Brain Extraction for Analysis of Magnetic Resonance Imaging in Patients with Multiple Sclerosis

Marcela de Oliveira — School of Sciences, São Paulo State University, UNESP - Brazil
marcela.oliveira@unesp.br

Marina Piacenti-Silva — School of Sciences, São Paulo State University, UNESP - Brazil

Paulo Noronha Lisboa-Filho — School of Sciences, São Paulo State University, UNESP - Brazil

Fernando Coronetti Gomes Rocha — Medical School, São Paulo State University, UNESP - Brazil

Jorge Manuel Santos — ISEP, School of Engineering, Polytechnic of Porto - Portugal

Jaime dos Santos Cardoso — INESC TEC and Faculty of Engineering, University of Porto – Portugal

Abstract

Multiple sclerosis (MS) is a neurodegenerative disease that is increasing worldwide. MS diagnosis and monitoring treatment is vitally important. Due to neuronal damage, which occurs in neurons, this disease affects the ability of nerve cells in the brain and spinal cord to communicate. Magnetic resonance imaging is the gold standard exam for diagnosis and monitoring of multiple sclerosis. MS is characterized by brain lesions where the neurodegeneration process occurs, making it possible to visualize these affected areas on magnetic resonance images. The advancement of technology has allowed an improvement in the sequences for the visual detection of lesions caused by multiple sclerosis, aiding medical diagnosis. Imaging pre-processing is an important step in analysing specific structures. Thus, the purpose of this work is to perform image processing in MRI with skull stripping from MS patients for future detection and quantification of brain lesions. We concluded that the automatic pre-processing method applied in this work for skull stripping can be used for the brain extraction process and for future sclerotic lesions identification.

1 Introduction

Magnetic resonance imaging (MRI), due to the richness in the information details provided, is the gold standard exam for diagnosis and follow-up of neurodegenerative diseases, such as multiple sclerosis (MS) [1]. There is increasing prevalence and incidence of MS in both developing and developed countries [2, 3]. MS is a chronic neurological disease characterized by demyelination of axons [4]. This demyelination process (neurodegeneration) causes lesions in white matter that can be observed in vivo by MRI. In individuals with MS, radiological abnormalities can be identified even in the absence of clinical symptoms of the disease, and the areas where demyelination occurs can be seen in this type of image [5]. MRI allows the evaluation and follow-up of sclerotic lesions in different sequences such as T1, T2 and FLAIR (Fluid Attenuated Inversion Recovery) [6].

The sclerotic lesions observed in the T1-weighted MRI sequence are areas with less signal intensity when compared to normal areas [7]. In this type of sequence, the injured area becomes isointense within a few months after the cessation of inflammatory activity and with the process of repairing mechanisms, such as remyelination. The highlight of the lesions can also be seen in the T2 and FLAIR sequences, the affected area is characterized by hypersignal. Such lesions may provide quantitative assessments of the inflammatory activity of the disease, and possibly heralding future brain atrophy and clinical disability. Quantitative measures based on various features of lesions have been shown to be useful in clinical trials for evaluating therapies. In order to perform the identification and quantification of sclerotic lesions, it is necessary to perform a pre-processing of the images to extract the brain [8]. Thus, the purpose of this work is to perform image processing in MRI with skull stripping from MS patients for future detection and quantification of brain lesions.

2 Materials and Methods

2.1 Patient Sample

Patients in this test group were diagnosed with MS according to the McDonald criteria [9, 10], and recruited from the Hospital of Clinics Botucatu-Brazil (HCB). The dataset is not public and includes a test group which have 5 subjects with 10 scans. Each subject includes two types of sequences: T1 weighted (-w) and FLAIR. All datasets were fully anonymized for dissemination purposes. All the patients' imaging examinations and diagnostic evaluations of the test group were retrospectively obtained between 2014 and 2019. Patient information was acquired and analyzed in accordance with ethical committees of the author´s institutions, and all the patients gave their written consent to participate in the study.

2.2 Imaging Processing

For all MRI scans, the dataset contained the same number of images in T1-w and FLAIR sequences. MRIs were preprocessed in three steps: 1. rigidly registered; 2. skullstripped; and 3. corrected for intensity inhomogeneity [8]. In the first step the T1-w MRI of subjects in the test group were rigidly registered to the axial 1 mm^3 through general registration (BRAINS) [11]. The FLAIR images (other sequence) were registered to the T1-w image space, by applying the registration transform to the initial volume FLAIR, we generate a new volume spatially aligned with the volume T1. A first step example is shown in Figure 1, where an original T1-w image was rigidly registered for $1mm^3$, and FLAIR to T1 space registration.

