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Detecting the appearance of new T2-w multiple sclerosis lesions in longitudinal studies using deep convolutional neural networks

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Background: Magnetic Resonance Imaging (MRI) has become one of the most important clinical tools for diagnosing and monitoring multiple sclerosis (MS). In particular, new T2 lesions on brain MRI are considered a good biomarker for monitoring and predicting treatment response. Therefore, building automated and accurate methods for the detection of new T2 lesions is a need.

Objectives: To propose a fully convolutional neural network (CNN) to detect new T2 lesions in longitudinal brain MRI images.

Materials and methods: One year apart multi-channel 3T brain MRI were obtained in 60 MS patients, including transverse T2-FLAIR, PD-w, T2 and T1 images. 36 of those patients presented new T2 lesions that were visually and semi-automatically annotated by expert neuroradiologists. The remaining 24 cases had no new lesions. All Images were pre-processed and co-registered by affine registration. Afterwards, a fully CNN where the inputs were the basal and follow-up images was trained to detect new MS lesions. The first part of the network was a U-Net block that automatically learned the deformation fields (DFs) which nonlinearly registered the basal image to the follow-up space. The learnt DFs together with the basal and follow-up images were then feed to a second block, another U-Net that performed the final detection and segmentation of the new T2 lesions.

Results: We performed a leave-one-out cross-validation strategy using the 36 patients with new T2 lesions. The model obtained 82.67% of true positive fraction (TPF), 15.06% of false positive fraction (FPF), and a mean detection and segmentation Dice similarity coefficient of 0.79 and 0.52, respectively. Our model had significantly better results ($p < 0.05$) than those of other state-of-the-art approaches such as Sweeney et al. (2013), Cabezas et al. (2016) and Salem et al. (2018). Regarding the 24 cases with no new T2 lesions, a trained model with all the 36 cases provided only 2 false positive detections. The proposed CNN model was faster in testing time than other state-of-the-art methods since there is no need to perform a non-rigid registration.

Conclusions: The proposed CNN approach provides better results than other state-of-the-art methods both in terms of sensitivity and specificity. In addition, the end-to-end learning framework avoids the use of complex processes such as the non-rigid registration and the definition of hand-crafted image features.

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