Segmentation-based quantification of brain SWI for predicting the stroke evolution

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Introduction

Acute ischemic stroke (AIS) is one of the critical diseases about brain injury, which results primarily from a severe reduction in blood supply for brain tissue and could lead to abnormal oxygen metabolism and cell death ultimately [1]. In clinical, thrombolysis or endovascular treatment, such as intravenous recombinant tissue plasminogen activator (tPA), could be performed after the possibility of hemorrhagic stroke was ruled out [2]. However, the outcome is not easy to predict and is mainly dependent on residual perfusion and oxygen availability. Recently, susceptibility-weighted imaging (SWI) has been demonstrated to be beneficial in detecting the prominent hypointense vessels resulting from the increased oxygen extraction of penumbra area [3]. Although Kao et al. emphasize that SWI/DWI mismatch could provide comparable information with PWI/DWI mismatch [4], the value of SWI is still controversial. In addition, the determination of SWI ASPECT is sort of subjective and not suitable to reflect intra-region discrepancy. As a result, the purpose of this study is using an auto segmentation method based on data clustering to investigate the symmetry of brain SWI in normal subjects and facilitate the quantification of the asymmetric distribution of the deoxygenated vessels in patients with AIS for a better prediction of stroke evolution.

Methods

Twenty-five volunteers, including ten normal subjects (group1) and fifteen patients with AIS (7 with and 8 without infarct growth, belongs to group 2 and 3, respectively), were enrolled in this study. All of them were imaged in a supine position in 1.5 T MR system (Avanto, Siemens medical solutions, Erlangen, Germany). In addition to the conventional imaging, DWI image was acquired with an twelve-channel head coil to demonstrate the suspected infarct area within 24 hours of symptom onset and SWI images were acquired using fast gradient echo sequence with TR = 50 ms, TE = 49 ms, number of slice = 60, slice thickness = 2 mm, matrix size = 256×224, inplane resolution = 0.9×0.9 mm^2. Follow-up FLAIR image was obtained after 7 days for evaluation of the infarct growth. Total acquisition time was less than 30 minutes. After data acquisition, the signal intensity of the SWI image in the level closed to basal ganglia was chosen as the feature to be involved in data clustering of fuzzy C-means (FCM) [5], and spatial constraint was added by considering the relationship between each pixel with the neighbors to avoid some sharp error points.

$$J_{FCM} = \sum_{j=1}^{c}\sum_{i=1}^{n}\mu_{ij}^{z}\left\|x_i - m_j\right\|^2 + \alpha\sum_{j=1}^{c}\sum_{i=1}^{n}\mu_{ij}^{z}\left\|\hat{x_i} - m_j\right\|^2$$

J_{ECM} is the objective function, where x_i represents the clustering data, and m_j are the corresponding centroids of different clusters in the feature spaces of image. x_i^ is a mean of the neighbors around x_i, and μ_{ij} is the weighting matrix describing the memberships between data and every cluster, whose fussiness can be controlled by z. The parameters, α adjusts the percentages of spatial constraint. After segmentation, an index of asymmetric ratio was obtained by calculating the difference of the vessel signals between the ipsilateral and contralateral side and then normalized by the later for the following comparison of their susceptibility discrepancy.

Results

The results of the acquired SWI, DWI, follow-up FLAIR and segmented images in normal subjects, patients with and without infarct growth were shown in Fig 1, respectively. No significant difference between two hemispheres was found in the segmented images of normal subjects. In stroke patients, DWI lesions reflects the potential infarct area, however, significant infarct growth was only observed in the follow-up FLAIR image of group 3 whose SWI image showed prominent vessels. As to the comparison of the asymmetric ratio of the segmented images among three groups, no significant difference was shown between group 1 and 2. However, the index of group 3 was significant higher than that of the other two groups ($p < 0.001$). Moreover, a good correlation was obtained between the asymmetric ratio and infarct growth factor of the stoke patients (r=0.8885).

Discussion

The present study indicates the feasibility of FCM-based segmentation of SWI images to facilitate predicting the following stroke evolution for patients with AIS. Compare with the original SWI, the segmented image shows the prominent vessels clearly and the index of asymmetric ratio reveals the degree of susceptibility change due to high oxygen demand of the brain tissue in stroke patients, which could suggest how severe the progressive stroke is. In conclusion, our preliminary finding demonstrates that the proposed method provides objective information for evaluation of the patients with acute ischemic stroke, and may have a potential to contribute to determining the penumbra and predicting of the stroke prognosis, as well as the following treatment.

Reference

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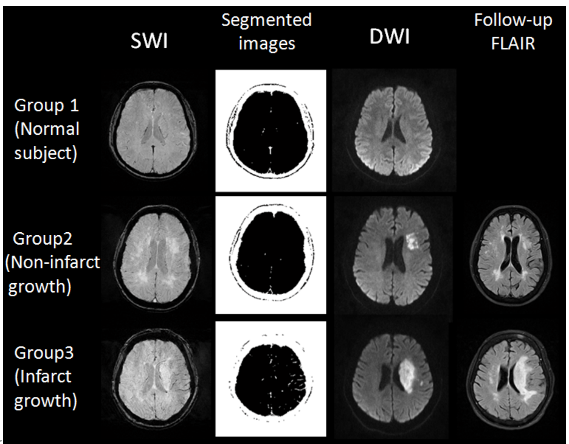

Figure 1 Images acquired from the normal subjects and stroke patients.

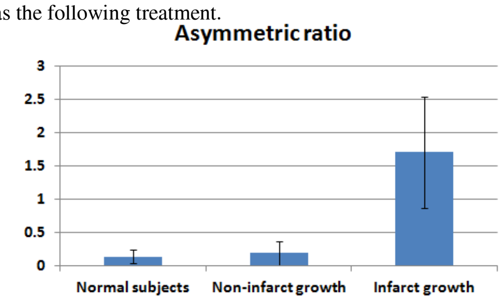

Figure 2 Asymmetric ratios of the three groups.

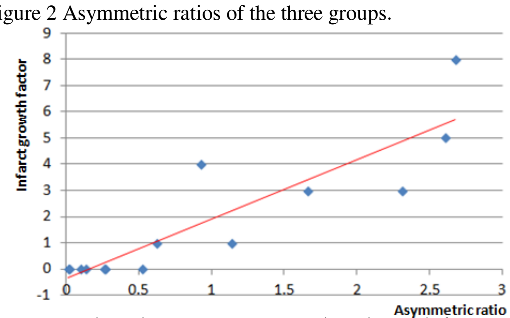

Figure 3 Relationship between asymmetric ratio and infarct growth factor of the patients.