Fully automatic white matter lesion load quantification in geriatric subjects

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Introduction

The role of quantitative image analysis in large clinical trials is continuously increasing. Several methods are available for performing white matter lesion (WML) load quantification. They vary in the amount of the human interaction involved. In previous work [1] we developed an accurate semi-automated method to quantify WML load , which has been successfully used in a large study in geriatric subjects and produced clinically relevant results [2]. The goal of the present work was to fully automate this procedure using an extra MR image (FLAIR) in order to speed up the processing of large data sets and reduce inter-observer and inter-center rating variability.

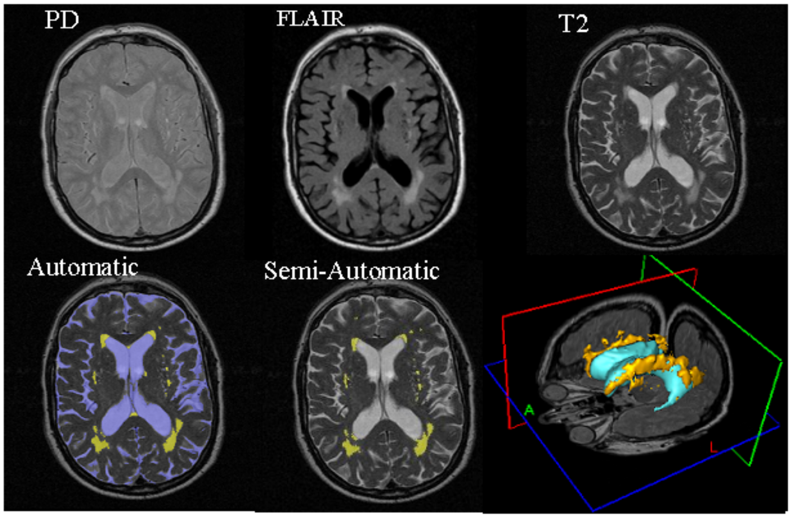

Fig1. Top row: MR image of the same patient. Bottom-left: fully automatic segmentation of CSF (blue) and WML (yellow). Bottom-center: semi-automatic delineation of WML. Bottom right: 3D rendering of automatically delineated WML.

Material and Method

The MR images were acquired on a 1.5 Tesla field strength system (Philips Medical Systems, Best, The Netherlands), and comprised dual (PD, T2) fast spin-echo imaging (TE 27/120ms, TR 3000 ms,) and FLAIR (TE 100 ms, TR 8000) Both had an echo train length factor of 10, 48 contiguous 3mm slices, matrix 256x256, FOV 220).

WML are hyper-intense in PD, T2 and FLAIR (see Fig. 1). The advantage of FLAIR is the inherent CSF suppression what makes the discrimination between WML and CSF straightforward. One might think of using only FLAIR for segmentation. However, FLAIR has some limitations: it has a low sensitivity in the infratentorial area and may present some hyper intense artifacts that look like lesions. Our Automatic WML detection approach consists of 3 main steps:

(1) *Brain stripping*: ***:*** An average PD image (from the Montreal Neurological Institute (MNI)) is first co-registered to the PD image of a subject using a multi-resolution 12-parameter affine registration [3]. The standard deviation of ratio images was used as cost function. The resulting transformation matrix is used to resize an Intra-Cranial (IC) prior probability map in order to mask automatically non-brain voxels (skin, bone and eyeballs). A prior probability map of white matter (from MNI) is aligned using the same transformation matrix to guide the detection of the WML. For a more accurate IC delineation, fuzzy clustering, mathematical morphology and region growing, are applied and constraint to remain within the resliced IC mask. This step takes on average less than 1 minute per scan.

(2) *CSF detection*: The FLAIR image is first co-registered to the T2 image. A ratio image (Flair/T2) is then computed after rescaling the FLAIR voxel-intensity range to that of the T2 image. The CSF is extracted in this ratio image using fuzzy clustering (c=2). The voxels belonging to the cluster with the darkest signal intensities within the IC mask are classified as CSF.

(3*)* *Lesion detection*: The voxels of the T2 image and those of the FLAIR image are clustered in 3 clusters. A voxel is labeled as WML if it fulfils 3 conditions: (i) Its T2 intensity belongs to the brightest cluster and it does not intersect with the CSF mask detected in step 2; (ii) its FLAIR intensity belongs to the brightest cluster; (iii) it has a relatively high probability (>0.4) to belong to the WM (using the aligned WM map). Lesions smaller than 6 voxels are automatically excluded. On average the time the software requires to perform steps 2 and 3 does not exceed 1 minute on a Pentium 4 computer.

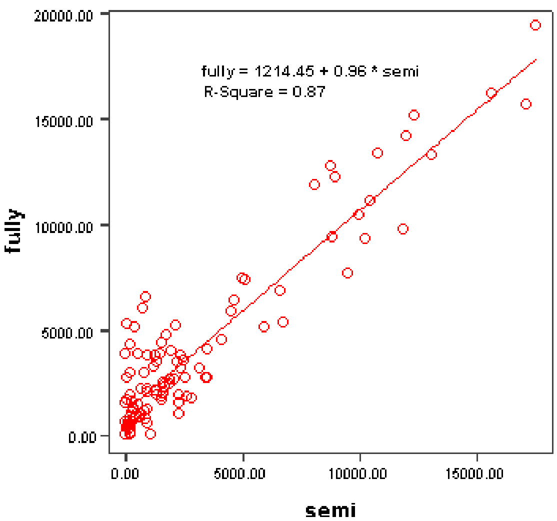

Fig2. Linear regression between fully automatic and semi-automatic WML segmentation in 100 patients (volume is in voxels).

Results and Discussion

The software has been evaluated on scans of 100 patients for which WML had been semi-automatically delineated by well-trained operators in a previous work [1,2]. The total lesion load measured automatically and semi-automatically have been compared using the intra-class Correlation Coefficient (ICC), with one-way random effect model. The ICC was 0.91 and the reliability coefficient (alpha) was 0.969. Figure 2 gives the outcome of a linear regression analysis; a correlation coefficient of 0.96 was found. This indicates a very good agreement between semi-automatic and fully automatic WML delineation. The largest disagreement between semi-automatic and fully automatic segmentation was found in cases that presented infarcts and/or edema. The experts did not include these types of abnormalities while segmenting the lesions. The 3 rules applied in our approach do not exclude these hyper intensities. Therefore further research on categorizing WML automatically is required. Our method is integrated in a multi-platform user-friendly software package that allows for manual corrections and can run in batch mode over large data sets. The automatic image processing time is about 2 minutes per patient on a Pentium 4 processor.

References

1. F. Admiraal Behloul et al., ISMRM, 2003,
2. D. v.d. Heuvel et al., ISMRM, 2003,
3. R.P. Woods et al., J CAT, 1998, vol. 22, pp 153-165.