Perfusion-weighted Map and Perfused Blood Volume in Comparison with CT Angiography Source Imaging in Acute Ischemic Stroke:

Different Sides of the Same Coin?

Boris Buerke, MD, Gunnar Wittkamp, Cand Med, Rainer Dziewas, MD, Peter Seidensticker, MD, Walter Heindel, MD, Stephan P. Kloska, MD

Rationale and Objectives: Computed tomography angiography source imaging (CTA-SI) in acute ischemic stroke improves detection rate and estimation of extent of cerebral infarction. This study compared the new components color-coded perfusion weighted map (PWM) and color-coded perfused blood volume (PBV) derived from CTA data with CTA-SI for the visualization of cerebral infarction.

Materials and Methods: Fifty patients (women = 30; mean age = 74.9 ± 13.3 years) underwent nonenhanced computed tomography and CTA for suspected acute ischemic stroke. PWM, PBV, and CTA-SI were reconstructed with identical slice thickness of 1.0 mm with commercial software. Extent of infarction was measured using the Alberta Stroke Program Early Computed Tomography Score (ASPECTS). For statistical analysis, Spearman's R correlation and paired-samples *t*-test was used. $P < .05$ was considered significant.

Results: PBV had superior sensitivity for detection of cerebral infarction with 0.88 compared to PWM and CTA-SI with 0.79 and 0.76, respectively. The accuracy of correct diagnosis was superior for PBV with 0.82 compared to PWM and CTA-SI with 0.76, respectively. ASPECTS of PWM and PBV showed strong correlation with CTA-SI with r = 0.903 ($P < .001$) and $r = 0.866$ ($P < .001$), respectively. Mean ASPECTS of CTA-SI (6.24 ± 3.62) revealed no significant difference with PWM (6.26 ± 3.45), but a significant difference with PBV (5.62 ± 3.41; $P < .02$).

Conclusions: PWM was equal to CTA-SI in detection of cerebral infarction and estimation of extent of cerebral ischemia. Although PBV was superior to CTA-SI in detection of cerebral infarction, PBV seems to overestimate the extent of critical cerebral ischemia. Therefore, CTA-SI information is not identical to PBV and further clinical evaluation is mandatory.

Key Words: Computed tomography; source imaging; perfusion-weighted; cerebral infarction.

Stroke is one of the major diseases resulting in death or permanent disability worldwide. In Western countries, the age adjusted incidence rate is about 180 per 100,000 per year (1,2). Most strokes are caused by acute ischemia because of occlusion of a cerebral artery. Major efforts were made in the past to improve patient selection in thrombolysis therapy and to predict patient outcome (3,4). Sophisticated imaging strategies are considered the key technique to meet these demands. Both, computed tomography (CT) and magnetic resonance imaging (MRI), have been proven to be feasible for acute stroke imaging (5,6). CT is the most frequently used method due to its wide availability and nonenhanced CT (NECT) of the brain is the basis of any thrombolysis therapy. In addition to NECT, contrast-enhanced CT angiography (CTA) is

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* Boris Buerke and Gunnar Wittkamp contributed equally to this work.

From the Departments of Clinical Radiology (B.B., G.W., S.P.K.) and Neurology (R.D.), University of Münster, Albert-Schweitzer-Str. 33, 48149 Münster, Germany; Bayer Schering Pharma AG, BU Diagnostic Imaging, 13342 Berlin, Germany (P.S.); Department of Neuroradiology, University of Erlangen-Nürnberg, Schwabachanlage 6, 91054 Erlangen, Germany (S.P.K.). Received September 21, 2010; accepted October 23, 2010. P.S. is employee of Bayer Schering Pharma AG, Berlin, Germany. Study was supported in part by a grant from Bayer Schering Pharma AG, Berlin, Germany. The study design, collection, analysis, and interpretation of the data, as well as the writing of the report were exclusive responsibilities of the authors. In particular, the sponsoring company (Bayer Schering Pharma AG, Berlin, Germany) had neither influence on the preparation of this report nor the decision to submit it for publication. The corresponding author had full access to the data of this study at any time and is finally responsible for the decision to submit for publication. **Address correspondence to:** S.P.K. e-mail: kloska@uni-muenster.de

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frequently used in acute stroke imaging to visualize the cerebral vasculature (7). However, CTA data also include hemodynamic information (8). The so named CTA source imaging (CTA-SI) has proven better visualization of the infarcted brain tissue (8–11) as well as improved prediction of patient outcome in acute ischemic stroke in several studies (12–14).

