Correlation between angiographic transit times and neurological status on admission in patients with aneurysmal subarachnoid hemorrhage

Alexander Ivanov, MD; Andreas Linninger, PhD; Chih-Yang Hsu, BS; Sepideh Amin-Hanjani, MD; Victor A. Aletich, MD; Fady T. Charbel, MD; and Ali Alaraj, MD

Departments of Neurosurgery and Bioengineering, University of Illinois at Chicago, Illinois

OBJECT The use of digital subtraction angiography (DSA) for semiquantitative cerebral blood flow (CBF) assessment is a new technique. The aim of this study was to determine whether patients with aneurysmal subarachnoid hemorrhage (aSAH) with higher Hunt and Hess grades also had higher angiographic contrast transit times (TTs) than patients with lower grades.

METHODS A cohort of 30 patients with aSAH and 10 patients without aSAH was included. Relevant clinical information was collected. A method to measure DSA TTs by color-coding reconstructions from DSA contrast-intensity images was applied. Regions of interest (ROIs) were chosen over major cerebral vessels. The estimated TTs included time-to-peak from 0% to 100% (TTP0–100), TTP from 25% to 100% (TTP25–100), and TT from 100% to 10% (TT100–10) contrast intensities. Statistical analysis was used to compare TTs between Group A (Hunt and Hess Grade I–II), Group B (Hunt and Hess Grade III–IV), and the control group. The correlation coefficient was calculated between different ROIs in aSAH groups.

RESULTS There was no difference in demographic factors between Group A (n = 10), Group B (n = 20), and the control group (n = 10). There was a strong correlation in all TTs between ROIs in the middle cerebral artery (M 1, M 2) and anterior cerebral artery (A 1, A 2). There was a statistically significant difference between Groups A and B in all TT parameters for ROIs. TT100–10 values in the control group were significantly lower than the values in Group B.

CONCLUSIONS The DSA TTs showed significant correlation with Hunt and Hess grades. TT delays appear to be independent of increased intracranial pressure and may be an indicator of decreased CBF in patients with a higher Hunt and Hess grade. This method may serve as an indirect technique to assess relative CBF in the angiography suite.

http://thejns.org/doi/abs/10.3171/2015.4.JNS15134

KEY WORDS digital subtraction angiography; transit times; subarachnoid hemorrhage; Hunt and Hess; neurological outcome; vascular disorders

Aneurysmal subarachnoid hemorrhage (aSAH) remains a devastating disease with significant morbidity and mortality.1-3,21-23 The morbidity of aSAH depends on multiple factors that affect the postictal cerebral metabolism status,16 with alteration in cerebral perfusion, intracranial pressure (ICP), and cerebral blood flow (CBF).6,11,22,26 There are several techniques for noninvasive assessment of CBF including CT angiography11,19 and quantitative MR angiography.1-3,9,13,33,35 New computational methods have been developed to evaluate cortical transit times (TTs).15,28 However, not all of these methods are available in the angiography suite, and they often require additional radiation or contrast exposure. There are no prior studies that attempted to correlate the angiographic contrast TTs with the neurological exams of patients with aSAH.

In our current study, we sought to apply a computational method based on digital subtraction angiography (DSA) analysis to evaluate the relative CBF in patients with aSAH. This method does not require additional ra-
diation or contrast exposure and may be applied during angiography in real-time. This technique is based on the analysis of DSA contrast TTs in multiple regions of interest (ROIs), corresponding to the major components of the anterior intracranial circulation. We report the correlation of DSA contrast TTs in patients with aSAH in relation to the clinical presentation graded by the Hunt and Hess classification.20

