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Automated detection of cerebral microbleeds in MR images: A two-stage deep learning approach

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ABSTRACT

Cerebral Microbleeds (CMBs) are small chronic brain hemorrhages, which have been considered as diagnostic indicators for different cerebrovascular diseases including stroke, dysfunction, dementia, and cognitive impairment. However, automated detection and identification of CMBs in Magnetic Resonance (MR) images is a very challenging task due to their wide distribution throughout the brain, small sizes, and the high degree of visual similarity between CMBs and CMB mimics such as calcifications, irons, and veins. In this paper, we propose a fully automated two-stage integrated deep learning approach for efficient CMBs detection, which combines a regional-based You Only Look Once (YOLO) stage for potential CMBs candidate detection and three-dimensional convolutional neural networks (3D-CNN) stage for false positives reduction. Both stages are conducted using the 3D contextual information of microbleeds from the MR susceptibility-weighted imaging (SWI) and phase images. However, we average the adjacent slices of SWI and complement the phase images independently and utilize them as a two-channel input for the regional-based YOLO method. This enables YOLO to learn more reliable and representative hierarchal features and hence achieve better detection performance. The proposed work was independently trained and evaluated using high and low in-plane resolution data, which contained 72 subjects with 188 CMBs and 107 subjects with 572 CMBs, respectively. The results in the first stage show that the proposed regional-based YOLO efficiently detected the CMBs with an overall sensitivity of 93.62% and 78.85% and an average number of false positives per subject (FP_{avg}) of 52.18 and 155.50 throughout the five-folds cross-validation for both the high and low in-plane resolution data, respectively. These findings outperformed results by previously utilized techniques such as 3D fast radial symmetry transform, producing fewer FP_{avg} and lower computational cost. The 3D-CNN based second stage further improved the detection performance by reducing the FP_{avg} to 1.42 and 1.89 for the high and low in-plane resolution data, respectively. The outcomes of this work might provide useful guidelines towards applying deep learning algorithms for automatic CMBs detection.

1. Introduction

Cerebral Microbleeds (CMBs) are small foci of chronic brain hemorrhages that are generated by structural malformation of the small blood vessels and the deposits of blood products. CMBs have a high prevalence in several populations, including healthy elderlies (Martinez-Ramirez et al., 2014). It is observed that CMBs may cause a high risk of future intracranial hemorrhage and can be a biomarker for cerebral amyloid angiopathy and cerebral small-vessel diseases. Besides, the presence of microbleeds could increase the possible clinical implications of ischemic stroke, traumatic brain injury, and Alzheimer's diseases. Indeed, direct pathological observations have also revealed that CMBs bring about damage to the surrounding brain tissue, which cause dysfunction, dementia, and cognitive impairment (Koennecke, 2006, Charidimou et al., 2013). Therefore, accurate differentiation of CMBs from different suspicious regions (i.e., CMB mimics) such as calcifications, irons, and veins is important for proper diagnosis and appropriate treatment.

Currently, Computed Tomography (CT) and Magnetic Resonance (MR) imaging technologies are the most reliable screening modalities

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