ORIGINAL

Sensitivity of CT perfusion for the diagnosis of cerebral infarction

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Abstract : We aimed to determine the sensitivity of CT perfusion (CTP) for the diagnosis of cerebral infarction in the acute stage. We retrospectively reviewed patients with ischemic stroke who underwent brain CTP on arrival and MRI-diffusion weighted image (DWI) after hospitalization between October 2008 and October 2011. Final diagnosis was made from MRI-DWI findings and 87 patients were identified. Fifty-five out of 87 patients (63%) could be diagnosed with cerebral infarction by initial CTP. The sensitivity depends on the area size (s) : 29% for $S < 3$ cm^2, 83% for $S \geq 3$ cm^2-< 6 cm^2, 88% for $S \geq 6$ cm^2-< 9 cm^2, 80% for $S \geq 9$ cm^2-< 12 cm^2, and 96% for $S \geq 12$ cm^2 ($p < 0.001$). Sensitivity depends on the type of infarction : 0% for lacunar, 74% for atherothrombotic, and 92% for cardioembolism ($p < 0.001$). Sensitivity is not correlated with hours after onset. CT perfusion is an effective imaging modality for the diagnosis and treatment decisions for acute stroke, particularly more serious strokes. J. Med. Invest. 61 : 41-45, February, 2014

Keywords **:** *cerebral infarction, perfusion, CT, MRI, stroke*

INTRODUCTION

In the diagnosis of acute stroke, any method that enhances the accuracy, reliability, and speed is important for the effective use of a time-critical drug, recombinant tissue plasminogen activator (rt-PA). The most widely used radiological modality in the evaluation of stroke in the acute stage is non-enhanced CT. Plain CT is very useful for excluding hemorrhage, but is not sensitive for recognizing early signs of ischemia. Diffusion-weighted images (DWI) on MRI are currently considered the most reliable for the diagnosis of stroke, although limited availability and a longer scan time limit their utility as a primary diagnostic tool for stroke (1, 2). CT has been long researched as a modality to evaluate blood flow and ischemic changes in the brain : Kety-Schmidt method (3), Xe-CT (4), positron emission tomography (PET), single photon emission CT (SPECT) and CT perfusion (CTP) (5-7). Among them, CTP has been increasingly applied in the diagnosis of acute stroke in clinical practice. The aim of this study was to determine the diagnostic sensitivity of CTP imaging in cerebral infarction in the acute phase.

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MATERIALS AND METHODS

Patients and ethics

We routinely use CTP and CT angiography (CTA) to initially diagnose acute ischemic stroke on arrival, final diagnosis is made using MRI-DWI after hospitalization. We retrospectively reviewed patients with ischemic stroke who underwent a brain CTP on arrival and MRI-DWI after hospitalization between October 2008 and October 2011. We chose patients who were classified as subtypes 1, 2, and 3 according to the Trial of Org 10172 in Acute Stroke Treatment (TOAST) criteria (8). A total of 225 patients with ischemic stroke were treated in this period, and 87 were identified on the basis of our protocol. We recorded the age, sex, neurological status, time elapsed from the onset of symptoms until examination, responsible vessel, findings of CTP and MRI, and outcome at discharge. The infarction area size was measured by MRI-DWI using the INFINITT PACS 2D tool (INFINITT Healthcare, Seoul, Guro-dong, Korea). Our institutional ethics committee exempted this retrospective study from documented patient consent because patient identifiers were removed, and the study was conducted in accordance with the Declaration of Helsinki.

Imaging protocols

Our routine protocol for stroke includes a plain head CT, a CTP scan to evaluate perfusion disturbance and helical CTA (Figure). We used a 64-row detector CT scanner (LightSpeed VCT XT ; GE Healthcare, Milwaukee, WI, USA) and the toggling-table CT technique to extend scan coverage to 80 mmin the z-axis for a perfusion scan with scanning parameters of 80 kVp, 180 mA, and 0.4 s/rotation (9). We intravenously administered 40 mL iodine contrast medium (iopamidol, 370 mg iodine/mL) followed by a 20-mL saline push. Five seconds after injection, we performed 18 intermittent axial scans at 2.8-second intervals in each table position.

