Quantitative assessment of Nigrosome-1 volume, area and susceptibility in Parkinson's Disease

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AIMS

Parkinson's disease (PD) is characterized by loss of dopaminergic neurons in the substantia nigra pars compacta, with early involvement of nigrosome-1 (N1), a neuromelanin-rich subregion visible on susceptibility-weighted imaging (SWI). The typical "N1 sign" loss is a potential biomarker for distinguishing PD patients from healthy subjects (HC) [1]. However, as few investigations have quantitatively assessed N1 imaging features in PD [2], our study aims to provide novel insights through a quantitative approach.

MATERIALS AND METHODS

Participants underwent standardized neurological evaluation and 3T brain MRI including SWI and quantitative susceptibility mapping (QSM) sequences. Visual assessment of N1 (bilateral, unilateral, or absent) was performed independently by two expert neuroradiologists blinded to diagnosis. Visible N1 were manually segmented on SWI to calculate volume and area, and co-registered QSM maps were used to extract magnetic susceptibility values. Data were analyzed using ANCOVA with age and sex as covariates. ROC curves were used to assess the diagnostic performance of N1 features.

RESULTS

We enrolled 48 PD patients and 35 healthy individuals. Among PD patients, 16 had bilateral N1 loss and 32 had unilaterally (n=27) or bilaterally (n=5) preserved N1. The qualitative unilateral/bilateral N1 loss showed 89.6% sensitivity (43/48), 94.3% specificity (33/35) and 91.6% accuracy (76/83) in distinguishing PD from HC. The visible N1 were significantly smaller in PD than in HC (p<0.001), while had similar susceptibility values (p=0.251). N1 area and volume showed excellent performance (AUC: 0.97-0.98) in distinguishing PD from HC. The results were nearly identical after removing the effect of age and sex (Volume, AUC:0.98 [0.96-1.00]; Area, AUC:0.97 [0.95-1.00], QSM, AUC:0.58 [0.42-0.73]), demonstrating that the performances were not influenced by demographic variables.

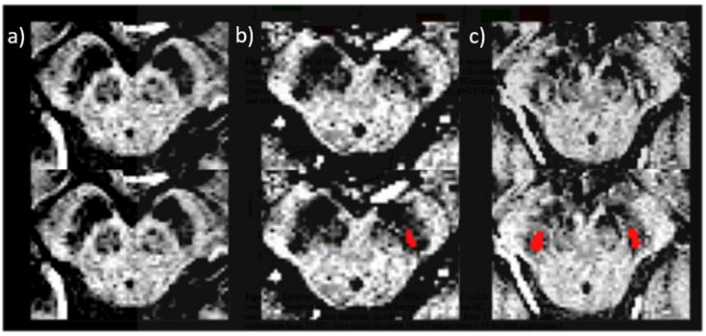

Figure 1. *Representative SWI sequences showing the nigrosome-1 region in the substantia nigra: a) PD patient with bilateral absence of the N1 signal; b) PD patient with unilateral preservation of the N1 signal; c) PD patient with bilateral preservation of the N1 signal.*

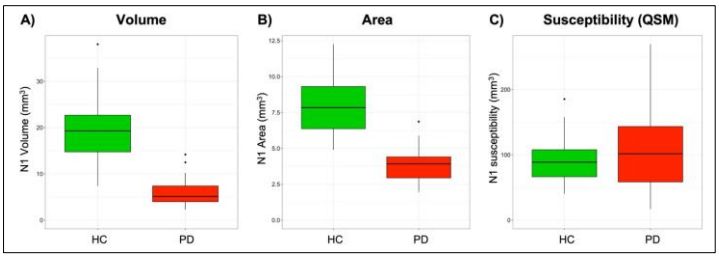

Figure 2. *Boxplots of Nigrosome-1 volume (A), area (B), and susceptibility (C) in patients with Parkinson's disease (PD) and healthy controls (HC). Volume, p<0.001; Area, p<0.001; Susceptibility, p=0.878 in ANCOVA with age and sex as covariates.*

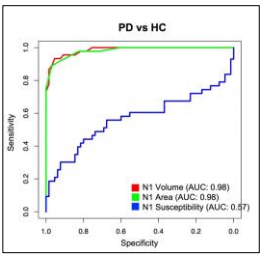

Figure 3. *ROC curves show that N1 volume and area achieved excellent diagnostic accuracy (AUC = 0.99), whereas susceptibility performed poorly (AUC = 0.59) in distinguishing PD from HC.*

DISCUSSION AND CONCLUSION

This study demonstrates that even when the N1 sign is preserved, visible nigrosome-1 in PD patients is structurally altered, with significant reduction in size compared to HC. These findings suggest that N1 morphometric changes precede complete N1 loss, possibly due to peripheral-to-central iron accumulation in N1, causing reduction of the bright SWI region [3].

Quantitative assessment of N1 volume and area provides accurate, non-invasive markers that can complement traditional visual analysis in PD diagnosis and may improve diagnostic accuracy.

References

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