Identification of Abnormal White Matter in Multiple Sclerosis

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Introduction: Part of the white matter (WM) in Multiple Sclerosis (MS) that appears normal on conventional MRI is known to be pathological. This so called "normal appearing white matter (NAWM)", which is particularly prominent around the MS plaques, is considered to be tissue at risk and could be amenable to treatment. Identification and quantification of NAWM is particularly important in objectively evaluating the efficacy of pharmacological intervention. On multiparametric image segmentation, based on our and other investigator's experience, NAWM is generally classified as gray matter (GM). In addition, the NAWM on fractional anisotropy (FA) maps, derived from the diffusion tensor imaging (DTI), appears reduced diffusion anisotropy. Thus, by combining the FA maps with multiparametric segmentation of MRI, it is possible to identify the NAWM in MS brains.

Methods: Magnetic resonance images of the whole brain were acquired on a 3T, Philips Intera scanner with the dual fast spin echo (TE1/TE2/TR = 9.5/90/6800 ms) and FLAIR (TE/TR/TI = 80/10000/2600 ms) sequences. Diffusion weighted images were acquired using the Icosa21 encoding scheme with an EPI-FLAIR readout sequence (b = 1000 s mm^{-2} and TE/TR/TI = 90/5834/2400 ms) [1]. In all cases, the total number of slices was 44, each with 3 mm thickness and contiguous, covering the whole brain, field-of-view of 240 mm X 240 mm, and image matrix of 256 X 256.

All the images were stripped of the extrameningeal tissues using a semiautomatic technique, filtered using anisotropic diffusion filter, RF corrected, co-registered, intensity normalized [2]. The dual FSE and FLAIR images were segmented into parenchyma, CSF, and lesions using a Parzen window classifier [2]. The parenchyma was segmented into GM and WM using FSE images iteratively with using the expectation maximization method as described in detail elsewhere [2]. The diffusion-weighted images were analyzed for computing the FA as described in [1]. The diffusion MRI images were corrected for eddy current distortions, registered to the dual echo images using the 30 parameter 2nd order nonlinear transformation model of AIR 5.0 [3]. Any pixel that has FA>0.2 was considered to represent WM and this criterion was used for generating the WM mask using the FA maps. The algorithm used for generating the NAWM is summarized below.

Segmented intracranial content (IC) = Segmented WM + Segmented GM + Segmented Lesions + Segmented CSF (where segmented GM contains both GM and NAWM)
Estimated GM = Segmented IC – Estimated WM on FA maps – Segmented CSF
Estimated NAWM = Segmented GM – Estimated GM

Results: The results of the above procedure on a typical MS patient are summarized in Figure 1. The NAWM, shown in magenta, superimposed on a T2-weighted image is shown in Figure 1E. As can be seen from this figure, pixels around the plaques which are classified as GM in the segmented image (B) are classified as NAWM (D).

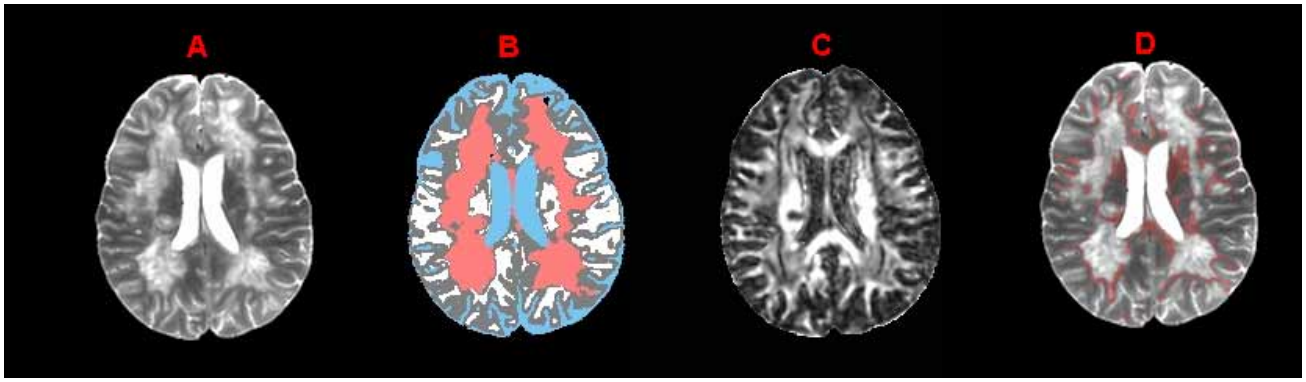

Figure 1: T2 Weighted (A), Segmented (B), FA (C), and estimated NAWM overlay on T2 weighted background (D) images. The colors shown in image B are: salmon- lesion, white – WM, gray –GM and blue– CSF; The NAWM is shown as magenta in image D.

Discussion: The proposed method which is based on the combination of multiparametric feature map segmentation and DTI involves minimal operator intervention, appears to be robust in detecting and quantifying the NAWM. Verma et al [4] have identified NAWM in MS on FLAIR images and quantified the FA values. However, the identification of NAWM was restricted to tissue just around the lesions by 2 pixels. In addition, in contrast to our technique, they manually identified lesions on FLAIR images. This ability to identify and quantify the NAWM with minimal supervision might have important clinical implications and could play a role in objectively assessing the efficacy of the treatment in multi central clinical trials.

Reference:

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