Methods

Patient Data

Institutional review board approval was obtained prior to the initiation of the study. This is a retrospective study on prospectively collected data at a tertiary center. A cohort of 30 patients with aSAH and 10 recent consecutive patients without aSAH (control group) was included in the study period from November 2011–May 2013. The patients with aSAH were also part of a study that evaluated vasospasm treatment as they developed clinical vasospasm following hospital admission. Demographic variables, neurologic status (Hunt and Hess grade) on admission, and medical comorbidities data were collected. To increase the prognostic power of our scale, patients with Hunt and Hess Grades I–II were defined as having mild aSAH (Group A), and patients with Hunt and Hess Grades III–V were considered to have severe aSAH (Group B).31,37 Outcomes were assessed at 6 months using the Glasgow Outcome Scale (GOS) and the modified Rankin Scale (mRS). Patients who underwent DSA within 24 hours of aneurysm rupture were included in this assessment. Patients who underwent angiography more than 24 hours after aneurysm rupture, patients with non-aSAH (traumatic, angiogram negative), and those with angiographic vasospasm on presentation or associated with large hematomas were excluded from the study. Patients with hydrocephalus on admission or those with Hunt and Hess Grades III–V typically had an external ventricular drain (EVD) catheter inserted on admission prior to DSA. Only 3 patients in the cohort, all with Hunt and Hess Grade III, did not have EVDs inserted. All EVDs were opened to drain at 10 mm Hg during angiography as part of our routine practices.

Image Acquisition

All angiography was performed using the standard transfemoral approach. A 5F diagnostic catheter (Angiodynamics) was inserted into the internal cerebral arteries, and 12 ml of the iodine-based contrast agent iohexol (300 mg/ml) (Omnipaque, GE Healthcare) was injected into the internal carotid artery (ICA) over 2 seconds by a power contrast injector (Medrad, Bayer HealthCare). The power contrast injector was synchronized to a fluoroscopy angiographic machine with a 1.2-second delay in the contrast injection. A biplane neuroangiography suite (Artis ze, Siemens Medical Solutions) was used to capture DSA images at a rate of 4 frames/sec in standard anterior-posterior, lateral, and oblique transorbital projections. Digitally subtracted images were saved to the Picture Archiving and Communicating System. In addition, the entire unedited angiogram was archived on a separate DVD in Digital Imaging and Communications in Medicine (DICOM) format.

Estimation of TTs

To interpret relative blood flow within ROIs in the intracranial circulation, we developed a custom MATLAB-based software code (MathWorks). Representative consecutive DICOM images from DSA runs were loaded to a separate personal computer and analyzed for time-intensity using this novel method. The MATLAB-based software analyzed the image intensity throughout the entire angiogram and identifies various intensity plots including the maximum gray intensity in consecutive DICOM images. Various ROIs were selected throughout the major cerebral vessels: ICA, segments of anterior cerebral artery (A1 and A2), segments of the middle cerebral artery (M1 and M2). The ROI includes 3 to 4 pixels, and the average TT over individual ROIs was calculated. The time-intensity plots were analyzed at the selected ROI with regard to the image intensity over the angiography run-time. The time-intensity plot was divided into 3 components, and estimated TTs were defined as follows (Fig. 1): TTP 0%–100% (TTP 0–100) was defined as the time needed for the contrast density profile to reach maximum level (time to peak; TTP) from the time of the injection; TTP 25%–100% (TTP 25–100) was defined as the time needed for the contrast density profile to reach maximum (100%) from 25% of the maximum density, and TTP 100–100 was the time needed for the contrast density to reach 10% from its maximum value (100%) (Fig. 1). These 3 different TTs represent TTs during the early portion of the contrast passage in the intracranial circulation (TTP 0–100 and TTP 25–100) as well as the late phase of the contrast curve (TTP 100–100) as it transverses the intracranial circulation. Only data from the anterior circulation TTs (right and left hemispheres) were collected; no posterior circulation data were collected so as to avoid heterogeneity of the data in this manuscript (Fig. 2).

Statistical Analysis

Demographic variables were compared between Group A (Hunt and Hess Grade I–II), Group B (Hunt and Hess Grade III–V), and the control group. Patients with an altered level of consciousness (Hunt and Hess Grade III–V) were grouped together in an attempt to determine whether delayed TTs represent a common finding related to the neurological examination in DSA analysis. The