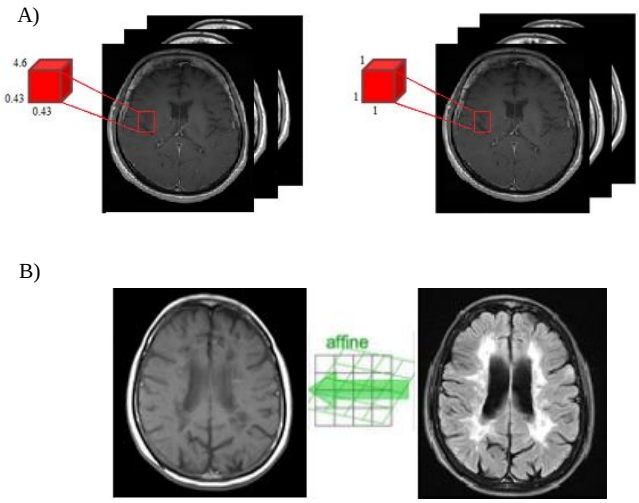

Figure 1: First step example. A) Original image voxel size 0.43x0.43x4.6 mm^3 and image rigidly registered to 1 mm^3. B) FLAIR to T1 space registration.

In the second step, both sequences were stripped by swiss skull stripper [12]. At this point, the algorithm registered a grayscale atlas image to the grayscale patient data. Through registration transform, an atlas mask was propagated with patient data. This brain mask was eroded and served as initialization for a refined brain extraction. Finally, in order to correct the nonuniform intensity in magnetic resonance images caused by field inhomogeneities, the third step performed image bias correction by N4ITK after brain stripping [13].

3 Results

The imaging preprocessing was performed using MRI with T1-w and FLAIR sequences. The results for the first step of the processing was the rigidly register, where the size images 0.43x0.43x4.6mm^3 were transformed to $1mm^3$ (see Figure 1.A). The results of special registration from FLAIR to T1 is represented in the Figure 1.B. Figure 2 shows the skullstripping (second step) and bias correction (third step) processes for brain extraction. Brain extraction process was applied to all slices of the exam, and we obtained the brain volume (see Figure 3).

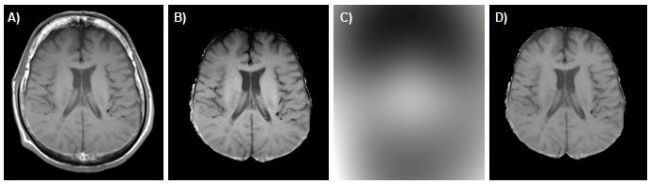

Figure 2: A) Rigidly registered image. B) Skull stripped image. C) Bias correction. D) Final image.

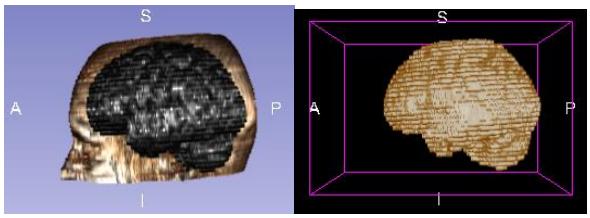

Figure 3: Brain Volume after brain extraction process applied to all slices.

Figure 4: A) Images for identification and segmentation of sclerotic lesions. B) Brain with lesions volumetric representation. C) Segmented volumetric lesion.

4 Conclusions and Future Work

Radiologically, areas where demyelination may occur can be observed by magnetic resonance imaging. We concluded that the automatic preprocessing method applied in this work for skull stripping can be used for the brain extraction process. This is an important and necessary pre-process for future analysis of brain lesions. Thus, the development and application of computer programs can contribute to assist health professionals in the diagnosis and monitoring of patients with neurodegenerative diseases. Manual segmentations brain lesions in MRIs is considered as the gold standard, however, this process is time consuming (the lesion has to be manually segmented in each slice) and suffers intra- and inter-observer variability [14]. Figure 4 shows an example where the segmentation was performed on all slices and represented volumetrically. In future works, we expect to implement more automated methods to lesions identification and segmentation process, including machine-learning approaches, to provide accurate analysis. In addition, we will perform the automatic lesion quantification to assist physicians to decide whether they should follow a treatment with a disease modifying therapy modality, as well as identifying the disease progression.

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