Influence of Recanalization and Time of Cerebral Ischemia on Tissue Outcome after Endovascular Stroke Treatment on Computed Tomography Perfusion

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Background: The Alberta Stroke Program Early Computed Tomography Score (ASPECTS) has been proposed as a straightforward alternative to the less reliable visual estimation of tissue at risk. We evaluated the association between admission ASPECTS on computed tomography perfusion (CTP) parameter maps and final infarct ASPECTS in patients with acute ischemic stroke who were treated by endovascular therapy (eT) and compared the results with thrombolysis candidates treated conservatively. *Methods:* eT was performed in 26 consecutive ischemic stroke patients within 6 hours of symptom onset. The control group was matched for age and admission National Institutes of Health Stroke Scale having the same admission imaging protocol and a transcranial Doppler sonography within 24 hours. ASPECTS determined from CTP maps of cerebral blood flow (CBF), cerebral blood volume (CBV), and time to peak (TTP) were compared with final infarct ASPECTS on day 5 noncontrast CT. *Results:* Recanalization rate was 73% in treatment and 50% in control group. ASPECTS for all CTP parameters were significantly lower than ASPECTS-CT in both groups ($P < .005$). In the treatment group, this applied to patients with successful recanalization. Only controls without recanalization showed a strong correlation between ASPECTS-CTP parameters and ASPECTS-CT (CBV: $P = .005$; CBF and TTP: $P = .028$). Patients with early recanalization (≤4 hours) had greater differences between ASPECTS-CTP and ASPECTS-CT than patients with late recanalization (>4 hours; CBF: $P = .056$; CBV: $P = .095$; TTP: $P = .048$). *Conclusions:* The initial ASPECTS-CTP lesion was significantly larger than the final infarct determined by ASPECTS in case of recanalization. Initial perfusion lesion, including CBV, is reversible in case of reperfusion, especially in early reperfusion. **Key Words:** Ischemic stroke—intra-arterial thrombolysis—endovascular intervention—perfusion CT—ASPECTS.

Introduction

Acute reperfusion procedures are aimed at salvaging tissue at risk of infarction. Magnetic resonance imaging (MRI) diffusion weighted imaging (DWI), and perfusion-weighted imaging (PWI), and measurement of cerebral blood flow (CBF) and cerebral blood volume (CBV) by computed tomography perfusion (CTP) allow determination of clinical imaging surrogate markers for tissue at risk, known as DWI/PWI mismatch and

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Received February 4, 2015; revision received June 9, 2015; accepted June 14, 2015.

The authors did not receive any grant support.

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1052-3057/$ - see front matter

http://dx.doi.org/10.1016/j.jstrokecerebrovasdis.2015.06.025

CBF/CBV mismatch, respectively. Mismatch criteria are still evolving, and mismatch-guided delayed thrombolysis has not yet been shown to improve clinical outcome.[1] There are several approaches to mismatch quantification. One is the visual estimation method, which was initially derived from quantitative volumetric analysis of the DWI-PWI mismatch of MRI studies in acute stroke.[2,3] This method, however, has been shown to be inadequate in terms of reliability and interrater agreement.[4,5] Volumetric approaches seem to be more reliable[4,5] but are also more time-consuming. To overcome these shortcomings, the semiquantitative Alberta Stroke Program Early Computed Tomography Score (ASPECTS) has been proposed as an alternative.[6] Lin et al[7] have shown that, in patients with middle cerebral artery (MCA) infarction, the ASPECTS of the admission CTP CBV map has the best predictive value for final infarct size determined by ASPECTS in MRI-DWI. Another study reports that ASPECTS-CBV is predictive of the final infarct ASPECTS after major reperfusion following intravenous thrombolysis (IVT).[8] Our aim was to evaluate the association between the initial preinterventional ASPECTS determined using CTP maps of CBF, CBV, and time to peak (TTP) and final infarct ASPECTS in follow-up CT after endovascular treatment in acute ischemic stroke and to compare the results with thrombolysis candidates who received neither endovascular therapy (eT) nor IVT.

