Computer-Aided Diagnosis Scheme for Detection of Lacunar Infarcts on MR Images[1]

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Rationale and Objectives. The detection and management of asymptomatic lacunar infarcts on magnetic resonance (MR) images are important tasks for radiologists to ensure the prevention of severe cerebral infarctions. However, accurate identification of the lacunar infarcts on MR images is a difficult task for the radiologists. Therefore the purpose of this study was to develop a computer-aided diagnosis scheme for the detection of lacunar infarcts to assist radiologists' interpretation as a "second opinion."

Materials and Methods. Our database comprised 1,143 T1- and 1,143 T2-weighted images obtained from 132 patients. The locations of the lacunar infarcts were determined by experienced neuroradiologists. We first segmented the cerebral region in a T1-weighted image by using a region growing technique for restricting the search area of lacunar infarcts. For identifying the initial lacunar infarcts candidates, a top-hat transform and multiple-phase binarization were then applied to the T2-weighted image within the segmented cerebral region. For eliminating the false positives (FPs), we determined 12 features—the locations x and y, signal intensity differences in the T1- and T2-weighted images, nodular components from a scale of 1 to 4, and nodular and linear components from a scale of 1 to 4. The nodular components and the linear components were obtained using a filter bank technique. The rule-based schemes and a support vector machine with 12 features were applied to the regions of the initial candidates for distinguishing between lacunar infarcts and FPs.

Results. Our computerized scheme was evaluated by using a holdout method. The sensitivity of the detection of lacunar infarcts was 96.8% (90/93) with 0.76 FP per image.

Conclusions. Our computerized scheme would be useful in assisting radiologists for identifying lacunar infarcts in MR images.

Key Words. Lacunar infarcts; magnetic resonance imaging; computer-aided diagnosis (CAD); filter bank; support vector machine.

Cerebrovascular disease is the third major cause of death in Japan (1). Therefore, a health check system for cerebral and cerebrovascular diseases, which is named Brain Dock, is widely performed in Japan. In this system, unruptured cerebral aneurysms and asymptomatic lacunar infarcts are often detected using magnetic resonance angiography (MRA) and magnetic resonance imaging (MRI). However, their accurate identification is difficult task for radiologists. Thus we have been developed computer-aided diagnosis (CAD) schemes in Brain Dock for the detection of cerebral and cerebrovascular diseases on brain magnetic resonance images (2–7) in order to assist radiologists' diagnosis as a "second opinion."

The detection of unruptured aneurysms in MRA studies is important because aneurysms rupture is the main cause of subarachnoid hemorrhage. However, it is difficult to detect small aneurysms in MRA studies because of the overlapping of aneurysms and adjacent vessels on maximum intensity projection image. Therefore several CAD schemes have

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been reported for the detection of aneurysms in MRA studies (5,6,8–11). CAD schemes can determine the locations of the candidates for unruptured aneurysms by analyzing certain image features such as the size or shape of the candidate (5,8–11). Approximately 90%–95% of the aneurysms can be accurately detected using the current CAD schemes. An observer study for conducting the effect of a developed CAD scheme was also carried out (12). The results of this study indicated that the CAD improved the performance of neuroradiologists' and general radiologists' in detecting intracranial aneurysms by MRA. Although a number of studies have reported on CAD schemes for the detection of aneurysms, there have been no reports on the detection of lacunar infarcts without our previous study.

The detection of asymptomatic lacunar infarcts in MRIs is also important because their presence indicates an increased risk of severe cerebral infarction (13,14). However, accurate identification of lacunar infarcts on MRIs is difficult for radiologists because of the difficulty in distinguishing the lacunar infarcts from normal tissues such as enlarged Virchow-Robin spaces (15). Therefore we have been developed a CAD scheme for the detection of lacunar infarcts.

In our previous study, Yokoyama et al developed two methods for detection of isolated lacunar infarcts and lacunar infarcts adjacent to a lateral ventricle (2). These methods were applied to 80 cases and the results obtained indicated that the methods were useful in the detection of two different types of lacunar infarcts (3). However, further studies using a larger dataset were necessary for evaluating our computerized method. Therefore in this study, we selected 1,143 T1- and 1,143 T2-weighted images obtained from 132 patients and made a larger database. In addition, we developed a new method for eliminating the false positives (FPs). We determined 12 features by using a new filter bank technique, and then the rule-based schemes and a support vector machine (SVM) with 12 features were employed for distinguishing between the lacunar infarcts and FPs. Furthermore, the detection performance of our improved CAD scheme was evaluated using a larger database.

MATERIALS AND METHODS

Clinical Cases

Our database consisted of 1,143 T1- and 1,143 T2-weighted MR images, which were selected from 132 patients (mean age 63.4 years; age range 28–83 years). These images were acquired using a 1.5 T magnetic imaging scanner (Signa Excite Twin Speed 1.5 T; GE Medical Systems, Milwaukee, WI) at the Gifu University Hospital (Gifu, Japan). The T1- and T2-weighted images were obtained using the fast spin-echo method with an effective echo time of 8–12 milliseconds, and 96–105 milliseconds, respectively, and a repetition time of 300–500 milliseconds and 3000–3500 milliseconds, respectively. All MRIs were obtained in the axial plane with a section thickness of 5 mm with a 2-mm intersection gap, which covered the whole brain. The matrix size of the MRIs was 512 × 512, with a spatial resolution of 0.47 mm/pixel.

Gold Standard

We performed an observer study to determine the location of the lacunar infarcts on the images in our database. On a CRT monitor and using a mouse, two experienced neuroradiologists independently marked the location of the lacunar infarcts (diameter 3–15 mm) on 1,143 T1- and 1,143 T2-weighted MRIs. T1- and T2- weighted images of the same section were displayed together. The slice images for each study were changed manually by the observer. The windowing in T1- and T2-weighted images was initially set to a default value that could be adjusted by the observer. The results revealed that the observer A selected 120 candidates for lacunar infracts, whereas the observer B selected 154 candidates, implying that accurate identification of lacunar infarcts is difficult.

In this study, a candidate that was identified by both the neuroradiologists was considered as a "lacunar infarct." The sensitivity for the detection of lacunar infarcts was calculated based on the location of the lacunar infarct. On the other hand, the number of FPs per image was calculated based on the "non-lacunar slices." A slice was determined as non-lacunar when a point on the slice was not identified as a lacunar infarct by either of the two neuroradiologists. Our database included 93 lacunar infarcts and 1,063 non-lacunar slices.

Extraction of the Cerebral Region

Lacunar infarcts were generally detected in the basal ganglia region and in the white matter regions. Therefore we first segmented the cerebral region using the region growing technique to avoid detecting false findings located outside the cerebral region. A 3 × 3 median filter was applied to the T1-weighted image for eliminating impulse noise, and we plotted a histogram of the T1-weighted image thus obtained. All pixels of the brightest