IJNRD.ORG ISSN : 2456-4184
INTERNATIONAL JOURNAL OF NOVEL RESEARCH AND DEVELOPMENT (IJNRD) | IJNRD.ORG
An International Open Access, Peer-reviewed, Refereed Journal

"LOSS OF SWALLOW TAIL SIGN AS A RADIOLOGICAL MARKER IN DIAGNOSIS AND SEVERITY STAGING OF IDIOPATHIC PARKINSON'S DISEASE"

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Abstract:

- The loss of radiologic swallow tail sign on MRI scans of the substantia nigra is a promising diagnostic marker of Parkinson's disease.
- An early influential study showed that the hyper intense inner part of the swallow tail on T2 weighted images corresponds to iron poor areas in substantia nigra and suggested it to equal nigrosome 1 ,the dopaminergic region affected earliest and strongest in Parkinson's disease
- Nigrosomes, are a small group of dopaminergic cells in the Substantia Nigra pars compacta(SNc). They are partially pigment-free in the immunohistochemical staining of the

calcium antagonist protein D28K for healthy people. While it is absence in the SNc can be detected using immunohistochemistry staining in Parkinsonism patients.

- Nigrosomes consists of 5 families, among which nigrosomes-1 is the largest. Nigrosome-1 appears as a hyperintense droplet giving swallow tail appearance in healthy people.
- MRI is performed as an ancillary investigation to increase the certainty for the correct diagnosis of parkinsonism and to look for findings that can support the diagnosis of atypical parkinsonism

Keywords: Loss of swallow tail sign, Idiopathic parkinson's disease, Nigrosome.

Abbreviations: SNc- Substantia Nigra pars compacta, PD-Parkinson's Disease
STS – Swallow tail sign

Introduction:

Parkinson's disease (PD) is one of the most common neurodegenerative disorders, affecting millions of people worldwide. It primarily results from the progressive loss of dopamine-producing neurons in the substantia nigra (SN), a key region in the brain responsible for coordinating movement[(1)]. This loss leads to classic motor symptoms like tremors, rigidity, slowed movements, and balance issues, often accompanied by non-motor symptoms such as sleep disturbances, depression, and cognitive changes. Diagnosing PD, especially in its early stages, is crucial to ensuring timely treatment and better quality of life for patients. However, distinguishing it from other Parkinsonian syndromes can be challenging, as symptoms often overlap[(2)].

Magnetic Resonance Imaging (MRI) has become an essential tool in studying brain changes in neurodegenerative diseases. In recent years, a specific imaging feature, known as the "swallow tail sign," has gained attention as a potential marker for Parkinson's disease. This sign represents the normal appearance of a structure in the substantia nigra, known as Nigrosome-1, on high-resolution MRI scans. In people with PD, this sign often disappears due to the underlying degeneration of neurons, offering a potential clue to the diagnosis[(3)].

This study explores whether the loss of the swallow tail sign on MRI can reliably help identify Parkinson's disease in individuals with suspected cases. By focusing on this non-invasive imaging marker, we aim to provide insights into its diagnostic accuracy and its possible role in understanding disease severity. Ultimately, this research hopes to bridge the gap between clinical suspicion and definitive diagnosis, making early detection more accessible and effective for patients. By improving how we use imaging to detect PD, this study could play a role in guiding treatment strategies and improving outcomes for those living with the disease.

Typical Imaging Findings in Parkinson's Disease

Table 1: Typical Imaging Findings in Parkinson's Disease

MRI Technique	Findings
T2-weighted imaging	Hypo intensity in the substantia nigra due to iron deposition.
SWI	Loss of the swallow tail sign in the substantia nigra.
Neuromelanin-sensitive imaging	Reduced signal intensity in the substantia nigra.
DTI	Decreased fractional anisotropy in the substantia nigra and basal ganglia.
QSM	Increased magnetic susceptibility indicating iron accumulation.

