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ORIGINAL ARTICLE

ASPECTS is a predictor of favorable CT perfusion in acute ischemic stroke

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Summary
Background and purpose: Computed tomography perfusion (CTP) is used by some stroke centers to stratify stroke patients who may potentially benefit from endovascular treatment. Our aim is to identify predictors of a favorable CTP in acute ischemic stroke patients evaluated within 8 h from symptoms onset for possible endovascular treatment.
Materials and methods: We reviewed records of patients who had CTP studies between August 2010 and September 2012. We included all patients with anterior circulation strokes with evidence of large vessel disease. All patients had CT head and CT angiography head and neck as part of our protocol. Favorable CTP was defined as core infarct size less than one third the middle cerebral artery distribution and penumbra > 20% of infarct size. The patients were divided into two groups based on favorable CTP or not. Baseline characteristics, time parameters, laboratory data and radiological data were compared between both groups. For statistical analysis, we used independent and Fisher's exact tests and a multivariate logistic regression model.
Results: During this period, 60 patients met the inclusion criteria. Patients with favorable CTP were likely to be $\geq$ 80 years (33% vs 9%, $P = 0.026$), have Alberta Stroke Program early CT score (ASPECTS) > 7 (81% v. 21%, $P \leq 0.001$) and lower mean time from symptom onset to CTP (234 ± 91 vs 305 ± 122, $P = 0.015$). On regression analysis, ASPECTS was the only independent predictor of a favorable CTP (OR = 16.2, CI: 4.3—62.2, $P < 0.001$).
Conclusion: ASPECT score may be used as a tool to predict a favorable CTP. Larger studies are needed to confirm our findings.

Introduction

Computed tomography perfusion (CTP) in addition to non-contrast CT and CT angiogram (CTA) has been used as an emergency tool in the initial evaluation of acute ischemic stroke patients who are potential candidates for revascularization therapy. Studies have shown that CTP accurately

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predicts ischemic penumbra volume and infarct size correlating with diffusion MRI [1—3]. Although CTP is widely available, it may have some technical pitfalls [4]. In addition, patients with diabetes mellitus and renal disease are at risk of developing contrast-induced nephropathy from intravenous contrast; therefore, weighing the risks and benefits of performing a CTP in these patients is needed. Thus, identifying predictors of a favorable CTP, which may help guide further acute stroke treatment when CTP could not performed or has some technical difficulties, is necessary.

To our knowledge, only one study attempted to identify predictors of a favorable CTP and showed that no clinical or radiological factors were associated with a favorable CTP, but favorable CTP was associated with good outcome [5]. The aim of our study is to identify predictors of favorable CTP.

Methods and methods

Study population and clinical data collection

IRB approval was obtained to retrospectively review the records of all patients with acute ischemic stroke who underwent CTP to select candidates for further neuro-interventional treatment between August 2010 and September 2012. All patients with anterior circulation strokes and evidence of large vessel occlusion were included. In addition to CTP, all patients had non-contrast brain CT and CTA as part of our protocol. At our institution, CT at 24 h was the imaging of choice on most occasions. This may be deferred based on the clinical status and goals of care.

The demographic data (age and gender), clinical information (hypertension, diabetes, hypercholesterolemia, congestive heart failure, coronary artery disease, atrial fibrillation, prior intravenous thrombolytic therapy, time to thrombolysis, time to CTP, admission systolic blood pressure, and admission NIHSS), laboratory data (blood glucose), and radiological data (ASPECTS and location of occlusion on CTA) were recorded. The ASPECTS was calculated on the non-contrast admission CT by a neurologist who was blinded to the CTP result. Favorable ASPECTS was defined as ASPECTS > 7. Favorable CTP was defined as core infarct size less than one third the middle cerebral artery (MCA) distribution and penumbra > 20% of infarct size as defined in the literature [6]. Patients were divided into two groups based on whether they had a favorable CTP or not. Baseline characteristics, risk factors, admission blood pressure and NIHSS, time parameters, laboratory data, and radiological data were compared between the two groups.

Imaging protocol

At our institution, the imaging protocols for all patients included a non-contrast CT scan, CTP and CTA of the head and neck to include the origins of the great vessels. Perfusion scans were obtained on a Philips Brilliance CT 64-detector scanner (Philips Healthcare, Andover, MA, USA). Protocol parameters were 80 kV; 150 mAs, 50 mL of non-ionic contrast agent with a flow rate of 5 mL/s; and a delay of 5 s. The gantry angle was parallel and superior to the orbital roof. Eight 10 mm slabs were acquired at the suitable locations in the brain determined by the radiologist in charge. The scanning parameters resulted in a temporal sampling resolution of 1.3 s. We used the toggling table technique (''jog-mode'') in order to analyze perfusion of the entire supratentorial brain. Motion artefacts were corrected by registering the images prior to selecting the arterial and venous input functions. The anterior cerebral artery or when clearly defined, the contralateral MCA were selected as the input artery. A large venous structure, such as the torcular herophili was chosen as the input vein.

CTP data were analyzed using the CTP package in the Extended Brilliance Workspace Workstation (Philips Healthcare, Cleveland, OH, USA). The mean transit time (MTT) maps were calculated by closed-form (non-iterative) deconvolution technique using the arterial reference. The cerebral blood volume (CBV) values were calculated as the area under the time attenuation curves. Finally, the cerebral blood flow (CBF) values were obtained from the CBV and MTT values using the simple formula CBF = CBV/MTT.

Statistical analysis

For statistical analysis, we used the Statistical Package for the Social Sciences software Version 18.0 (SPSS, Chicago, IL, USA). We used independent *t*-test and Fisher's exact tests and multivariate logistic regression model. *P* value of < 0.05 was considered statistically significant.

Results

We identified 75 patients with acute ischemic strokes who were evaluated for neuro-interventional treatment using our standard protocol. Of these, 60 patients met the above mentioned inclusion criteria and only these 60 patients were included in our analysis. The rest 15 patients lacked evidence of large artery occlusion and normal perfusion studies and hence were excluded. Of these 60 patients, 18 received intravenous tissue plasminogen activator (tPA), 7 received intravenous (tPA) and thrombectomy, 4 underwent thrombectomy alone, 2 received both intravenous and intrarterial tPA and 1 received intrarterial tPA alone. Of these 60 patients, 17 had hypodensity affecting more than two thirds a middle cerebral artery stroke and 19 had hypodensity affecting less than one third of middle cerebral artery territory on follow up CT at 24 h. The extent of hypodense lesions correlated with the admission ASPECT in all these patients.

On univariate analysis, patients with favorable CTP were more likely to be elderly $\geq$ 80 years (33% vs 9%, $P = 0.026$), have ASPECTS score > 7 (81% vs 21%, $P \leq 0.001$) and lower mean time from symptom onset to CTP (234 ± 91 vs 305 ± 122, $P = 0.015$). Other factors that were not statistically significant are listed in Table 1. On multivariate regression, ASPECTS was the only independent predictor of a favorable CTP (OR = 16.2, CI: 4.3—62.2, $P < 0.001$) (Table 2).

Discussion

CTP is an important neuroimaging tool in patients with acute ischemic stroke, providing data about the infarct size