CTP data were analyzed using the CTP software developed by GE Healthcare. After defining arterial input and venous output reference points, CTP maps of mean transit time (MTT), cerebral blood volume (CBV), and CBF were obtained using deconvolution model (10).

The perfusion maps were visually evaluated by two neurosurgeons, blinded to clinical and imaging data, to determine the presence of perfusion deficits, defined as areas of decreased CBF and/or elevated MTT (11). We aimed to evaluate the sensitivity and usefulness of CTP during emergency diagnosis, and therefore, visual evaluation of the images was adopted without using any special quantification software. After the images were reviewed independently, a consensus was reached. JMP Version 7 (SAS Institute Inc., Cary, NC, USA) was used to perform the statistical analyses. Sample distribution was analyzed using the chi-square test and correlation of samples with the analysis of variance.

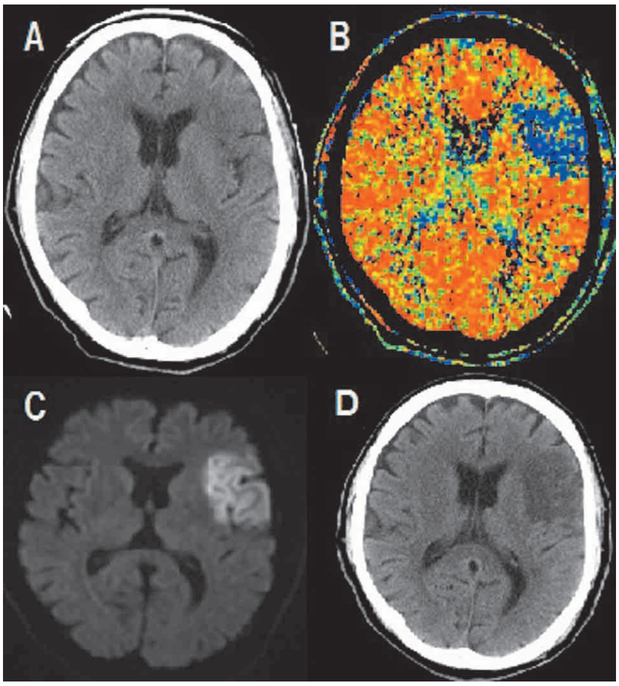

Figure Plain CT of a 65-year-old patient on arrival shows early CT signs in the inferior frontal gyrus (A). CT perfusion-mean transit time following plain CT shows a low perfused area (B). The final diagnosis was made from an MRI-diffusion-weighted image (C). Plain CT was performed 4 days after hospitalization (D).

RESULTS

Fifty-five out of 87 patients (63%) were diagnosed with cerebral infarction by CTP on arrival. CTP had higher sensitivity when the size of infarction was over 3 cm^2 ($p<0.001$). Sensitivity also depends on the type of infarction : 0% for lacunar infarction, 74% for atherothrombotic infarction, and 92% for cardioembolism ($p<0.001$). There were no statistically significant differences in sensitivity among sex, age, and time from onset to CTP scanning. Responsible vessels were also evaluated. However, since the numerical deviation was very strong, it was not suitable to compare sensitivity of CT perfusion (Table). Five patients were treated with rt-PA.

