The Prediction of Malignant Middle Cerebral Artery Infarction: A Predicting Approach Using Random Forest

Ru Chen, MD,* Zelin Deng, PhD,† and Zhi Song, MD, PhD*

Background: Malignant middle cerebral artery infarction (MMI) is always associated with high mortality rates. Early decompressive craniectomy is crucial to its treatment. The purpose of this study was to establish a reliable model for an early prediction of MMI. *Methods:* Using a retrospective survey, we have collected the data of 132 patients with middle cerebral artery infarction. According to a prognosis, the patients are divided into the MMI group (n = 36) and the non-MMI group (n = 96). All the patients are represented by their clinical, biochemical, and imaging features. Then a random forest (RF) prediction model is established on the clinical data. Meanwhile, 3 traditional prediction models, including univariate linear discriminant analysis (LDA) model, multivariate LDA model, and binary logistic regression analysis (BLRA), are built to compare with the RF model. The prediction performance of different models is assessed by the area under the receiver operating characteristic curves (AUCs). *Results:* Four parameters, Glasgow Coma Scale, midline shifting, area, and volume of focus, selected as predictors in all models. As independent predictors, their AUCs are .72-.80, and when the sensitivities are high (.91-.95), the specificities are low (.32-.53). The AUC of RF model is .96, 95% confidence interval (CI) is (.93-.99), sensitivity is 1, and specificity is .85. The AUC of the multivariate LDA model is .87 and 95% CI is (.80-.93). The AUC of the BLRA model is .86 and 95% CI is (.80-.93). *Conclusions:* The RF performs very well in the given clinical data set, which indicates that the RF is applicable to the early prediction of the MMI. **Key Words:** Brain edema—acute stroke—risk prognostication—decompressive craniectomy—random forest.
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Among all the cases of cerebral infarction, approximately 10% involves large infarctions in the middle cerebral artery (MCA) territory.[1,2] Some of the large MCA infarction patients die within the first day after stroke. Space-occupying cerebral edema is the leading cause of death.[2,3] As a consequence, the label "malignant" middle cerebral artery infarction (MMI) has become widely used for this subgroup of stroke patients.[1] Clinical characters including disturbance of consciousness and clinical sign of brainstem herniation can imply the deterioration.[1] Decompressive craniectomy (DC) has been shown to reduce the mortality rate, while improving the clinical outcomes of the patients with the MMI.[4-7] Recent studies have shown that early rather than late decompressive interventions can lead to better outcomes.[8-10] This fact suggests that the decision to perform the DC should be taken before the clinical deterioration occurs. Therefore, the early identification of the patients who are likely to develop the MMI becomes crucial.

Several clinical and imaging parameters have been identified as the predictors of fatal brain swelling,

From the *Neurological Department, The Third Xiangya Hospital of Central South University, Hunan; and †Department of software engineering, School of Computer and Communication Engineering, Changsha University of Science and Technology, Hunan, China.

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Address correspondence to Zhi Song, MD, PhD, Neurological Department, The Third Xiangya Hospital of Central South University, Hunan 410013, China. E-mail: doc_sz@126.com.

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such as coma on admission and severe neurologic deficit mirrored by high scores on the National Institutes of Health Stroke Scale.[11-14] In a prospective multicenter study, the diffusion-weighted magnetic resonance imaging (DWI; lesion >82 mL) was identified as a predictor of the MMI, with a high specificity of .98, but a low sensitivity of .52.[14] So far, there is still no effective method for an early identification of the patients with the MMI.

The classification algorithms, which are computer programs with learning capabilities, can mine the patients' clinic data to derive the relationships between the patients' clinic parameters and the diseases. Thus, the prediction models based on the classification algorithms have higher predicating capabilities than the traditional clinical methods. Among the numerous classification algorithms, the random forest (RF) algorithm is a high-performance classifier, and it has been applied successfully to gene selection,[15] tumor classification,[16] medical image processing,[17] and so forth.

In the present study, the RF is used to forecast the MMI in a bid to provide a more accurate clinical operation standard for the DC.

Materials and Methods

Patients

We have retrospectively analyzed the records of the patients admitted to our neurologic intensive care units between February 2008 and April 2014. Inclusion criteria are as follows: (1) ischemic stroke is listed as the primary diagnosis, identified using the International Classification of Diseases, 10th Revision, Clinical Modification (ICD-10CM) diagnostic codes G45.1, G45.2, I63, I64, I65, and I66; (2) onset time is accurately recorded; (3) the DWI is performed within 72 hours of the symptom onset; (4) the patients with the diagnoses of intracranial hemorrhage that are identified by ICD-10 CM diagnostic codes I60 and I61 are excluded; (5) the patients with the diagnoses of posterior intracranial circulation occlusion (ICD-10CM diagnostic codes G45.0, I65.0, I65.1, I66.3, and I63.904) are excluded; (6) deaths caused by other internal organ failures are excluded.

Diagnosis of the MMI is done according to the following 2 clinical criteria: (1) clinical signs show uncal herniation, including deterioration of neurologic and consciousness status and anisocoria; (2) mass effect leads to an early death. Accordingly, the patients are divided into 2 groups, that is, the MMI group and the non-MMI group.

All of the patients in the neurologic intensive care units are treated according to the national and international guidelines, including the conservative treatment of increased intracranial pressure. All the treatment decisions are made by an experienced medical team consisting of neurologists and neurosurgeons.

Clinical Assessment

The demographic and clinical characteristics, laboratory test values, and imaging findings are collected to represent the patients in our models. These parameters include age, sex, side of infarction, delay from onset to DWI, medical history, Glasgow Coma Scale (GCS), National Institutes of Health Stroke Scale score, blood routine, blood electrolytes, hepatic and renal function, selected tests of thrombosis, and hemostasis.

Magnetic Resonance Imaging Protocol: Image Acquisition and Analysis

The magnetic resonance imaging studies were performed with a 1.5-T scanner equipped with a 20-mT/m gradient system (Magnetom Avcnto, Siemens). T1-weighted imaging, T2-weighted imaging, fluid-attenuated inversion recovery sequence, and the DWI were acquired within a standardized protocol within approximately 20 minutes. Matrix = 256 × 256; field of view = 230 × 230. Lesions were measured on the apparent diffusion coefficient maps and the analysis took the following steps:

(1) Each lesion area was traced manually with a generous safety margin on every axial scan, and the areas were calculated through the region-of-interest analysis automatically. The biggest value was chosen as the maximum cross-sectional area of the focus.
(2) The method for measuring the length and width of the maximum cross-sectional area: the connecting line between frontal and parietal median crests was the y-axis; the line vertical to it was the x-axis. The lesion's projection on the y-axis was the length, and its projection on the x-axis was the width.
(3) The formula for calculating the lesion thickness in the axial slices was, thickness = slice number × (slice thickness + slice gap).
(4) We opened the sagittal, coronal, and axial windows in the workstation at the same time, and then delineated the extent of the lesion manually in the axial window, while monitoring the outline of the lesion in the other 2 windows to check that they did not exceed the corresponding ranges. The workstation then calculated the lesion volume through the region-of-interest analysis automatically.
(5) The specific method for measuring the midline shifting at the septum pellucidum level: using the connecting line between frontal and parietal median crests as a benchmark, we determined

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