Methods

Ethics Statement

The study was approved by the local ethics committee. Written informed consent was obtained from all patients or their legal representatives.

Patient Selection and Thrombolytic Treatment

We prospectively enrolled all patients with acute ischemic stroke admitted to our stroke center over a 3-year period. Inclusion criteria were as follows: clinical symptoms of acute stroke, a moderate or severe neurologic deficit (defined as National Institutes of Health Stroke Scale (NIHSS) score ≥5), age between 18 and 80 years, and full imaging workup with the aim of initiating eT within 6 hours of symptom onset. If there was no intracranial hemorrhage on noncontrast cranial CT (NCCT) and early signs of infarction involved less than one third of the MCA territory, CTP and CT angiography (CTA) were performed. Patients qualified for eT—as described elsewhere[9]—if CTA demonstrated occlusion of the distal internal carotid artery, the carotid T, or the proximal MCA. The degree of recanalization was assessed on the final angiogram using the Thrombolysis In Cerebral Infarction (TICI) criteria.[10] For further analysis, successful recanalization was defined as TICI grades 2b or 3, persistent occlusion (no recanalization) as TICI grades 0, 1, or 2a. In patients with successful recanalization, time of cerebral ischemia was calculated as time from symptom onset to time of recanalization.

Follow-up NCCTs were performed 24 hours and 5 days after eT or whenever a patient showed neurologic deterioration.

Imaging

All patients were examined on a 16-row multislice CT scanner (Somatom Sensation 16; Siemens Healthcare Sector, Forchheim, Germany). Scanning parameters for the initial NCCT were 4.5 mm section thickness, 120 kV tube voltage, 360 mAs tube current, and a pitch of 1. Next, CTA of the cervicocranial arteries was acquired from the level of the sixth cervical vertebra up to the vertex after administration of 80 mL of contrast agent (Visipaque 270; GE Healthcare Buchler, Braunschweig, Germany) via an antecubital venous line using a power injector (MedRad Medical Systems, Volbach, Germany). The contrast agent was administered at a flow rate of 4 mL/second followed by a saline flush of 40 mL at the same flow rate. Semiautomated bolus tracking in the common carotid artery on the affected side at the level of the sixth vertebra was used, and the scan was started without delay at a threshold of 150 Hounsfield units. Thereafter, CTP was performed by acquisition of 2 slices with a slice thickness of 12 mm at the level of the basal ganglia according to previously described criteria.[8,11] Images were acquired for 60 seconds with 1 image per second after administration of an IV bolus of 60 mL of iodinated contrast agent (Visipaque 270, GE Healthcare Buchler), followed by a 40-mL saline flush, both at 6 mL/second. Postprocessing and image analysis of CTP data sets were performed using the vendor's software (NeuroPCT, SyngoCT 2007S; Siemens Healthcare Sector, Forchheim, Germany). The arterial input function was determined in the anterior cerebral artery, in accordance with Wintermark et al.[12] Color-coded maps of regional CBF, CBV, and TTP were created from both 12-mm slices of the raw data sets. The 2 slices were scored for each perfusion parameter (CBF, CBV, and TTP) according to the modified ASPECTS method, assigning 1 of 10 possible points for each section of the MCA territory not affected by perfusion disturbance as compared with the contralateral hemisphere (ASPECTS-CBF, ASPECTS-CBV, and ASPECTS-TTP).[8,13] This was done by visual inspection and accounting for any change in perfusion disturbance in the ischemic hemisphere compared to the contralateral side using the perfusion maps without additional use of perfusion parameter thresholds. Three experienced raters (2 board-certified neuroradiologists and 1 experienced stroke neurologist) scored ASPECTS values for CBF, CBV, and TTP in a consensus manner.