Acute Ischemic Stroke Lesion Pattern Classification in DWI Using Deep Learning

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I. Introduction

STROKE has long been a major cause of death, with 22.9% fatality rate on average, and 67.3-87.5% of them are classified as ischemic stroke [1]. One of the most important ways to visualize acute ischemic stroke in the brain tissue is through brain imaging. But given the nature of brain tissue images for ischemic stroke, it is often found to be difficult to narrow down the range of the damaged area where actually corresponds to this specific type of stroke. Therefore, the need of accurate visualizations for acute ischemic stroke arises and it is necessary to detect damaged regions accurately in a narrow window for further clinical analysis of the actual type of disease and symptoms. And above requirements naturally bring up several different techniques of brain imaging. Two major methods of brain imaging are computed tomography(CT) and magnetic resonance imaging (MRI). And within these two categories, there is a variety of brain imaging modalities. Several studies have been conducted to compare existing imaging modalities for acute ischemic in terms of the effectiveness and limitation, and they have done the detailed comparison for different imaging modalities in a single study to achieve the most accurate result [4, 5]. The result shows that Diffusion-weighted magnetic resonance imaging (DW-MRI or DWI) is the most sensitive diagnostic modality to detect and diagnose acute ischemic stroke [2, 3]. Specifically, one result that is concluded from many studies is that the larger the lesion volume is in the DWI, the worse the stroke is [6,7,8]. However, most of these studies focus on one aspect of the possible outcome, for example, the recurrence of stroke, which does not fully represent the association of the DWI with the outcome of the stroke. As a result, current progress made with respect to identifying this association mostly lies in ischemic volume (i.e. the volume of lesion identified on DWI) and diffusion-perfusion mismatching. But besides these two measures, our knowledge in this subject is very limited.

Previous studies report that the pattern of lesions identifies on DWI is correlated with the pathogenic mechanisms underlying the stroke [9]. In addition, it is found that the lesion pattern plays an important role in correlating the information shown in DWI with actual outcomes of the stroke. The process of using the lesion pattern is especially useful in the acute phase of ischemic stroke for being simpler and less time consuming than the traditional lesion volume analysis approaches [9]. Therefore, a more comprehensive measure of the connection of lesion area and pattern with the outcome of the stroke is needed to better utilize the imaging information as inputs to further clinical analysis and evaluations.

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In this paper, our work tries to detect and classify DWI lesions into 6 different categories, which is useful in the early prediction stage of prognosis of three different endpoints: unstable hospital course, recurrence of stroke, and neurological outcome at 90 days after an ischemic stroke. The definition of these 6 categories of lesion patterns have been studied [9], but we wish to discover a fully-automated way to do this classification, which will vastly increase the efficiency in predicting outcome of strokes based on lesion features shown in the DWI.

II. Related Works

The shapes and locations of certain lesion patterns can be very useful in the prognosis of treatment outcomes. Here we list some of the works that are related to discovering the volumes and locations of acute ischemic lesions.

A. Works related to the segmentation of acute ischemic lesions

While FCN [15] is the first end-to-end CNN to tackle the problem of semantic segmentation and U-net [16] is a widely used model in the field of medical imaging, the state-of-art is achieved by modifying or combining different network structures for the lifting of certain limitations. For example, the authors of [10] used a combination of the EDD Net and the multiscale convolutional label evaluation net, which obtained a lesion detection rate of 0.94 on a large DW dataset. By using a densely connected three-dimensional convoluted neural network and Dice objective function, the model in [11] was able to outperform other CNN-based methods on a DWI dataset containing 242 subjects.

B. Works related to the classification of acute ischemic lesion patterns

In medical imaging classification researches, many earlier methods consist of ”manually crafted low-dimensional features”, as mentioned in [12]. Beyond that, Dou et al. (2015) tried to detect MR images with cerebral microbleeds through feature extraction via stacked convolutional Independent Subspace analysis network and a SVM classifier, which turns out to be a sensitive method though the false positive per subject is relatively high (7.7 per subject) [13]. In recent years, various structures of deep neural network structures have been studied and three dimensional convolutional neural networks are widely used in such tasks. For example, researchers in [14] aim to automatically label cerebral microbleeds from MR images. By using fully convolutional network (FCN) and a well-trained discrimination model, the proposed method turns out to have better performance and be faster than the previous ones. Luo, Brubaker & Brudno also explored using 3D CNNs for the task of "predicting the malignancy of identified lung nodules in CT scans", which shows that CNNs achieved "close to perfect results on the LIDC dataset" [12].

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