Ischemic Volume and Neurological Deficit: Correlation of Computed Tomography Perfusion with the National Institutes of Health Stroke Scale Score in Acute Ischemic Stroke

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Background: The National Institutes of Health Stroke Scale (NIHSS) is the most adopted stroke patients' evaluation tool in emergency settings to assess the severity of stroke and to determine the patients' eligibility for specific treatments. Computed tomography perfusion (CTP) is crucial to identify salvageable tissue that can benefit from the reperfusion treatment. The aim of this study is to identify the relation between the NIHSS scores and the hypoperfused volumes evaluated by CTP in patients with hyperacute ischemic stroke. *Methods:* This retrospective study was conducted on 105 patients with ischemic stroke who underwent NIHSS assessment and CTP in the hyperacute phase. Hypoperfused volume was evaluated by CTP maps processed with semi-automatic algorithm. An analysis was conducted to determine the degree of correlation between the NIHSS scores and the ischemic lesion volumes and to investigate the relation between the anterior and the posterior circulation strokes, as well as between the right and the left hemispheric strokes. *Results:* A significant correlation was found between ischemic volume and NIHSS score at baseline ($r = .82$; $P < .0001$) in the entire cohort. A high NIHSS-volume correlation was identified in the anterior circulation stroke ($r = .76$; $P < .0001$); whereas, it was nonsignificant in the posterior circulation stroke. NIHSS score and volume correlated for the left and the right hemispheric strokes ($r = .83$ and $.81$; $P < .0001$), showing a slightly higher slope in the left. *Conclusion:* This study showed a strong correlation between the baseline NIHSS score and the ischemic volume estimated by CTP. We confirmed that NIHSS is a reliable predictor of perfusion deficits in acute ischemic stroke. CTP allows fast imaging assessment in the hyperacute phase. The results highlight the importance of these diagnostic tools in the assessment of stroke severity and in acute decision-making. **Key Words:** CTP—NIHSS—ischemic stroke—ischemic volume—neurological deficit.

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Ethical approval: This study has been approved by the local ethics committee and has been performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki and its later amendments. All participants released their informed consent.

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Introduction

Stroke is the third cause of death and a leading cause of disability in adults worldwide. Specific stroke scales are used to provide standardized evaluation of different signs and symptoms, which determine the extent of neurological deficit.[1,2] Over the years, a number of scales were proposed to evaluate stroke severity, monitor neurological status, and predict clinical outcome.[3-5] The National Institutes of Health Stroke Scale (NIHSS), consisting of 11 items to assess the main neurological functions, has become the most adopted tool in the actual medical practice.[6-8] Particularly, it is widely used in emergency settings to assess the severity of stroke, determine the patients' eligibility for specific treatments, such as thrombolysis and thrombectomy, and evaluate their consequences. NIHSS has proved to be a powerful predictor of clinical outcome.[9]

Moreover, in order to identify those patients who can most benefit from the recanalization treatment, assessing the extent of the salvageable tissue and the ischemic core as quickly and accurately as possible is crucial. Neuroimaging techniques like perfusion CT and MRI can define the extension of salvageable tissue, thus playing a central role in patient selection for both intravenous and intra-arterial treatments.[10,11] Computed tomography perfusion (CTP) is less time-consuming compared with MRI, and because of its short imaging time, it is more widely available and affordable. Also, CTP shows high sensitivity (80%) and specificity (95%).[12] Although CTP application in ischemic stroke has been widely researched, no studies have been conducted on the correlation between the clinical assessment and the hypoperfused area detected by CTP. Assessing the relation between the NIHSS score and the neuroimaging perfusion parameters in the hyperacute phase of stroke may be of greater importance for clinical decision-making.[7]

The aim of this study is to identify the relation between the NIHSS scores and the hypoperfusion volumes evaluated by CTP in patients with hyperacute ischemic stroke and to investigate the relation between the right and the left hemispheric strokes, anterior and posterior strokes, as well as between the small and the large vessel occlusions.

Methods

Patients and Clinical Management

This retrospective study was conducted on patients admitted to the Stroke Unit of the University Medical Hospital of Trieste (Italy) between March 2016 and December 2016. Patients with acute focal neurological symptoms compatible with ischemic stroke, who were performed a CTP evaluation on, were included (stroke developed within 4.5 hours, wake-up stroke, undetermined onset). The definition of stroke is based on the WHO MONICA criteria that is the rapidly developing signs of focal or global disturbance of cerebral function, lasting more than 24 hours or leading to death, with no apparent cause other than vascular origin.[13] Both genders were included in the study sample and no age limit was applied. To verify diagnosis of ischemic stroke, we included patients with a persistent focal neurological deficit after 24 hours and/or a positive computed tomography (CT) or magnetic resonance imaging (MRI) for ischemic lesion 24 hours after stroke onset. Visual inspection assessed whether CTP core infarction size was equal or smaller than the ischemic lesion detected by a CT scan performed after 24 hours.

Patients with previous stroke, history of epilepsy, migraine, brain neoplasm and previous brain surgery, seizure at stroke onset, internal carotid artery occlusion or T-occlusion, and aplasia of intracranial arteries were excluded, because they would compromise the CTP assessment.[14] Other exclusion criteria were inadequate CTPs owing to technical reasons, such as excessive motion artifacts, bolus suboptimal time, and insufficient postprocessing.

The following data of included patients were collected: (1) demographic information (age and gender); (2) stroke risk factors (hypertension, diabetes, dyslipidemia, smoking, ischemic cardiopathy, and atrial fibrillation); (3) time span between symptom onset and CTP; (4) NIHSS score at baseline; (5) localization of ischemic area (side, cerebral vascular territory, stroke syndrome categorized by the Oxfordshire Community Stroke Project Classification [OCSP])[15]; (6) stroke subtype classification at discharge classified by Trial of ORG 10172 in Acute Stroke Treatment[8]; (7) presence or absence of aphasia; (8) direct CT, CT angiography, and CTP; and (9) control of direct CT performed after 24 hours.

NIHSS evaluation was carried out at the time of presentation at the Stroke Unit by a vascular neurologist trained in performing NIHSS examination. The NIHSS test was performed within 15 minutes before CTP scanning.

CTP Acquisition, Postprocessing, and Analysis

CTP imaging was performed with one of the latest generation CT (Brilliance iCT 256 slices; Philips Medical Systems, Best, Netherlands). CTP acquisition protocol involves the intravenous injection of 75 mL of contrast medium, followed by a 40 mL saline bolus, both administered at an injection rate of 4 mL/s, and 3-dimensional axial acquisitions on a whole brain volume with a reconstruction of the slices set to 5 mm using a series of repeated movements of the scanner table. The acquisitions were carried out every 4 seconds, resulting in a total scanning time of 60 seconds. The exposure parameters used were 80 kVp and 150 mAs. Analytic methods used in this study is summarized in Figure 1. Analysis of the CTP images raw data were carried out on a separate console (brain perfusion software; Extended Brilliance Workstation v 3.0, Philips Medical Systems) and the perfusion maps mean transit time (MTT), cerebral blood