Fully-Automated Single-Image T2 White Matter Hyperintensity Mapping and Quantification with FSL

Nathan C Wetter[1,2], Elizabeth A Hubbard[3], Robert W Motl[3], and Bradley P Sutton[1,2]

[1]Bioengineering, University of Illinois at Urbana-Champaign, Urbana, IL, United States, [2]Beckman Institute for Advanced Science and Technology, University of Illinois at Urbana-Champaign, IL, United States, [3]Kinesiology and Community Health, University of Illinois at Urbana-Champaign, IL, United States

Purpose: White matter (WM) hyperintensities on T2-FLAIR images have long been a defining feature of Multiple Sclerosis (MS) in both research and clinical contexts, becoming incorporated into the standard McDonald Criteria in 2010. Measurement of the total volumes of these lesions (T2 Lesion Volumes; T2LV) has become an important biomarker for the summative effect of these lesions on the WM. Recent improvements in acquisition, such as high resolution 3D T2-FLAIR, have improved visual contrast of these lesions. Likewise, many methods have emerged to quantify T2LV. However, these methods have had significant drawbacks: They are often not freely available, are not fully automated, or require multiple images. Our purpose is to present a fully-automated T2LV quantification method that is freely available, fully automated, and requires only a single image. We have built our method using standard tools from the popular open-source imaging package FSL[1], combined in an intuitive way to produce lesion maps and volumes. We hope this method will enhance research in MS and other lesion-related diseases by making lesion quantification more accessible and more comparable across studies.

Methods: We developed our method on images obtained by scanning subjects with MS on a Siemens Trio 3T MR scanner with a 12-channel head coil, using a FLAIR T2-weighted 3D TSE sequence with a variable flip angle. We acquired 1mm isotropic resolution with a sagittal prescription, covering the whole brain in 7 minutes. The parameters were 2.2s TI, TE/TR of 388ms/6s, and a GRAPPA factor of 2. We combined various programs within FSL in an intuitive way to produce a new method for T2 lesion mapping and quantification that is fully automated and requires only this single image.

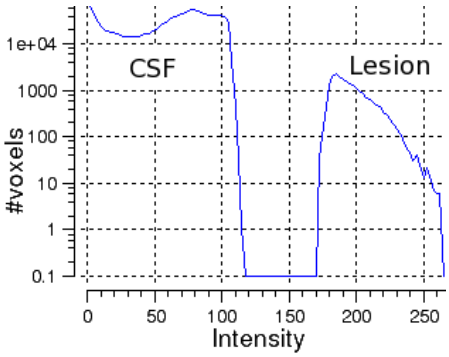

Figure 1: Histogram of CSF image from FAST. Separation of lesions from CSF is trivial.

Our method begins by stripping the skull, then slightly blurring the image to reduce noise. The main step in our method is the use of FAST to segment the image into two tissue types: brain tissue and nonbrain/CSF. Crucial to our method is the realization that although hyperintensities are bright and CSF is dark, they are so bright that FAST does not classify them as brain tissue, and so they end up in the CSF mask. From here, it is trivial to distinguish the hyperintensities from CSF, as the histogram of FAST's CSF output image is bimodal with a large region of empty bins between peaks (Figure 1). Our method to this stage is very sensitive in marking the lesions, but it does also mark some false positives in a few regions: the septum pellucidum, several bright regions of midbrain gray matter, and small areas of peripheral gray matter. These false positives are fairly consistent in their appearance, and so we add three additional steps to reliably eliminate them: We use FAST a second time to select only the lesions that contain the brightest hyperintense voxels. Then, we apply masks warped from standard space to select only lesions within the white matter, and to exclude midline false-positives. Final lesion volumes are expressed as a percentage of total brain volume.

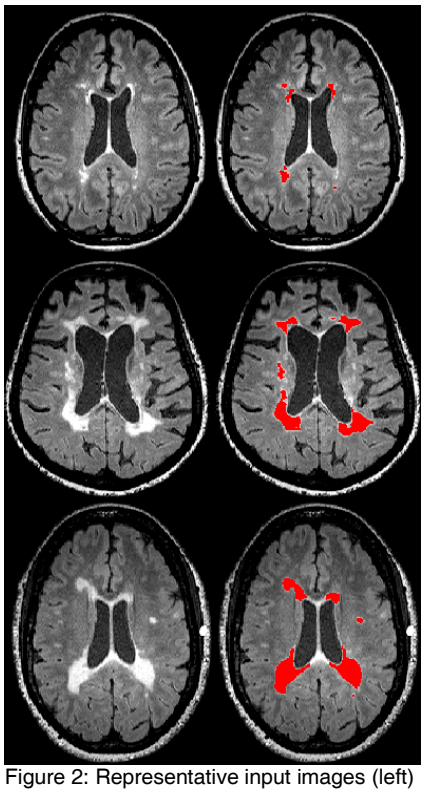

Figure 2: Representative input images (left) with output lesion masks (right, in red).

Results: Our method ran successfully on 54 subjects. Images were reviewed and appeared accurate except for one case where extremely large lateral ventricles caused difficulty with the midline false positive removal parameters. A few representative example output slices are shown in Figure 2.

Conclusions: To the best of our knowledge, this is the first fully-automated, single-image T2LV quantification method. It is based on the open and freely available FSL toolkit that is already widely popular, and is easy to use and understand. We hope that the release of this method will lower research costs, improve comparability across imaging studies of T2 WM hyperintensities, and lower the barriers to using T2LV as a clinical measure of MS disease progression.

References: [1]: fMRIB Software Library, fMRIB, Oxford, http://fsl.fmrib.ox.ac.uk/fsl