Commercial software now allows the fast and standardized postprocessing of CTA data with calculation of color-coded perfusion weighted map (PWM) images and color-coded perfused blood volume (PBV) images (15–17) to extract hemodynamic information of the whole brain. PWM is the color-coded visualization of the CTA-SI, whereas PBV is based on the subtraction of NECT and CTA data sets and visualizes the cerebral blood volume with a defined color-coded map. Both methods are considered to visualize mainly the irreversible infarcted brain tissue.

This study aims to evaluate if the imaging information of PWM and PBV is identical to CTA-SI and hence the proven clinical application of CTA-SI can be transferred to these new CT components. Therefore, we 1) evaluated CTA-SI, PWM, and PBV images for the detection of cerebral infarction and 2) compared PWM and PBV with CTA-SI for the estimated size of ischemic brain tissue in patients with acute ischemic stroke based on the Alberta Stroke Program Early CT Score (ASPECTS) (18). The study hypothesis was that PWM and PBV estimate the extent of irreversibly infarcted brain tissue similar to CTA-SI.

MATERIALS AND METHODS

Study Population

The CT data of 50 consecutive patients with suspected acute ischemic stroke of the anterior circulation were analyzed. Multimodal CT consisting of NECT and CTA was performed according to hospital guidelines in all patients with onset of stroke symptoms of ≤12 hours at the time of admission.

In all patients, treatment was performed according to current guidelines (3,19). Informed consent was obtained from the patients or the next of kin according to legal requirements. The study was approved from the institutional ethics commission.

Imaging Protocol

All CT examinations were performed on a dual-source 64-row multidetector CT scanner (Somatom Definition, Siemens Medical Solutions, Forchheim, Germany). All contrast injections were performed through an 18-gauge cannula (Insyte-W; BD Biosciences, Madrid, Spain) placed in a cubital vein with a double piston injector (Stellant CT injection system, Medrad Europe, Beek, The Netherlands) using iopromide with 370 mg iodine per mL (Ultravist 370, Bayer Schering Pharma, Berlin, Germany).

First, a NECT (detector collimation, 20 × 0.6 mm; tube voltage, 120 kVp; tube current, 480 mAs; table feed, 30.7 mm/rotation; rotation time, 1 second; field of view, 200 mm; reconstructed slice thickness, 1.0 mm; kernel, H23s) of the brain was performed. The following CTA (detector collimation, 2 × 32 × 0.6 mm (z-flying spot); tube voltage, 120 kVp; tube current, 175 mAs; table feed, 30.7 mm/rotation; rotation time, 0.5 seconds; field of view, 200 mm; reconstructed slice thickness, 1.0 mm; kernel, H22f; contrast agent, 80 mL; saline flush, 50 mL; flow rate, 4 mL/sec; test bolus triggered delay with peak enhancement in the superior sagittal sinus) covered a scan range extending from the level of the aortic arch to the vertex.

Postprocessing

All reconstructions were performed on a CT workstation (Syngo MMWP, Version VE30A, Siemens Medical Solutions).

From the CTA data, CTA-SI was reconstructed with a slice thickness of 1.0 mm similar to previous reports (9,20).

PWM images with a slice thickness of 1.0 mm were reconstructed using standard software (NeuroPWM, Siemens Medical Solutions). This fully automated algorithm converts the information of the CTA images similar to the principle of CTA-SI but uses a color scale to display different density values of the brain parenchyma. Hence, higher perfused tissue is addressed to yellow to red color, whereas lower perfused tissue is displayed with green to blue color.

The algorithm of the used software for the calculation of PBV images (NeuroPBV, Siemens Medical Solutions) (16) is based on the work of Hamberg et al and described elsewhere (21). The full-automated software registers the volume dataset of the NECT and CTA data set. The software coregisters the head position and performs three-dimensional corrections to the data sets for identical head position if head movement occurred between the two CT scans. By subtraction of the NECT data from the CTA data, the enhancement of the brain parenchyma is yielded. Then, a distinct color scale is addressed to the absolute parenchymal enhancement on a voxel-by-voxel basis. For the comparative assessment, identical slices compared to CTA-SI and PWM were reconstructed with a slice thickness of 1.0 mm.

A comparative example for CTA-SI, PWM, and PBV is shown in Figure 1.

Image Analysis

All images were reviewed by two readers in consensus in blinded order and separately for CTA-SI, PWM, and PBV on a CT workstation (MMWP, Siemens Medical Solutions). The readers were aware of the suspected diagnosis of ischemic stroke of the anterior circulation, however without information of clinical symptoms. CTA-SI served as the reference method to determine cerebral ischemia. First, the different CT components were visually evaluated for the presence of cerebral ischemia. Second, the extent of cerebral ischemia was measured according to the ASPECTS (18) for all