Fully automatic lobe delineation for regional white matter lesion load quantification in a large scale study

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Introduction

White matter abnormalities often referred to as "hyperintensities" in MRI have been investigated in older adults for their role in normal aging, dementia and late-onset depression. Previously, [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 main goal of the present work was to develop a software tool that allows a more local analysis of WMHI load in anatomical regions (lobes and cerebellum), for correlation analyses with cognitive information in geriatric patients. We aimed at a relatively coarse lobe delineation (see fig1.a and fig.2b).

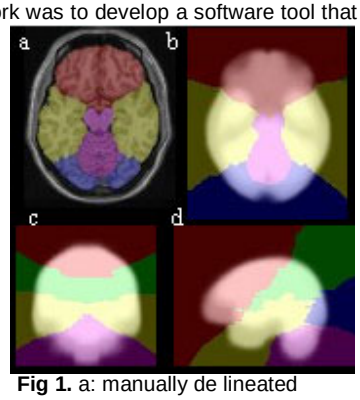

Fig 1. a: manually de lineated lobes. b: distance map on IC prior probabilities in axial view. c: in coronal view and d: in sagital view.

Material and Methods

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

1. *Lobe template generation*: 3 experts have delineated manually the lobes on a T1 high-resolution image resized and co-registered to the Montreal Neurological Institute (MNI) brain template space (109 slices, voxel size 2x2x2 mm) see figure1.a. Since delineating manually the lobe is time consuming (about 10 hours of work) it was not an option to have the expert delineate enough cases in order to generate prior probability maps. Instead, we generated distance maps: the 3D distance of every voxel of the volume (brain or non-brain) to each manually delineated lobe has been computed and every voxel has been assigned to the closest lobe. We call the obtained image the Extended Lobe-Image (ELI). A prior-like image has been obtained by multiplying the ELI by an IC probability map see figure 1.b.
2. *Fully-automatic brain stripping and lobe delineation:* An average MNI Proton Density (PD) image is first co-registered to the PD image of a subject using a multi-resolution 12 parameter affine registration. The standard deviation of ratio images was used as cost function [3]. The resulting transformation matrix is used to resize the IC prior probability map in order to mask automatically non-brain voxels (skin, bone and eyeballs). The same transformation matrix is used to align the ELI with the subject image. For a more accurate IC delineation, a foreground versus background (two clusters) fuzzy clustering was performed. Mathematical morphology filters (opening and closing) were then applied to delete the possible connections between intra-cranial non-brain voxels. A region-growing algorithm automatically seeded in the brain and constrained to remain within the resliced IC mask was applied. The obtained IC mask successively masked the aligned ELI. In previous work we developed semi-automatic segmentation software that has been used to segment the intra cranial mask (IC), the cerebro-spinal fluid (CSF), and the White Matter Lesions (WML) in the 1054 scans. Using the WML segmented masks, the system generates for each lobe and the cerebellum the WML load (see fig.2a).
3. *Quality control system:* The success of this method is highly dependent on the outcome of the registration. A minimum convergence rate (value of the cost function) of the registration algorithm has been pragmatically defined. If the registration step does not reach this minimum value after a limited number of iterations, the scan is automatically flagged as *"possible failure"*. However, if the minimum value is reached the scan is marked to be a "*successful*" segmentation. Although it is desirable to develop automatic quality control systems, visual inspection of the outcome of an automatic processing system remains mandatory. Our system saves all the segmentation results for true 3D inspection of every single subject. However, since that might be impractical in large data sets, the software also generates a mosaic image per subject showing selected slices for quick inspection (see figure 2.b). If the user would like a more thorough inspection of a particular subject they can review the full 3D segmentation masks in a user-friendly software interface.

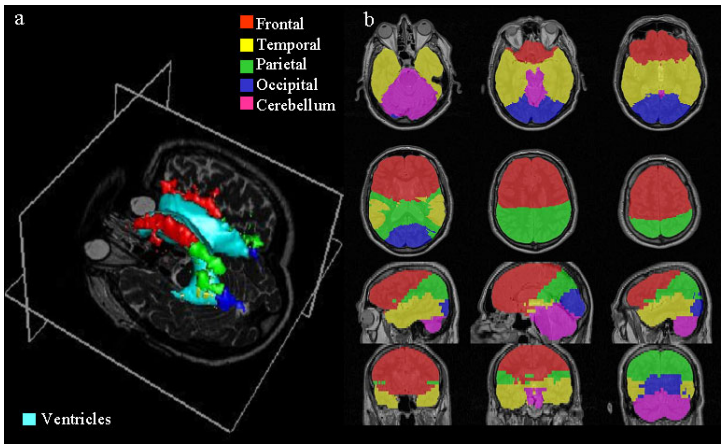

Fig 2 (a) WML assigned to intersecting lobes. (b) Mosaic view for quality control

Results and Conclusion

The reliability of our software was evaluated on 1054 scans. 941 scans were flagged as "successfully segmented" and the rest as possible failure. We compared the volumes of the semi-automatic IC and fully automatic IC masks using intra class correlation coefficient (ICC), with one-way random effect model. We obtained an ICC of 0.949 and the reliability coefficient (alpha) was 0.977. The mean degree of overlap was 97% ±15%; In average only 2.6% (± 2%) of the semi automatic mask did not overlap with the fully automatic one and only 3.6% (± 2%) of the automatic mask did not overlap with the semi automatic mask. This indicates a very high agreement between semi-automatic and fully automatic methods. The visual inspection of the lobes using the mosaic images in the 941 was very satisfactory. Only 1% cases were marked as non-accurate. We visually inspected the quality of the MR scans of the 120 subjects marked as failure. In most of the cases a different starting point for the registration algorithm was enough to correct the segmentation. Few cases failed because of image artifacts or missing slices (not the whole brain was covered).
We therefore conclude that this automatic approach is a valid and reliable tool for use in large-scale studies.

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.