The Processing Time for Recanalization and Size of Ischemic Lesions on DWI is Related With Complete Reperfusion After Mechanical Thrombectomy

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Recent studies demonstrated that modified thrombolysis in cerebral infarction (TICI) 3 reperfusion have better functional outcomes than modified TICI 2b after mechanical thrombectomy in acute ischemic stroke with large vessel occlusion. The purpose of this study was to determine significant factors to forecast the presence of complete reperfusion after mechanical thrombectomy based on multimodal magnetic resonance imaging (MRI). We investigated 96 consecutive patients with acute large intracranial artery occlusion of anterior circulation who based on multimodal MRI. Also, we compared clinical and radiologic parameters between patients with modified TICI 3 and those with modified TICI 0-2b. Among 96 eligible subjects received mechanical thrombectomy, 39 patients (40.6%) showed complete reperfusion and 57 partial or nonreperfusion (mTICI 2b-26, mTICI 2a-9, mTICI 1-8, and mTICI 0-14) after mechanical thrombectomy. Patients with mTICI 3 had significantly smaller initial Diffusion weighted images (DWI) lesion volume ($P < .01$) and much shorter time interval from onset to reperfusion ($P < .01$) than those patients with mTICI (0-2b). In multivariate analysis, smaller initial DWI volume (odds ratio [OR], 1.78; 95% confidence interval [CI], 1.23-2.57; $P < .01$) and faster reperfusion time (OR, 1.07; 95% CI 1.01-1.14; $P = .015$) had an independence significance for complete reperfusion after mechanical thrombectomy. In this study, the ischemic lesion volume on DWI and faster processing time are critical factor to predict the state of complete reperfusion after mechanical thrombectomy.

Key Words: Mechanical thrombectomy—Stroke—Reperfusion—Multimodal MRI

Introduction

Thrombectomy is now recommended as the standard of care for acute ischemic stroke with proximal large-vessel occlusion in the anterior circulation[1] and successful reperfusion has been considered a powerful predictor of good long-term outcome after mechanical thrombectomy in acute large vessel occlusion.[2] Until now, the thrombolysis in cerebral infarction (TICI) score is currently used to estimate the status of reperfusion after using mechanical thrombectomy.[3] Many studies showed that mTICI 3 and 2b represent the successful recanalization in endovascular therapy.[4] However, several studies suggested that those patients with mTICI3 have much better clinical outcomes than those with mTICI 2b.[5-7]

Generally, it has been known that the reperfusion might be related with time from onset to recanalization,[5] size of ischemic lesion,[8] and presence of collateral circulation[9] after acute ischemic stroke. Using the multimodal MRI including DWI and perfusion-weighted imaging (PWI) before thrombolysis enabled us to estimate the presence of viable brain tissues, the status of vessel occlusion, and of collateral circulation after Acute ischemic stroke (AIS).[10] Regarding on the occurrence of complete reperfusion after mechanical thrombectomy, there has been limited data using multimodal MRI to know its predicting value.

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In this study, we would like to know predicting factors about the occurrence of complete reperfusion after mechanical thrombectomy based on using multimodal MRI in acute anterior large artery occlusion.

Methods

We retrospectively studied in patients with AIS admitted to our stroke center from 2013 to 2016. To satisfy our study aims, we included patients as followed: (1) those patients who have symptomatic M1 occlusion or intracranial internal carotid artery occlusion without associated cervical internal carotid artery occlusion/critical stenosis. Patients referred for AIS with cervical internal carotid occlusion/critical stenosis and basilar occlusion were excluded from this study to decrease bias because of the heterogeneity of patients and endovascular approaches, (2) those patients who did take mechanical thrombectomy, and (3) those patients who had MRI including diffusion and perfusion weighted images before thrombectomy.

Critical Pathway for Hyperacute Ischemic Stroke

Our stroke critical pathway is based on CODE RED program is a kind of computerized physician order entry system, which enables activation, communication, notification, entering of predetermined standing order sets, and provides protocols and guidelines.[11] In our stroke code system, MRI was routinely performed to screen patients for thrombolytic therapy. However, when an immediate MRI was not available because it was being used for other patients, we used brain computed tomography for intravenous tissue-plasminogen activator, which was administered according to the NINDS criteria.[12] In such cases, we performed MRI before mechanical thrombectomy.

