Automatic Segmentation of Black Holes in Multiple Sclerosis on MR Images

S. Datta[1], B. R. Sajja[1], R. He[1], P. A. Narayana[1]

[1]Diagnostic and Interventional Imaging, University of Texas Medical School at Houston, Houston, Texas, United States

Introduction: Hypointense lesions on T1-weighted images (black holes) are considered to be a better predictor of clinical disability in multiple sclerosis (MS). Currently, the identification and quantitation of black holes is a manual process that introduces significant human bias. In addition, manual processing is impractical in analyzing a large number of MR images that are typically encountered in multi-center clinical trials. The objective of these studies is to describe a novel technique for identification and quantification of black holes with minimal human intervention.

Image Acquisition: Brain MR images on 15 clinically definite MS patients were acquired on a 1.5T GE scanner using a quadrature birdcage resonator for RF transmission and signal reception. As a part of the protocol, dual FSE images were acquired with TE1/TE2/TR=12/86/6800 ms, contiguous and interleaved 3mm slices, image matrix 256x256 with a field of view 240 mm x 240 mm. FLAIR images were acquired with TR=10002 ms, TI=2200 ms and TE=91 ms. Pre- and post Gd, T1 weighted images were acquired with TE/TR=14/600 ms.

Methods: Following image preprocessing that included filtration with an anisotropic diffusion filter, image registration, RF correction, removal of extrameningeal tissues, and intensity normalization, the dual FSE and FLAIR images were segmented into gray matter (GM), white matter (WM), CSF, and lesions using a combination of Parzen window classifier and the hidden Markov random field – Expectation maximization (HRMF-EM) algorithm [1]. The FSE, pre- and post-contrast images were aligned to a subvoxel accuracy using the rigid body, 3D registration technique [2]. Morphological grayscale reconstruction was used to segment black holes on T1 images. This was achieved by computing the *regional maxima* through iterative application of elementary grayscale geodesic dilations on inverted T1 images [3]. This procedure may include some regional maxima which are not associated with black holes causing the presence of false positives. These false positives were minimized by using a mask generated by the orthogonalization of T2 and T1 images defined as: $T2-\frac{<T2,T1>}{<T1,T1>}T1$, where < , > is an inner product. Since black holes are T2-hyperintense and T1-hypointense, the mask represents locations of black holes. False Positives were further reduced by restricting these locations to the pre segmented T2 lesions [1]. Gadolinium enhanced lesions were excluded from the segmented black holes [4]. Finally, black holes were delineated using Fuzzy-connectivity [5]. The method was quantitatively evaluated by comparing with the manual delineation by an experienced neuroradiologist.

Results and Discussion: Figure 1 shows the presence of lesions as hyperintensity on PD (A), T2 (B), and FLAIR (C) images. Some of these lesions appearing as hypointense on T1 (D) image indicate the black holes (arrows). The classification of CSF, GM, WM and lesions based on PD, T2 and FLAIR images is shown in E [1]. The black holes segmented with present method are shown on F along with other tissue classifications. The results were validated by comparing with the manual segmentation, performed by an experienced neuroradiologist using in-house developed editing tools. The quantitative analysis was performed by computing similarity index (SI) between manual and automatic segmented black holes defined as: $SI=\frac{2\times(Ref\cap Seg)}{Ref+Seg}$, where Ref and Seg represent the reference (manually segmented by the expert) and automatic segmented volumes of black holes. The results of this quantitative analysis indicate excellent performance of the automatic technique.

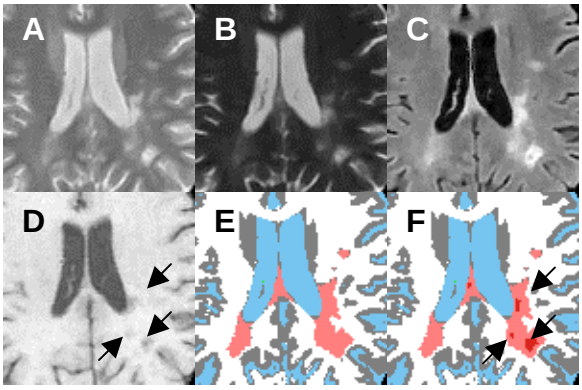

Fig. 1: A-D: PD, T2, FLAIR, and T1 images of a MS brain. E: Segmented image: CSF (blue), GM (gray), WM (white) and lesions (salmon). F: Segmented image (E) with black holes (red).

Conclusions: In this paper, we have presented and validated an automatic method for the segmentation of black holes in MS patients which manifest as T2-hyperintense and T1-hypointense lesions. This method is robust, accurate, and involves minimal operator intervention and is quite suitable for multi-center clinical trials where a large number of data needs to be processed.

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