Computer-Assisted Segmentation of White Matter Lesions in 3D MR images, Using Support Vector Machines

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INTRODUCTION. CerebroVascular Disease (CVD) is a very significant health problem and is highly prevalent in diabetic populations. From clinical findings, it is known that brain lesions, especially white matter lesions (WMLs), have strong association with CVD. MRI is currently the most widely used way to characterize *in vivo* the type and extent of brain lesions in CVD patients. However, such characterization has largely relied on qualitative, subjective, and not easily reproducible methods of human expert-based interpretation. Computer based methods for measuring WMLs load in CVD patients offer great potential, for many reasons: 1) they are quantitative; 2) they are reproducible; 3) they are highly automated, thereby enabling the analysis of large amounts of data that are often acquired in large neuroimaging studies. The development and validation of such methods will enable the accurate and precise quantification of. Most of the successful methods in the literature have been developed for the detection of Multiple Sclerosis (MS) lesions [1-3] using multi-modal based approaches. However, relatively less attention has been given to brain lesion segmentation in elderly individuals, and diabetic patients. Since MS lesions present different characteristics from lesions in elderly and/or diabetic individuals, those methods are not directly applicable to our studies, albeit they have formed the foundation for our development.

METHOD. In this paper, we present a novel computer-assisted WML segmentation approach that has been designed to process MR scans of elderly diabetes patients and used in a large clinical study**:** ACCORD-MIND (http://www.accordtrial.org/). For each patient, a multi-parametric imaging brain tissue profile is composed of four MR sequences, including T1-weighted, T2-weighted, Patron Density (PD) and Fluid-Attenuated Inversion Recovery (FLAIR). Our method uses a combination of image analysis and support vector machines (SVM), a powerful statistical learning method. Image intensities from multiple MR acquisition protocols, after co-registration, are used to form a voxel-wise attribute vector (AV) that helps to discriminate lesion from various normal tissue image profiles during segmentation. In general, there are four steps in our approach. *First*, a preprocessing step includes co-registration of different MR sequences of the same patient, skull-stripping, intensity normalization, as well as inhomogeneity correction. *Second*, a set of training samples is manually delineated by expert readers, and then used to build a classification model via SVM and AdaBoost; this step is applied only once, during training. *Third*, the SVM model is used to perform the voxel-wise segmentation. *Finally*, false positive voxels are further eliminated via thresholding the distance in Hilbert space from AVs of initial lesion masks to AVs of training samples, thereby producing final WML segmentation results.

RESULTS. In this study, 10 patients were used for training while 35 patients were used for testing. Two representative results are shown in Fig. 1. “Gold standard” (manual) and computer-assisted segmentation results are superimposed on the FLAIR images, respectively. ROC curve was also computed for our computer-assisted lesion segmentation algorithm. Fig. 2 shows a zoomed version of ROC curve showing detail in the region of interest. Different symbols on the ROC curve show different thresholds we used. Additionally, “*” shows 2nd rater’s manual segmentation result, compared to our gold standard. Statistical comparisons were also performed between the lesion volume obtained by manual and computer-assisted segmentation of these 35 testing subjects. Paired Spearman Correlation measurements among 1st rater, 2nd rater and computer-assisted method shows high correlation among them ($p < .001$ and $\rho = 0.95$ between 2nd rater and 1st rater; $p < .001$ and $\rho = 0.79$ between computer and 1st rater; $p < .001$ and $\rho = 0.74$ between computer and 2nd rater). Although high in correlation measurement, mean $\pm$ standard deviation (Median) of the lesion volumes obtained from 1st, 2nd and computer raters were 1494 mm^3 $\pm$ 3416 mm^3 (559 mm^3); 2839 mm^3 $\pm$ 6192 mm^3 (1461 mm^3); and 1869 mm^3 $\pm$ 3416 mm^3 (393 mm^3) respectively, the mean volume of 2nd rater is approximate twice of 1st rater, which suggests that manual segmentation is subject to large inter-rater variability as shown in Fig. 3.

DISCUSSION. Supervised machine learning methods based on support vector machines can provide robust and accurate tools for automated segmentation of brain lesions from MRI. The automated approach was comparable with the expert raters, while providing an objective and reproducible evaluation of lesion load. Computer-based analysis of large-scale neuroimaging studies can be greatly facilitated by computer-based image analysis tools that provide high-throughput tools for quantification of brain lesions, which are of importance in a variety of diseases, including vascular dementia, Alzheimer’s Disease, and diabetes.

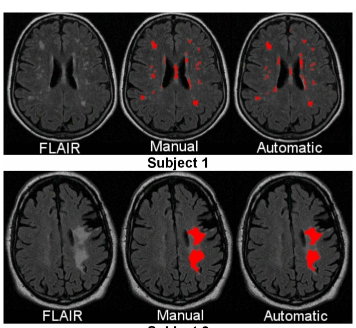

Fig. 1 WML segmentation results of two cases

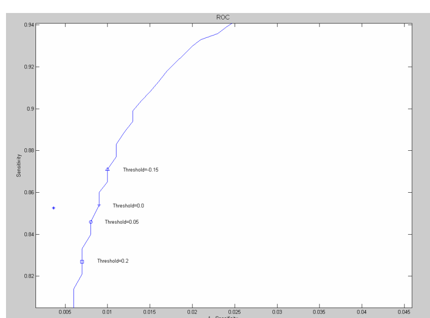

Fig. 2. Zoomed ROC curve

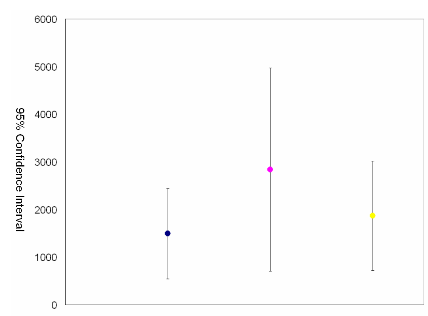

Fig. 3 95% Confidence Interval

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