Patients and Data Collection

For each patient, we recorded their age, sex, and the presence of vascular risk factors. All subjected patients were determined the National Institutes of Health Stroke Scale (NIHSS) at baseline by stroke neurologists. The modified Rankin Scale (mRS) was calculated at baseline and at 90 days after admission. We defined excellent outcome as an mRS ≤ 1 at 90 days after mechanical thrombectomy. The safety outcome was the presence of symptomatic hemorrhagic transformation, which was defined as local or remote parenchymal hemorrhage, combined with a neurologic deterioration of 4 or more NIHSS scores.[13]

In this study, we evaluated 3 processing time intervals for mechanical thrombectomy as follows; onset to arrival, onset to puncture, and onset to recanalization based on medical records. The recanalization time was recorded in each patient and was based on the first conventional angiography image with evidence of angiographic revascularization during or immediately after the mechanical thrombectomy.

Multimodal MRI

Our hospital routinely uses MRI-based screening protocols for acute ischemic stroke patients. All patients underwent initial and follow-up MRI using a 3.0-T MRI system (GE Medical Systems, Milwaukee, WI) with a 12-channel head-neck-spine array receiving coil. The MRI protocols were standardized and included DWI, 3-D time-of-flight MR angiography, fluid-attenuated inversion recovery imaging, T2$*$-weighted gradient echo imaging, extracranial MR angiography, and PWI. Gradient-recalled echo (GRE) T2 imaging was performed to screen for intracranial hemorrhage and susceptibility vessel sign (SVS). The acquisition parameters for GRE T2 included the following: Time to repeat (TR), 467 ms; Time echo (TE), 15 ms; section thickness, 5 mm; intersection gap, 2 mm; Field of view (FOV), 220 $\times$ 220 mm; and flip angle, 20°. The SVS was defined as the presence of a hypointense signal on GRE within the cerebral artery that exceeded the size of the homologous contralateral arterial diameter.

DWI images were acquired using echo-planar imaging techniques (b-value of 1000 s/mm^2 along 3 orthogonal directions, 22 slices, TR: 8000 ms, Time echo (TE): 63.5 ms, ET: 1 ms, FOV 22 $\times$ 22 cm, 5-mm slice thickness with a 2-mm gap, matrix 160 $\times$ 160), and apparent diffusion coefficient maps that were calculated automatically. Dynamic susceptibility contrast PWI was performed using a contrast bolus injection with very rapid echo-planar imaging-based image acquisition. The dynamic susceptibility contrast PWI parameters were as follows: TR: 2000 ms, TE: minimum, FOV: 22 $\times$ 22 cm, slice thickness: 5 mm, spacing: 2 mm, matrix: 128 $\times$ 128; flip angle: 60, and number of acquisitions (NEX): 1. A large-bore 18-gauge intravenous cannula was inserted to administer a .2 mmol/kg bolus of gadolinium diethylenetri-amine pentaacetic acid at a rate of 4 mL/s using an MR-compatible power injector. Postprocessing was performed using vendor-specific dedicated software (ADW 4.6 workstation; GE Medical Systems) to generate color-coded and parametric perfusion. The time to peak of the residue function (T_{max}) was generated using circular deconvolution of the tissue concentration over the time curve with an arterial input function from the contralateral middle cerebral artery.

DWI lesion volume was measured using a Picture archiving communicating system (PACS) workstation (Marosis, Marotech, Seoul, South Korea). The edge of the DWI abnormality was determined using the trace of the diffusion coefficient and was identified visually, and regions of interest were outlined using a pixel-wise method. The area of each regions of interest was multiplied by the section thickness plus the intersection gap and then summed to give the lesion volume. The PWI lesion volume was segmented with a T_{max} cut-off value of 6 second using semiautomated techniques on a Volume Viewer 11.3 (GE Healthcare, Waukesha, WI). All lesions were segmented on a slice-by-slice basis, and volumes were calculated as the product of the slice thickness and the total lesion area.[14]