SWALLOW TAIL SIGN: ANATOMY AND IMAGING

Anatomy of the Substantia Nigra and Its Role in Imaging

The substantia nigra (SN) is a critical structure located in the midbrain, playing a central role in the regulation of motor function through its dopaminergic neurons. It is part of the basal ganglia, and its degeneration is a hallmark of Parkinson's disease (PD). The SN can be anatomically divided into the pars compacta and the pars reticulata. The pars compacta contain dopaminergic neurons and is the region most affected in PD, with significant loss of pigmentation due to neuromelanin depletion[23].

Imaging the SN is essential in the evaluation of PD because changes in this region precede clinical symptoms. The degeneration of Nigrosome-1, a cluster of dopaminergic neurons within the dorsolateral part of the pars compacta, is a specific finding in PD. This anatomical region corresponds to the "swallow tail sign" (STS) seen on advanced imaging, which serves as an indirect marker of neurodegeneration[24].

MRI Techniques to Visualize the Substantia Nigra

Advances in MRI have enabled detailed visualization of the SN and its substructures, particularly Nigrosome-1. Key techniques include:

- Susceptibility-Weighted Imaging (SWI): SWI exploits differences in magnetic susceptibility to enhance contrast, making it highly effective for visualizing iron-rich regions such as the SN. Nigrosome-1 appears as a hyperintense area within the hypointense SN[25].
- *T2-Weighted Imaging:* This imaging modality detects iron accumulation and can highlight pathological changes in the SN, although it is less sensitive than SWI for detecting the STS.
- Neuromelanin-Sensitive MRI: This technique leverages the paramagnetic properties of neuromelanin to provide detailed visualization of dopaminergic neurons in the SN. Reduced signal intensity in this region correlates with neuronal loss[3].

- Quantitative Susceptibility Mapping (QSM): QSM measures magnetic susceptibility to assess iron deposition in the SN, a marker of neurodegeneration in PDClick or tap here to enter text..

- 7-Tesla MRI: Detects loss of nigral hyperintensity in the dorsolateral substantia nigra (nigrosome 1) with 100% sensitivity and specificity for PD diagnosis.

- Diffusion-Tensor Imaging (DTI)

- Detects microstructural changes in white matter tracts. Reduced fractional anisotropy in the SNpc and nigrostriatal pathways aids PD diagnosis.

Case history and imaging:

CASE 1:

