Fast and fully automatic differentiation of patients with idiopathic Parkinsonian syndrome and progressive supranuclear palsy using T1-weighted MRI datasets

Nils Daniel Forkert[1], Jan Sedlacik[2], and Kai Boelmans[3]

[1]Department of Radiology, Stanford University, Stanford, CA, United States, [2]Department of Diagnostic and Interventional Neuroradiology, University Medical Center Hamburg-Eppendorf, Germany, [3]Department of Psychiatry and Psychotherapy, University Medical Center Hamburg-Eppendorf, Germany

Purpose: Parkinsonian syndromes can be divided into the idiopathic Parkinsonian syndrome (IPS) and atypical Parkinsonian syndromes, such as the progressive supranuclear palsy (PSP) or multiple system atrophy (MSA). The correct patient-specific classification of the present Parkinsonian syndrome is most important due to syndrome-specific treatment strategies. Unfortunately, patients with an atypical Parkinsonian syndrome may exhibit clinical symptoms that are very similar to those of the idiopathic Parkinsonian syndrome, which makes the differentiation based on clinical criteria error-prone. This is especially the case for the differentiation of PSP and IPS patients, where post-mortem studies demonstrated failure rates up to 25%[1]. Several potential image-based biomarkers have been identified in the past for this purpose, whereas the morphological parameters describing the volume of certain brain regions[2] and metabolic parameters focusing mostly on the extraction of the regional iron content[3] seem especially suitable for an automatic differentiation of IPS and PSP patients. However, the potential of these image-based biomarkers for an automatic classification is so far limited due to long computation times or time-consuming manual measurements such that the diagnosis in today's clinical routine is still mainly based on clinical criteria. The aim of this work was, therefore, to develop and evaluate a fast and automatic IPS vs. PSP classification method using regional brain volumes derived from an atlas-based brain parcelation of high-resolution T1-weighted datasets together with a high-level machine learning technique.

Material and Methods: Overall, 78 datasets of patients with a Parkinsonian syndrome acquired with a 3T Skyra scanner (Siemens, Erlangen, Germany) were available for this study. Among others, a high-resolution T1-weighted dataset was acquired for each patient (TR = 1900ms, TE = 2.46ms, flip angle = 9°, isotropic resolution of 0.94mm³). These 78 datasets included 57 IPS and 21 PSP patients. The clinical diagnosis was performed by a movement specialist and according to established consensus criteria. Patients with an uncertain diagnosis were not included in this database. The automatic brain parcelation, which serves as the basis for the subsequent volume determination, was performed in this work using a non-linear registration of the 152 MNI brain atlas to each patient dataset. More precisely, an affine registration of the atlas was performed in a first step using a block-matching approach, which was then used for initialization of the subsequent non-linear registration using a free-form deformation as implemented in the NiftyReg package[4]. The calculated deformation field for each patient was then used to warp the Harvard-Oxford subcortical brain regions, as defined in MNI space, to each patient using a nearest-neighbor interpolation. These brain regions include the cerebral white matter, cortex, lateral ventricles, thalamus, caudate, putamen, pallidum,
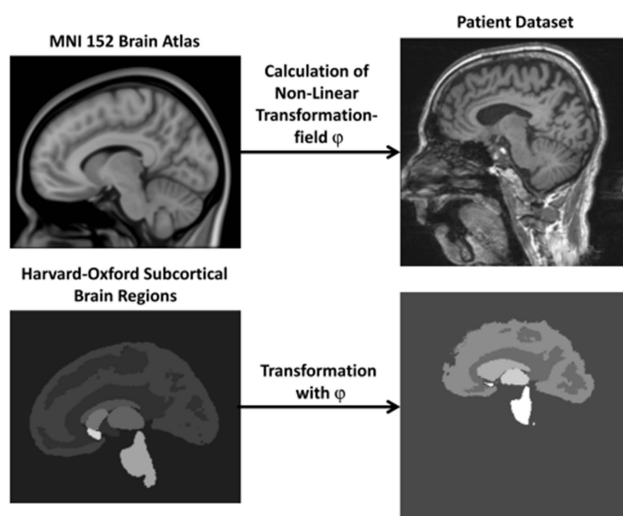

Fig. 1: Schematic representation of the atlas-based brain parcelation procedure using T1-weighted datasets

hippocampus, amygdala, accumbens and brainstem. All regions except for the brainstem are separately defined in the left and right hemisphere such that a total of 21 brain region volumes are determined after the non-linear transformation and used for the automatic classification. The automatic classification based on the volumetric parameters was implemented in this work using a support vector machine (SVM) and a linear kernel.

Experiments and Results: A leave-one-out cross validation was performed for evaluation of the proposed automatic image-based classification method. Therefore, all datasets except for the actual dataset to be evaluated were used for the training of the support vector machine. In this iterative manner, each dataset was classified into the IPS or PSP group and the corresponding classification result was compared to the ground-truth classification. Overall, the presented automatic classification method achieves an accuracy of 87.2% (68/78 datasets were correctly classified). More precisely, 4 IPS patients were falsely classified to PSP, and 6 PSP patients were falsely classified to IPS, which correspond to a sensitivity of 89.83% and a specificity of 78.95%. The complete classification procedure is fully automatic and takes approximately 10 minutes on a standard computer, including all processing steps such as data import, non-linear registration, and classification.

Discussion and Conclusion:

In summary, the first results of this study suggest that a fast and fully automatic differentiation of IPS and PSP patients based on an atlas-based morphological analysis of high-resolution T1-weighted datasets using a high-level classification method is feasible. The classification accuracy may be further enhanced by using other atlas brain region definition and exclusion of brain regions with no or only minor informative power prior to the classification.

References:

1. Davie CA. A review of Parkinson's disease. Br Med Bull 2008;86:109-27

2. Marquand AF et al. Automated, High Accuracy Classification of Parkinsonian Disorders. PLoS ONE 2013;8(7): e69237.

3. Forkert ND et al. Automated volumes-of-interest identification for classical and atypical Parkinsonian syndrome differentiation using T2' MR imaging. Methods Inf Med. 2013;52(2):128-36.

4. Modat M et al. Fast free-form deformation using graphics processing units. Comput Methods Programs Biomed. 2010;98(3):278-84.