Prognostic Assessment of Aneurysmal Subarachnoid Patients with WFNS Grade V by CT Perfusion on Arrival

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■ BACKGROUND: **The prognosis of patients with aneurysmal subarachnoid hemorrhage (aSAH) depends on their condition on arrival at the hospital. However, a small number of patients recover from an initially poor condition. We investigated the correlation between quantitative measures of computed tomography (CT) perfusion (CTP) on arrival and the outcomes of patients with World Federation of Neurosurgical Society (WFNS) grade V aSAH.**

■ METHODS: **We performed plain CT, CTP, and CT angiography (CTA) in all patients with aSAH on arrival. Aneurysms were surgically obliterated in patients with stable vital signs and the presence of a brain stem response. We measured the average mean transit time (aMTT) and compared it with the modified Rankin Scale (mRS) score at 1 month. Regions of interest were identified as 24 areas in the bilateral anterior, middle, and posterior cerebral artery territories and 2 areas in the basal ganglia.**

■ RESULTS: **A total of 57 patients were treated between 2007 and 2014. None of the 21 patients with aMTT >6.385 seconds achieved a favorable outcome, whereas 8 of the 36 patients with aMTT <6.385 seconds did achieve a favorable outcome ($P = 0.015$). Furthermore, comparing the number of areas showing a mean transit time (MTT) >7.0 seconds among the aforementioned 8 areas and mRS, favorable outcomes were not seen in 24 patients with more than 2 such areas ($P = 0.009$).**

■ CONCLUSION: **We cannot expect a favorable outcome for patients with WFNS grade V aSAH with aMTT >6.385 seconds or more than 2 of 8 areas with MTT >7.0 seconds.**

INTRODUCTION

Currently, the World Federation of Neurosurgical Society (WFNS) grading system is widely used throughout the world to evaluate the severity of aneurysmal subarachnoid hemorrhage (aSAH). This grading scheme is based on the Glasgow Coma Scale,[1] and the prognosis of patients classified with grade V is poor. It is also known that a small number of WFNS grade V patients are able to achieve a favorable outcome,[2-5] but the reason why these severe-status patients are able to achieve such favorable outcomes is not clear.

Since the 1970s, various imaging techniques have become available to assess cerebral perfusion. Magnetic resonance imaging and computed tomography (CT) perfusion (CTP) are powerful,

Key words
- CT perfusion
- Prognosis
- Subarachnoid hemorrhage

Abbreviations and Acronyms
ACA: anterior cerebral artery
aMTT: average mean transit time
aSAH: aneurysmal subarachnoid hemorrhage
CBF: cerebral blood flow
CBV: cerebral blood volume
CT: computed tomography
CTA: computed tomography angiography
CTP: computed tomography perfusion
DWI: diffusion-weighted image
ICH: intracerebral hematoma
ICP: intracranial pressure
IVH: intraventricular hematoma
MCA: middle cerebral artery
mRS: modified Rankin Scale
MTT: mean transit time
PCA: posterior cerebral artery
ROI: region of interest
SD: standard deviation
WFNS: World Federation of Neurosurgical Society

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widely used tools for investigating a patient's cerebral perfusion state in the emergency room. CTP is a relatively new technique that allows rapid qualitative and quantitative evaluation of cerebral perfusion by generating maps of cerebral blood flow (CBF), cerebral blood volume (CBV), and mean transit time (MTT).[6] CTP is currently applied in not only for cerebrovascular disease, but also for traumatic brain injuries or brain tumors.[7-10] Perfusion imaging techniques, including positron emission tomography, magnetic resonance perfusion, single-photon emission computed tomography, and xenon-CT, are not widely available, require patient cooperation, involve long scanning times, and require much manpower. These techniques are not suitable for evaluation of the perfusion state of patients with acute-stage aSAH, especially those with poor status. CTP requires only 1 minute for scanning, and can facilitate qualitative and quantitative analyses.[11] For such qualitative and quantitative analyses, after brief training, there is no difference among observers, and objective analysis is possible.[12]

We retrospectively investigated the correlation between the quantitative measures in initial CTP and outcomes in patients with WFNS grade V aSAH, and here suggest guidelines for to prognostic assessment of these patients.

