Prediction of Infarct Lesion Volumes by Processing Magnetic Resonance Apparent Diffusion Coefficient Maps in Patients with Acute Ischemic Stroke

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Objective: We aimed to investigate the diagnostic value of apparent diffusion coefficient (ADC) maps in magnetic resonance imaging (MRI) in the volume of acute cerebral infarction (ACI). *Methods:* A total of 207 ACI patients were selected in our study. The cerebral infarction (CI) volume in the initial diffusion-weighted imaging examination, minimum ADC value, relative apparent diffusion coefficient (rADC) value, and mean ADC value were measured. The correlations between age, smoking, drinking, hypertension, diabetes, coronary heart disease, clinical stage, the lowest ADC value, the mean ADC value, and the mean rADC value with CI volume were analyzed by logistic regression analysis. A receiver operating characteristic (ROC) curve was used to analyze the diagnostic value of the ADC value in the ACI volume. *Results:* There was a significant difference in the distribution of the CI volume in ACI patients ($P < .05$). A significant difference was found in the signal intensity and percentage distribution of ADC map in patients of different CI groups with different CI volumes ($P < .05$). The signal of the ADC map was positively correlated with the CI volume. The mean ADC and rADC values had significant differences between different CI volumes (all $P < .05$). Logistic regression analysis revealed that the mean ADC value was significantly correlated with the CI volume ($P < .05$). Analysis of the ROC curve showed that the quantitative value of ADC has a diagnostic value for the ACI volume. *Conclusion:* This study has shown that the signal intensity change on the ADC map in MRI and quantitative analysis of the ADC value can be used as a reference for predicting the ACI volume. **Key Words:** Acute cerebral infarction—magnetic resonance imaging—apparent diffusion coefficient—diffusion-weighted imaging—infarct volume—T1-weighted imaging—T2-weighted imaging—region of interest.

Introduction

Cerebral infarction (CI), also known as ischemic stroke, is the chief cause of disability worldwide, the second most frequent cause of dementia, and the third main cause of death.[1] After correction for age, the incidence rate of CI is 116-219/100,000/year, and the death rate is 58-142/100,000/year. There are over 7 million CI survivors who are living in China, among which 70% have suffered from acute cerebral infarction (ACI).[2] The etiology of ACI is complicated and involves inflammatory pathways, excitotoxicity mechanisms, ionic imbalances, oxidative damage, angiogenesis, apoptosis, and neuroprotection.[3] Additionally, ACI occurs due to a variety of complex risk

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factors such as cardiovascular disease and diabetes.[4] Nowadays, there are several ways to diagnose ACI patients, including computed tomography (CT) angiography, CT perfusion techniques, and magnetic resonance imaging (MRI)-based techniques.[5] Current treatment strategies for ACI focus mainly on decreasing the size of ischemic damage as well as rescuing dying cells early after occurrence.[6] Because ACI is invariably of sudden onset, and often contributing to serious consequences, it is important to develop fast and accurate diagnostic strategies so that ACI patients could undergo timely and proper treatment.

CT angiography and CT perfusion techniques, belong to multimodal imaging techniques, may have good diagnostic values in the aspects of vascular occlusion; both methods are insensitive to ACI while are not widely used timely at many institutions.[5] Diffusion-weighted magnetic resonance imaging (DW-MRI) is a noninvasive technique that measures the microscopic mobility of water molecules in tissues without contrast administration, and this mobility primarily depends on the cellularity of the underlying tissue and the integrity of cell membranes, thus reflecting biologic abnormalities.[7] DW-MRI is capable of providing image contrast susceptible to microstructural and cellular remodeling; particularly, DW-MRI has gained much interest among drug developers and oncologists due to its association with cellular density.[8] Additionally, DW-MRI was originally applied in the brain and gradually became the gold standard for diagnosing acute stroke for the reason that the microstructural changes observed on DW-MRI were clearer than the morphological changes that are detected on conventional cross-sectional imaging.[9] Over the decades, DW-MRI has been used for the assessment of cerebral diseases, especially to detect early ACI by its concomitantly restricted diffusion.[10] The apparent diffusion coefficient (ADC) is widely used in differential diagnosis, and diffusion-weighted imaging (DWI) has been reported to have the potential to differentiate benign and malignant tumors.[11] In the field of oncology, the ADC acts as a quantitative biomarker, and promising results were reported for the characterization of malignancy together with the prediction and monitoring of therapeutic responses.[12] Although DW-MRI has been applied to detect early ACI, few studies focused on the diagnostic value of DW-MRI on ACI volume. Therefore, our study aims to explore the diagnostic value of ADC maps in MRI in the volume of ACI.

Materials and Methods

Ethics Statement

The study was carried out with the permission of the Institutional Review Board of The Third Affiliated Hospital of Zhejiang Chinese Medical University. Written informed consent was obtained from all participants. Ethical approval for the present study conformed to the standards of the Declaration of Helsinki.[13]

Subjects

A total of 207 patients were diagnosed with ACI according to the onset time ranging between 6 and 24 hours after these patients had follow-up examinations in the emergency and neurology departments of the Third Affiliated Hospital of Zhejiang Chinese Medical University in March 2015. All 207 ACI patients received CT examination of the head to exclude cerebral hemorrhage and other nonischemic brain diseases. MRI was immediately conducted after finishing CT examination, and the time between MRI examination and the onset of disease was between .5 and 13.5 hours (median: 1.5 hours). All patients (154 male and 53 female) were aged between 41 and 81 years old, with a mean age of 61.27 ± 8.37 years old. Based on the Trial of Org 10172 in Acute Stroke Treatment (TOAST) criteria,[14] all patients were classified under lacunar infarction (LI, n = 48), atherothrombotic brain infarction (ATBI, n = 55), cardiogenic embolism (CE, n = 100), other cause of infarction (OI, n = 2), and cryptogenic stroke (CS, n = 2). The main clinical manifestations of patients included headache, facial paralysis, unilateral limb movement disorder, limb weakness, numbness, vomiting, dizziness, and coma aphasia. The exclusion criteria were patients who had hemorrhagic tendency or cerebral hemorrhage or combined with epilepsy, serious heart, liver, and kidney dysfunctions, or other severe somatic diseases; could not undergo normal examination or treatment due to unconsciousness; had a history of mental disorders; had metallic foreign body, such as pacemakers or other implanted electronic device, in vivo.

Conventional MRI–DWI Device Parameters and Scanning Method

The MRI equipment used in the present study was 1.5T Magnetom symphony superconducting magnetic resonance scanner produced by Siemens (Erlangen, Germany). Conventional MRI plain scan was conducted using an 8-channel head and surface coil. Scanning was taken for T1-weighted imaging (T1WI), T2-weighted imaging (T2WI), and single-shot spin-echo (SE) version of echo planar imaging sequences. First, the T1WI sequence was scanned with SE, with a time of repetition (TR)/time of echo (TE) of 500 milliseconds/15 milliseconds and a matrix of 256×256; second, the T2WI sequence was scanned with turbo spin echo, with a TR/TE of 3500 milliseconds/100 milliseconds and a matrix of 512×512; finally, the TR/TE of the SE version of echo planar imaging sequence was 2268 milliseconds/70 milliseconds, and three b values (0, 500, and 1000 s/mm^2) were used simultaneously. A 3-dimensional digital acquisition with 3 axial directions (X, Y, Z axes) was used to scan for 79 seconds, and the time of DWI imaging was 60 seconds. The imaging range of the transverse section was from the basis cranii to the vertex, and these 3 axial sequences had 20 layers, respectively, with a layer thickness of 5.0 mm, an interval