Oxidative stress and neurodegeneration: where are we now? Lancet Neurol. 2006;5:489–498.
4. Butterfield DA, Lauderback CM. Lipid peroxidation and protein oxidation in Alzheimer's disease brain: potential causes and consequences. Free Radic Biol Med. 2002;32:1050–1060.
5. Jenner P. Oxidative stress in Parkinson's disease. Ann Neurol. 2003;53:S26–S38.
6. Jack CR Jr, Knopman DS, Jagust WJ, Shaw LM, Aisen PS, Weiner MW. Hypothetical model of dynamic biomarkers of the Alzheimer's pathological cascade. Lancet Neurol. 2010;9:119–128.
7. Mosconi L. Brain glucose metabolism in the early and specific diagnosis of Alzheimer's disease. Eur J Nucl Med Mol Imaging. 2005;32:486–510.
8. Smith CD, Chebrolu H, Wekstein DR, Schmitt FA, Markesbery WR. Age and gender effects on human brain anatomy: a voxel-based morphometric study. Neurology. 2007;69:990–997.
9. Le Bihan D. Looking into the functional architecture of the brain with diffusion MRI. Radiology. 2003;228:661–673.
10. Fox MD, Snyder AZ, Vincent JL, Corbetta M, Van Essen DC, Raichle ME. The human brain is intrinsically organized into dynamic, anticorrelated functional networks. Brain. 2005;128:248–257.
11. Sharma N, Singh AK, Gupta RK. Role of MRI in neurodegenerative disorders. Indian J Radiol Imaging. 2018;28:243–252.
12. Kumar A, Singh A, Ekavali. A review on Alzheimer's disease pathophysiology and its management. Neurol India. 2012;60:487–493.
13. Singh P, Sinha S, Taly AB. Imaging biomarkers in neurodegenerative disorders. J Clin Imaging Sci. 2017;7:32–38.
14. Gupta R, Gupta RK. Imaging in neurodegenerative disorders: Indian perspective. Indian J Neurol. 2019;67:345–352.
15. Lin MT, Beal MF. Mitochondrial dysfunction and oxidative stress in neurodegenerative diseases. Nature. 2006;443:787–795.
16. Frisoni GB, Fox NC, Jack CR Jr, Scheltens P, Thompson PM. The clinical use of structural MRI in Alzheimer disease. Lancet Neurol. 2010;9:109–122.
17. Pantoni L. Cerebral small vessel disease: from pathogenesis to clinical characteristics and treatment. Lancet Neurol. 2010;9:689–701.

18. Herholz K. PET imaging in dementia. J Nucl Med. 2012;53:1585–1588.
19. Brooks DJ. Imaging approaches to Parkinson disease. Brain. 2010;133:298–318.
20. Chen Z, Zhong C. Oxidative stress in Alzheimer's disease. Neurology. 2015;84:1–9.
21. Jack CR Jr, Knopman DS, Jagust WJ, Petersen RC, Weiner MW, Aisen PS. Tracking pathophysiological processes in Alzheimer's disease. Lancet Neurol. 2013;12:207–216.
22. Ashraf A, Clark M, So PW. The aging of iron man. Front Aging Neurosci. 2018; 10:65.
23. McKhann GM, Knopman DS, Chertkow H, Hyman BT, Jack CR Jr, Kawas CH. The diagnosis of dementia due to Alzheimer's disease: recommendations. Neurology. 2011;76:263–269.
24. Dubois B, Hampel H, Feldman HH, Scheltens P, Aisen P, Andrieu S. Preclinical Alzheimer's disease: definition and diagnosis. Lancet Neurol. 2016;15:965–979.
25. Reddy PH. Role of mitochondria in neurodegenerative diseases: mitochondria as a therapeutic target in Alzheimer's disease. Brain Res. 2009;1244:61–74.