# 3-D Surface Analysis of the Substantia Nigra in Parkinson's Disease Obtained with 7T MRI

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## Introduction

High-resolution 7T MR image began to show markedly improved images of the substantia nigra (SN) and the surrounding midbrain structures, partly due to the increase of the magnetic susceptibility effects as well as improvements in sensitivity due to the increased strength of the static magnetic field. Moreover, the iron deposition in the SN increases the T2*-weighted image contrast on 7T MR system. This is of a great interest in Parkinson's disease (PD) study where pathological alterations of the structure in the SN are observed. Actually, our previous study with 7T MRI indicated that there is a potential for detection of PD especially looking at the 2D images of the SN and its surroundings.

## Methods

In this study, we obtained 3D fast gradient echo image in order to understand entire structure of the SN and performed quantitative surface analysis to observe statistically structural deformations of the SN in PD. Following the protocol, 20 age-matched subjects were studied: 10 healthy controls (age: 59.7±5.1 years) and 10 patients with PD (age: 60±7.2 years). All patients were evaluated for the severity of the disease by the Hoehn and Yahr scale from 1.5 to 3, and the unified Parkinson's disease rating scale. Images were obtained on a Siemens Magnetom 7T scanner (Enlargen) with an 8 channel SENSE head coil (NRI) using a T2*-weighted 3D flash sequence with TR/TE = 50/25 ms, flip angle = 10°, field of view = 175mm × 200mm, image matrix = 504 × 576, 64 slices with 0.35 mm slice thickness. In addition to the fast imaging techniques, we employed GRAPPA (R = 2), Partial Fourier (6/8), and asymmetric echo, thereby total acquisition time was reduced down to 8 minutes and 23 seconds. Although 7T MRI shows fine structures of the micro vessels as well as the surroundings of the SN (Fig.1), due to the similar MR contrast of the STN it was found that the clear parcellation of the SN from the surroundings was difficult. It was necessary therefore, to define SN in 3D MR magnitude image together with MR phase contrast images [1]. 3D surface analysis was performed using the algorithm of Chung et al [2]. This algorithm is a new morphometric framework which is both a global parameterization and data smoothing technique. Using this algorithm, we obtained the coefficients which represent 3D surface reconstructed from the tracing mask images. Coefficients of all subjects are represented as 3D surface models having the same number of mesh vertex. Therefore, statistical comparison with each mesh vertex at the same position on all surface models was made possible. Furthermore, P-value by the Hotelling's $T^2$ statistics could be projected onto the SN template constructed by averaging the one side and the mirror - coefficients of the other side's in all the normal subjects.

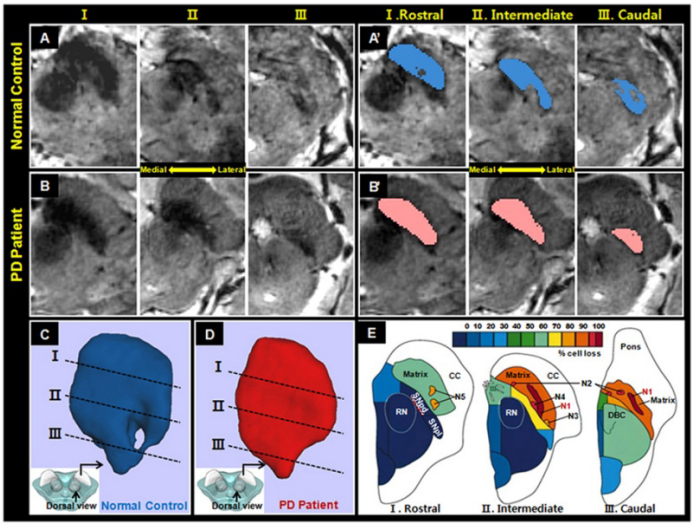


**Fig.1 (A-B) 7T 3D T2*-weighted MR images. (A'-B') Traced image mask. (C-D) 3D reconstruction of the SN. (E) The regional and intranigral loss of dopamine-containing neurons of the SN in PD. (E) is reproduced from reference:[4]**

## Results

In our previous study, we have observed a deformation of the lateral boundaries of the SN in the PD patients on 2D T2*-weighted images obtained with 7T MRI [3]. Since this present study is an extension of this series, we have also performed 3D surface analysis of the ventrolateral boundaries of the SN in each of the 3D surface models. The individual difference could be visualized by mapping the regions with P-value < 0.001 for each of all surface models of the PD, and counting map was projected onto the normal SN template so that one can visualize the degree of impairment of the SN (Fig.2). High-resolution 7T 3D MR images also began to show the inner structures of the SN in normal controls. We found a striking similarity between our results and the patterns of subdivisions of the SN as observed using calbindin D28K immunostaining [4]. These findings strongly suggest that two different contrasts in the SN observed with 7T MRI could be due to the nigrosomes, since these structures were scarcely seen in the patient group (Fig.1). The result of statistical analysis of 3D surface of the dorsomedial boundaries of the SN shows a significant group difference between the two groups in the range with P-value < 0.005, which is projected onto the normal SN template (Fig.3). Especially, in the caudal and intermediate aspects, the structural details of the SN which disappeared commonly in all the PD patients, were marked by a significantly low P-value.

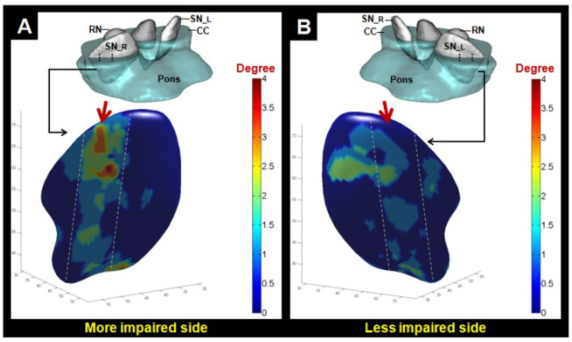


**Fig.2 Individual difference in the ventrolateral boundaries of the SN**

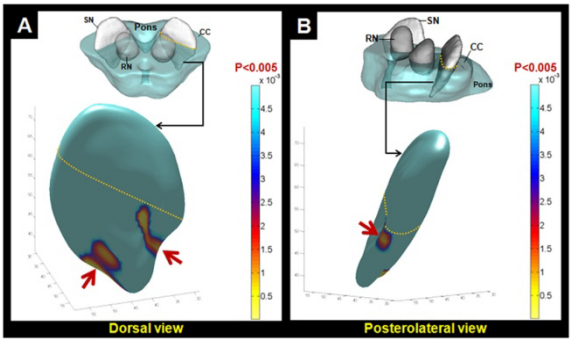


**Fig.3 Group difference in the dorsomedial boundaries of the SN**

## Discussion

Accordingly, this 3D imaging study demonstrates the potential of the 7T MRI for quantification of the deformed SN in PD. Especially, the identification of internal structures located in the caudal and mediolateral part of the SN would provide an important clue in the diagnosis of PD.

## Acknowledgements

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## Reference

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