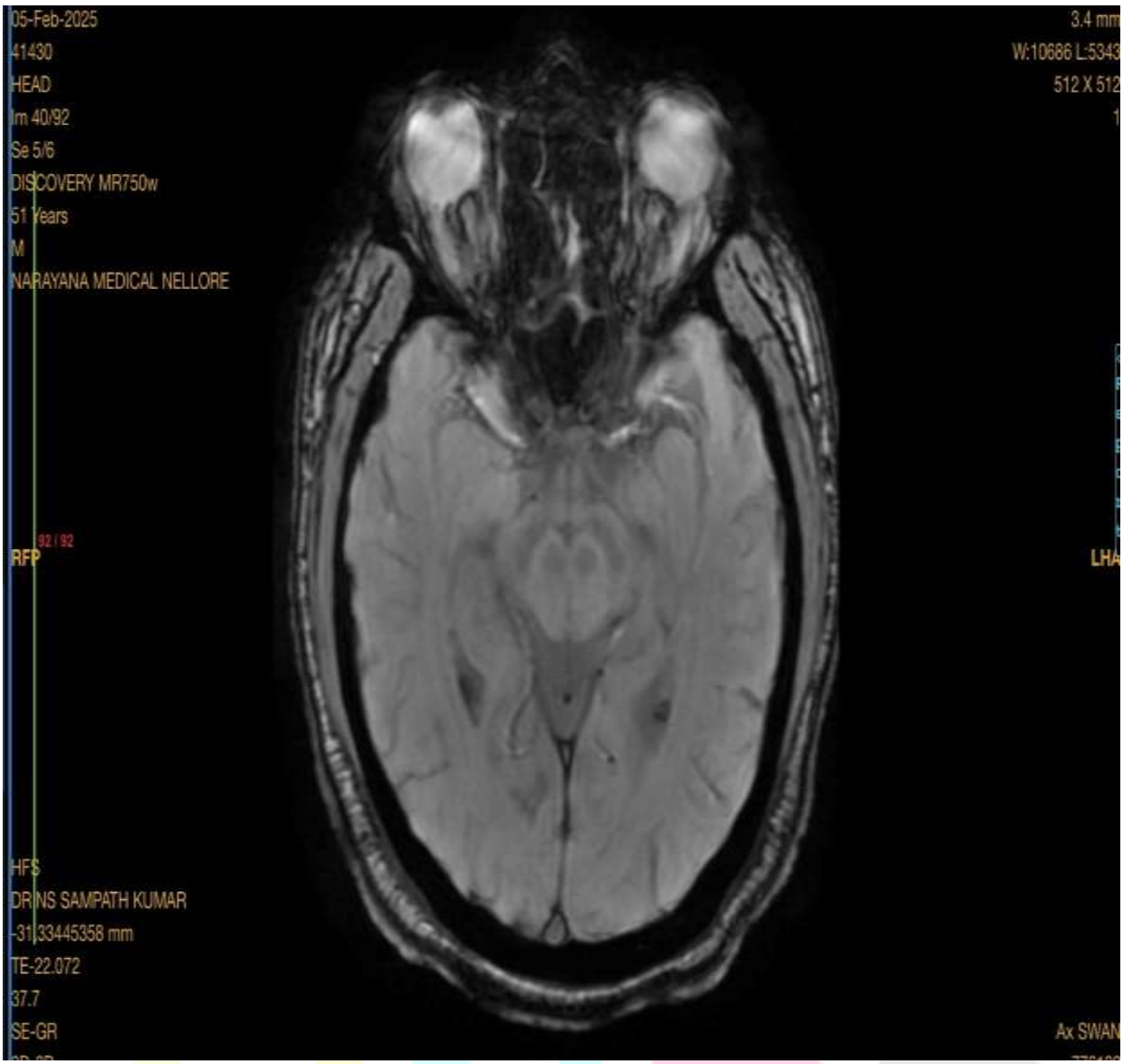