METHODS

Study Design

In our institution, all patients with aSAH routinely undergo plain CT, CTP, and CT angiography (CTA) on arrival to evaluate the state of cerebral perfusion and the location, shape, and size of the aneurysm. The study was approved by our institution's Ethical Committee (no. 2813). If vital signs are stable, brainstem response is preserved, and no severe systemic complications are seen, we treat the aneurysm. The patients were classified by WFNS grade on arrival. Among the 166 patients with aSAH treated between April 2007 and March 2014, 70 were classified with WFNS grade V, 57 of whom were treated for an aneurysm. We investigated these 57 patients to examine the correlation between CTP findings and outcomes. The volume of subarachnoid blood was classified based on modified Fisher group criteria.[13] Patient outcomes were evaluated at 1 month from onset with the modified Rankin Scale (mRS). The definitions of favorable outcome and poor outcome vary among studies, and here we investigated only grade V patients; therefore, we defined favorable outcome as mRS 0–3 and poor outcome as mRS 4–6. We selected patients with small (<5 mm) unruptured aneurysms in a random manner and measured CTP parameters in the same way.

CTP Protocol, Postprocessing, and Data Collection

We used 64-row detector CT scanners (LightSpeed VCT XT and Discovery CT750 HD; GE Healthcare, Milwaukee, WI, USA) and the toggling-table CT technique (VolumeShuttle; GE Healthcare) to extend scan coverage to 80 mm in the z-axis for a perfusion scan with scanning parameters of 80 kVp, 180 mA, 0.4 second/rotation, and a 2.8-second interval. We intravenously administered 40 mL of iodine contrast medium (Iopamiron 370; Byer Schering Pharma, Berlin, Germany), followed by a 20-mL saline push. To reduce image noise artifacts and to achieve a low-volume CT dose index of 85 mGy during the multiphase CTP scanning, we used an adapted statistical iterative reconstruction algorithm (ASiR; GE Healthcare) for perfusion source images.

Postprocessing of the acquired images into CBF, CBV, and MTT maps was performed on an Advantage Workstation using CTP software, version 3.0 (GE Healthcare). This software uses a deconvolution method, which is considered the most accurate for low-contrast injection rates. The postprocessing technique was standardized for all patients according to recommended guidelines, with the arterial input function as the A2 segment of the anterior cerebral artery (ACA) and venous function as the superior sagittal sinus. From the acquired CTP imaging, we determined 26 regions of interest (ROIs) as follows: 6 areas in the bilateral ACA territory, 12 areas in bilateral middle cerebral artery (MCA) territory, 6 areas in the bilateral posterior cerebral artery (PCA) territory, and 2 areas in the bilateral basal ganglia. Each round ROI was 157 mm^2, and CBF, CBV, and MTT were measured in each (**Figure 1**). We chose this slice because it contains areas perfused by all major vessels and perforators. Averages of all measured ROI values were taken as the individual measured values. Quantitative analysis was conducted using a standardized method with contiguous ROI placement when sampling the cerebral cortex.

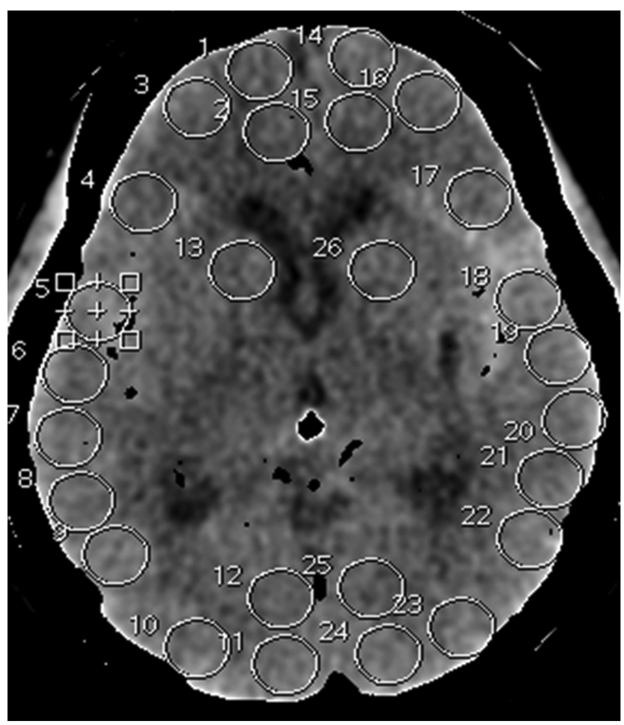

Figure 1. ROIs (157 mm^2): 6 areas in the ACA, 12 in the MCA, and 6 in the PCA territories, and 2 in the basal ganglia.