Table Factors and sensitivity of CT perfusion (CTP) in patients with cerebral infarction

Factors	Total	Positive on CTP	Sensitivity (%)
Sex			
female	27	19	70
male	60	36	60
			(P> 0.05)
Age			
< 60	7	3	43
60-69	28	16	57
70-79	32	21	66
> 80	15	11	75
			(P> 0.05)
Time from onset to CTP			
< 1 h	0	0	
≥ 1 h - < 3 h	19	15	79
≥ 3 h - < 6 h	13	8	62
≥ 6 h - < 24 h	13	8	62
≥ 24 h	18	8	44
unknown	24	16	67
			(P> 0.05)
Size of infarction on DWI			
< 3 cm^2	38	11	29
≥ 3 cm^2 - < 6 cm^2	6	5	83
≥ 6 cm^2 - < 9 cm^2	8	7	88
≥ 9 cm^2 - < 12 cm^2	10	8	80
12 cm^2≤	25	24	96
			(P< 0.001)
Type of infarction			
lacunar	19	0	0
atherothrombotic	42	31	74
embolism	26	24	92
			(P< 0.001)
Responsible vessels			
IC	0	0	
perforator of anterior circulation	15	0	0
perforator of posterior circulation	4	0	0
ACA	2	2	100
MCA	56	46	82
PCA	4	4	100
BA	5	2	40
VA	1	1	100
Total	87	55	63

IC=internal carotid artery. ACA=anterior cerebral artery. MCA =middle cerebral artery. PCA=posterior cerebral artery. BA =basilar artery. VA=vertebral artery.

DISCUSSION

Sixty-three percent of acute stroke patients were diagnosed accurately by CTP on arrival. CTP had higher sensitivity when the size of infarction was over 3 cm^2 ($p< 0.001$). CTP was not correlated with hours after onset. Chalela *et al.* compared modalities for the diagnostic imaging of acute ischemic stroke and investigated the sensitivity of MRI-DWI (12). They reported that the diagnostic sensitivity of MRI was 73% within 3 hours after onset, which is lower than our results (79%).

False-negative DWI may occur when the duration between onset and scan is insufficient for the development of cytotoxic edema for the degree of hypoperfusion (13, 14). The phenomenon of diffusion-perfusion mismatches is well recognized for regions of hypoperfusion extending beyond the zone of hyperintensity on DWI, which have been proposed to represent an MR imaging equivalent of an ischemic penumbra. Thus, hypoperfusion without restricted diffusion may produce symptoms and therefore be indicated for thrombolytic therapy ; however, infarction may be limited to the zone demarcated by DWI (15).

According to the type of infarction, the sensitivity of lacunar infarction was 0%, which results from the precision of the voxels of CTP. This problem may be solved by the evolution of CT apparatus and its software in the future. Patients with lacunar infarction tend to consult our stroke center several hours or days after onset because of their mild symptoms. This is reflected in the relationship between sensitivity and time from onset to CTP in our series (Table). Sensitivity over 24 hours after onset was lowest, since patients with lacunar infarction and mild symptoms were included in this group.

Our protocol has two major disadvantages : risk of renal damage from iodinated contrast material and radiation exposure. According to the ACR Manual on Contrast Media Version 7 (16), a CT protocol is allowed without prior ascertainment of serum creatinine. Cigarroa *et al.* reported the maximum permissible dose of contrast media to be given in case of renal dysfunction : K (ml) = body weight (kg) × 5/serum creatinine (mg/dl). The maximum amount of K is 300 (17). Based on these criteria, the 40 ml iodine contrast media used for our CTP protocol has little risk of clinical renal function. No subject presented with renal disorder in our 87 patients.

The radiation dose is doubled with CTP in addition to plain CT in our protocol. We have been trying to reduce the radiation dose and have now adopted a dose-reduction method such as ASiR (GE Healthcare), a new advanced reconstruction technique that reduces image noise and improves low contrast detectability and image quality (18, 19). We achieved up to 40% lower dose without loss of image quality in the CTP protocol and overdose radiation could also be avoided (20, 21).

CONCLUSIONS

Sixty-three percent of acute stroke patients were diagnosed accurately by CTP on arrival. Sensitivity depends on the size of infarction but not on the interval between onset and scan. CT perfusion is an effective imaging modality for the diagnosis and treatment decisions for acute stroke, particularly more serious strokes.

CONFLICTS OF INTEREST

The all authors have no actual or potential conflicts of interest, including any financial, personal or other relationships with other people or organizations that could inappropriately influence, or be perceived to influence, this work.

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