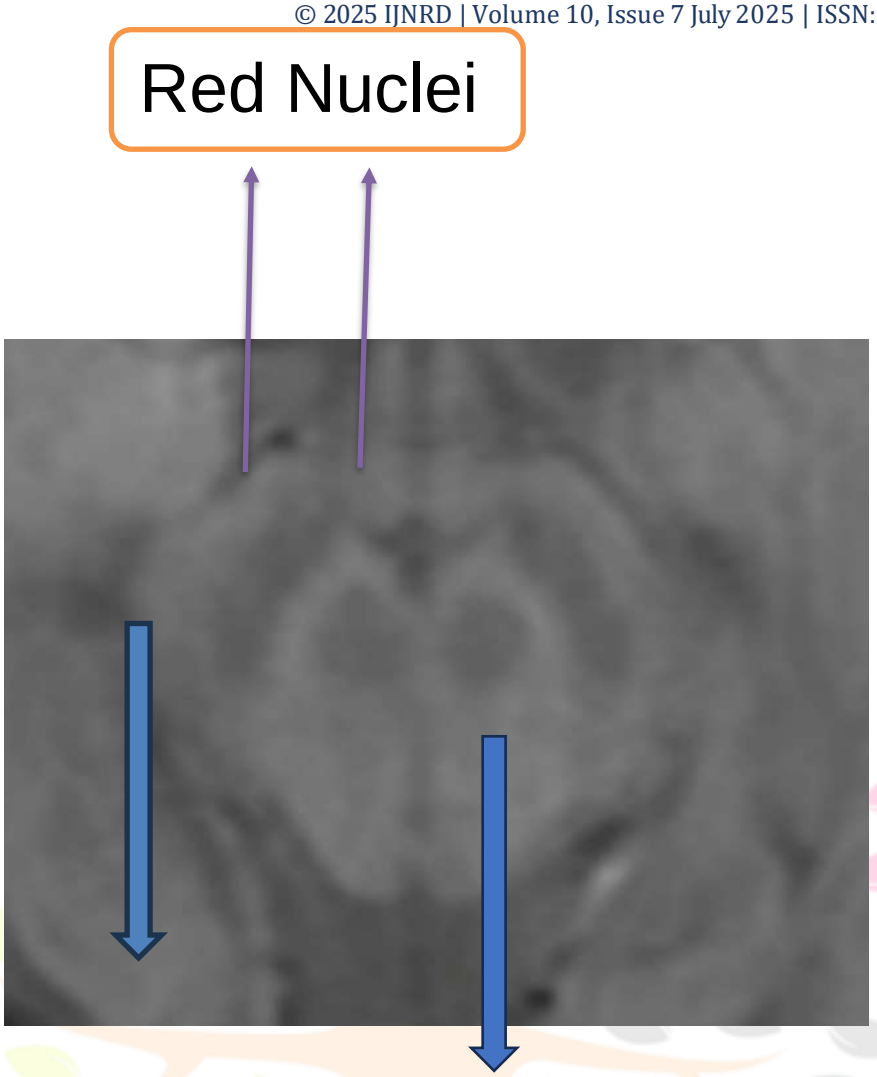


Figure1; A 51 years old male patient presented with resting pill rolling tremors ,paucity of movements, gait disturbances MRI axial SWI image showing bilateral loss of swallow tail sign diagnosed as Idiopathic Parkinsons Disease.



Findings :Zoomed image of Case 1 showing Bilateral loss of swallow tail sign along with above mentioned clinical features, diagnosed as Idiopathic Parkinson's

Case 2:

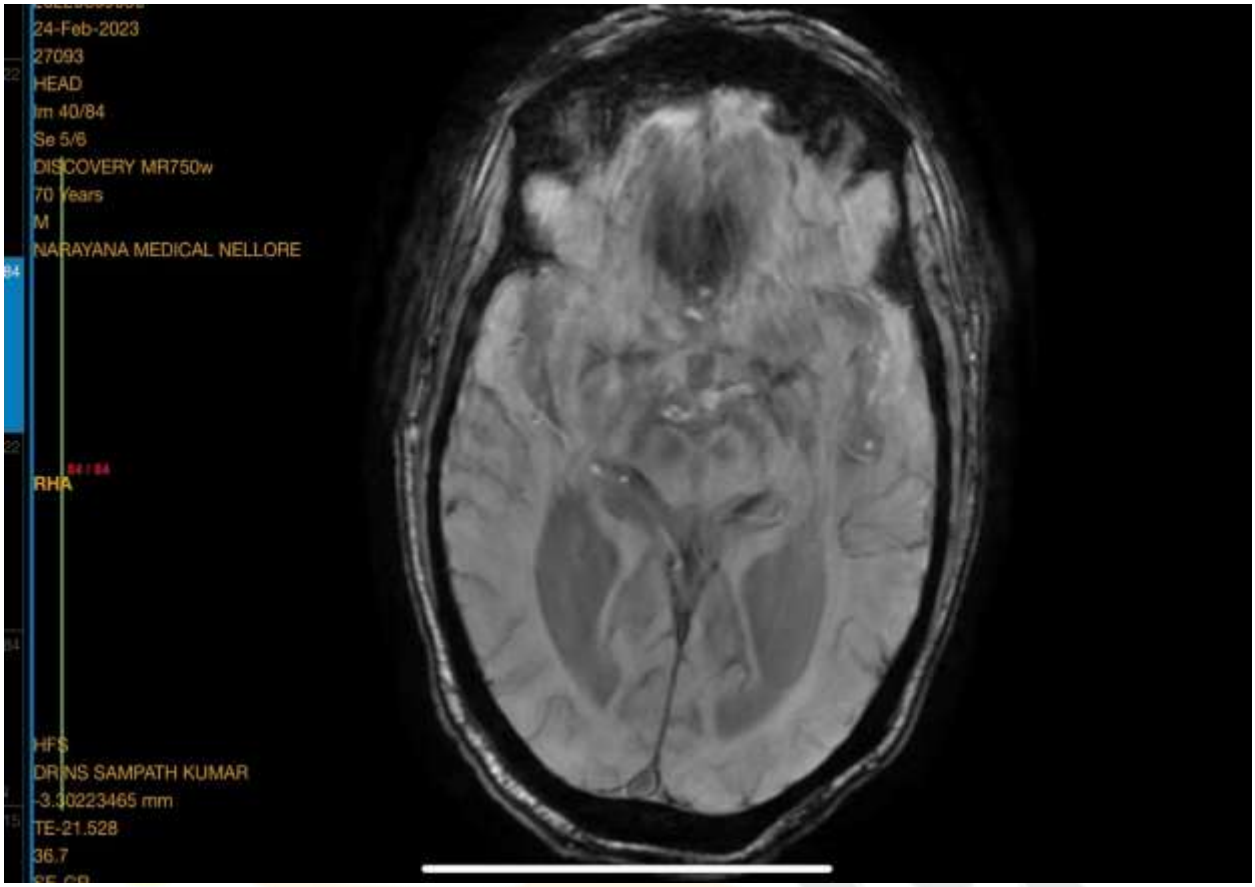
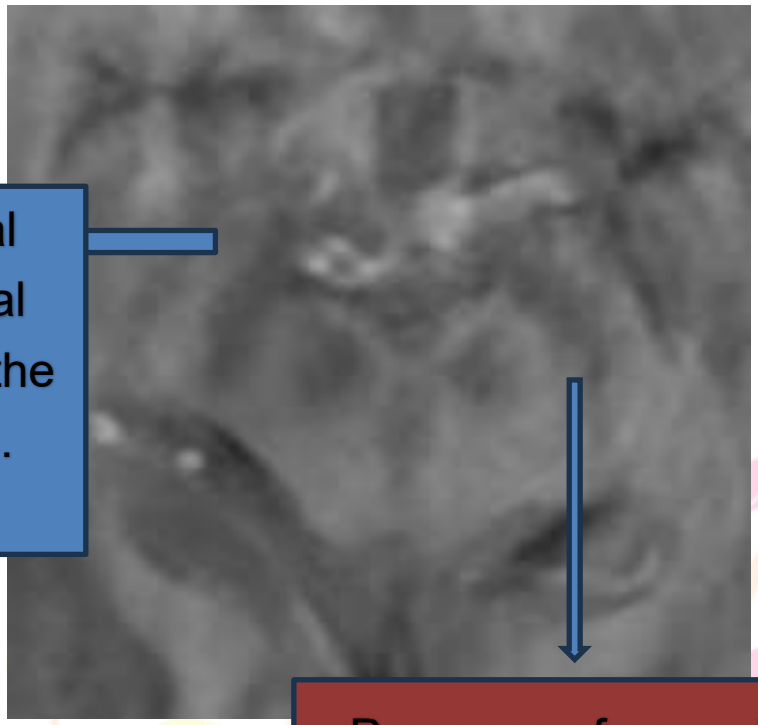


Figure 2 :A 70 years old male patient presented with recurrent falls ,slowness of activities,resting tremors MRI Axial SWI image sequence showing loss of swallow tail sign on right side diagnosed as IPD.



Findings:Normal swallow tail sign on left side , Loss of swallow tail sign on right side along with above clinical features diagnosed as IPD.

Case 3:

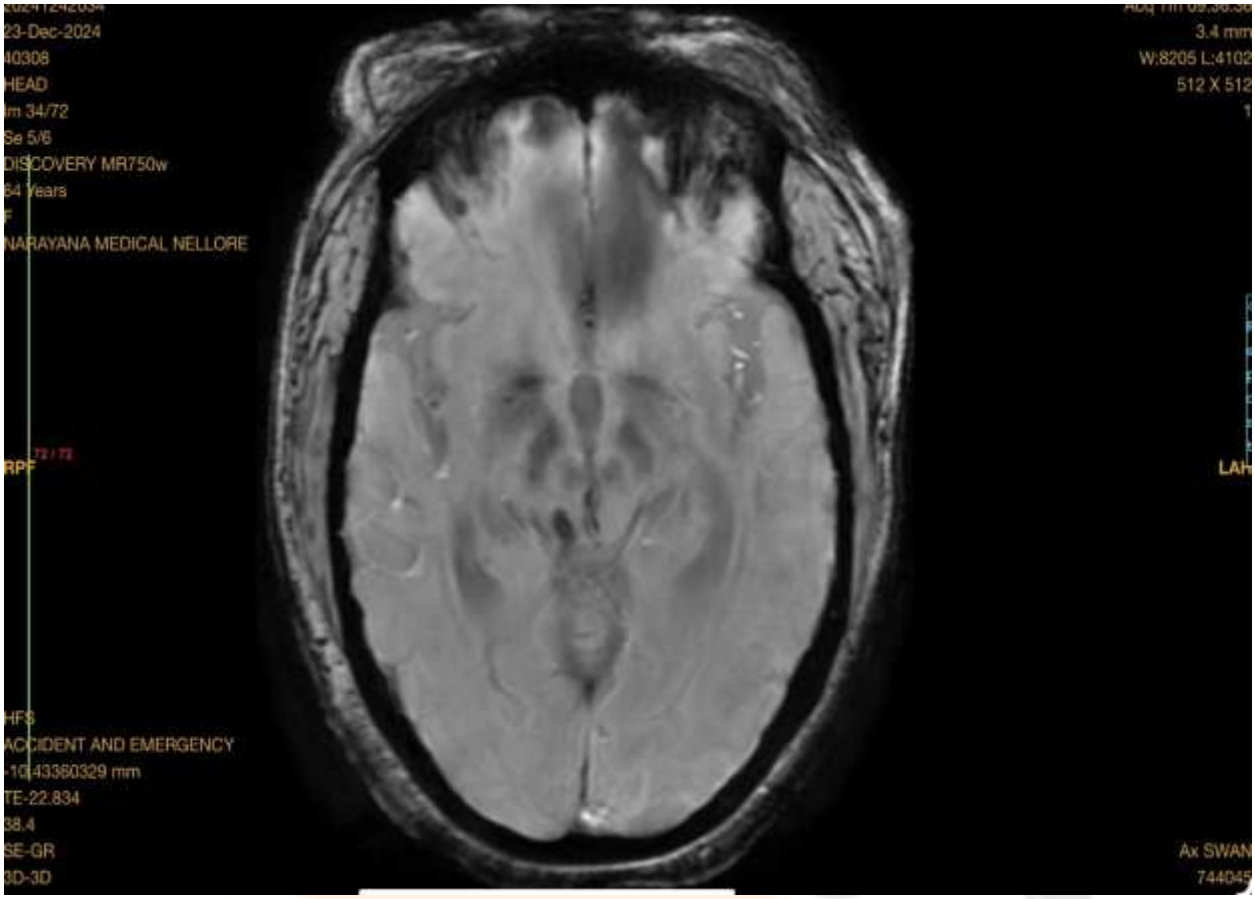
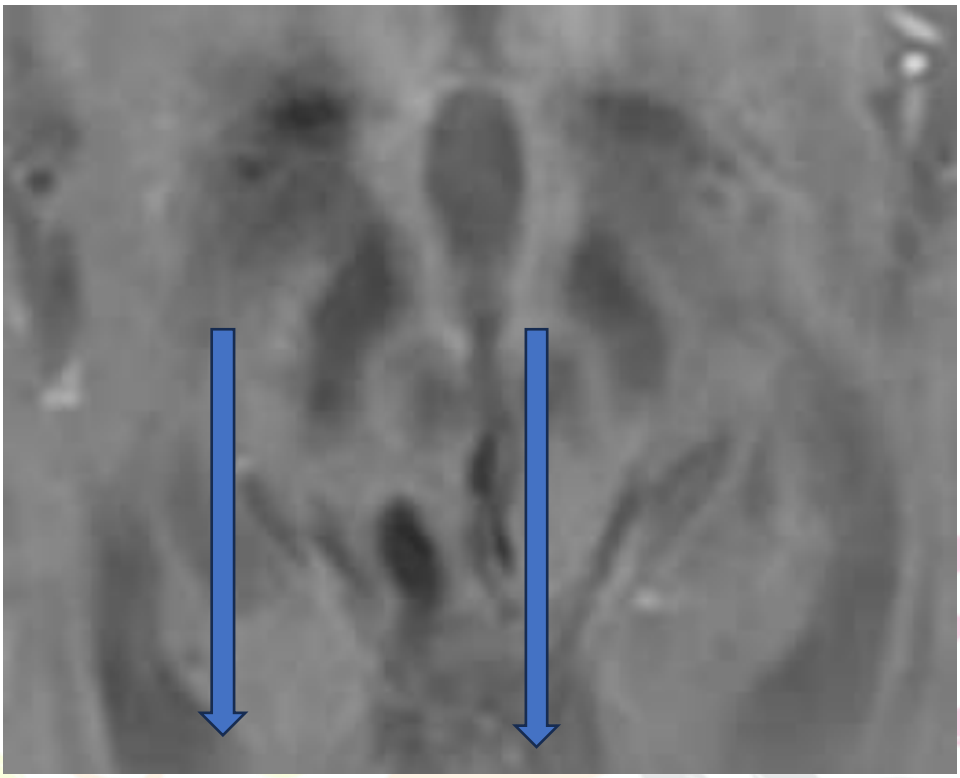


Figure 3 : A 64 years female patient presented with resting tremors,postural instability MRI Axial SWI image sequence showing bilateral loss of swallow tail sign diagnosed as IPD.



Loss of normal high SWI signal intensity within the nigrosome -1 bilaterally.

Findings : Bilateral loss of swallow tail sign , diagnosed as Idiopathic Parkinson's disease(IPD).

DISCUSSION

Parkinson's disease (PD) is a progressive neurodegenerative disorder characterized by the loss of dopaminergic neurons, particularly in the substantia nigra pars compacta (SNc). Accurate and early diagnosis of PD remains a clinical challenge, especially in distinguishing idiopathic Parkinson's disease from other atypical parkinsonian syndromes. Magnetic Resonance Imaging (MRI), especially susceptibility-weighted imaging (SWI), has emerged as a non-invasive tool with the potential to support clinical diagnosis through radiological biomarkers. One such marker is the "swallow tail sign," which represents the presence of nigrosome-1—a cluster of dopaminergic neurons in the SNc visible as a hyperintense region on SWI sequences in healthy individuals.

In this study, we investigated the diagnostic value of the loss of the swallow tail sign and changes in SNc thickness on MRI in clinically suspected PD cases. By comparing imaging findings between age- and sex-matched Parkinson's patients and controls, we aimed to assess the sensitivity, specificity, and accuracy of these markers. Additionally, we evaluated their association with clinical parameters such as disease duration and severity based on the Modified Hoehn and Yahr staging. The following discussion interprets the findings in the context of existing literature and highlights the clinical significance of these radiological features in the early diagnosis and staging of Parkinson's disease.

CONCLUSION OF THE STUDY

This study reinforces the diagnostic significance of MRI-based imaging markers, specifically the loss of the swallow tail sign and substantia nigra pars compacta (SNc) thickness reduction, in the early identification of idiopathic Parkinson's disease (PD). The findings demonstrate that the swallow tail sign, visualized through high-resolution 3T susceptibility-weighted imaging, is a highly sensitive (90.0%) and specific (85.0%) marker, with excellent diagnostic accuracy (87.5%) for differentiating PD from controls. Additionally, the study established that SNc thickness is significantly reduced in PD patients, providing a quantitative and objective correlate of dopaminergic neuronal loss.

Importantly, the majority of patients in this study were within Modified Hoehn & Yahr stages 1.5–3.0 and had a disease duration of ≤5 years, highlighting the relevance and reliability of these imaging markers in the early stages of PD, when diagnosis is often most challenging and impactful for long-term management.

The balanced age and sex distribution between the study groups minimized confounding, and the significant correlation between imaging abnormalities and clinical diagnosis strengthens the case for incorporating these MRI parameters into routine diagnostic protocols.While limitations such as small sample size and single-center design exist, the findings provide compelling evidence for the clinical utility of MRI in PD diagnosis, particularly in resource-constrained settings where access to nuclear imaging may be limited. Future studies with larger, multi-center cohorts and longitudinal follow-up are warranted to validate these markers further and explore their potential role in disease monitoring and therapeutic response assessment.

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