Original research article

A retrospective comparative assessment of the time consumption and success rate between CT angiography and Ct perfusion based imaging assessment strategy for patients with acute ischemic stroke

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Abstract

Aim: The aim of the present study was to compare the time consumption and success rate between CTA- and CTP- based assessment strategy, and to clarify the risk factors associated with the CTP scan failure.

Methods: The study was approved by our center's ethical committe. The requirement for a written informed consent was waived due to the retrospective nature of the study. We included consecutive patients admitted to our emergency department with a diagnosis of AIS for the period of 6 months. Among 400 patients enrolled in our study, 300 (75%) patients underwent CTA- based, while 100 (25%) patents underwent CTP- based imaging assessment strategy.

Results: The number of patients with occlusion in internal carotid artery or MCA, basilar and other sites was 204 (68%), 7 (7%) and 75 (25%) respectively for the CTA group, while 72 (72%), 7 (7%) and 20 (20%) for the CTP group. In the CTA group, 61 (20%) patients were treated with EVT after intravenous tPA, 150 (50%) patients were treated with intravenous tPA alone, and 90 (30%) patients were treated with EVT alone. While in the CTP group, 12 (12%) patients received EVT after intravenous tPA, 24 (24%) patients received intravenous tPA alone, and 87 (64%) patients received EVT alone.

Conclusion: In summary, our study found that CTP- based imaging assessment strategy needed more time consumption, and showed higher failure rate than CTA- based strategy. High baseline NIHSS score might be a risk factor associated with the CTP scan failure in AIS patients.

Keywords: Acute ischemic stroke, perfusion, angiography, time consumption, success rate

Introduction

Early detection of acute stroke helps to reduce mortality rate since rapid treatment decision can be made by clinicians [1]. Computed tomography angiography (CTA) and CT perfusion (CTP) of the brain are two imaging procedures which are reported to be of paramount importance in the evaluation of acute stroke apart from unenhanced CT for emergency situation [2-7]. With the introduction of intravenous contrast material, the exact site of occlusion in the cerebral vessels can be determined clearly through the vascular assessment of CTA [5, 8, 9].

Reconstructed CTA images are available in various formats for visualization of anatomical details such as maximum intensity projection (MIP), shaded surface display (SSD), multi-planar reformation (MRP) and volume rendering technique (VRT) [5, 10-12]. Moreover, reconstructed images of CTA provide sufficient diagnostic information which enables the CTA to replace MRI, and this could be an advantage for patients unfit for the MRI examination [9]. Stroke is a leading cause of disability and mortality in the worldwide [13]. Multimodal computed tomography (CT), including non-enhanced CT (NCCT), CT angiography (CTA), CT perfusion (CTP) imaging, are important imaging techniques for accurately assessing the patients with acute ischemic stroke (AIS) before treatment [14].

While for AIS patients within 6 h of onset with LVO, since the time to reperfusion has a significant effect on clinical outcome, the 2019 AHA/ASA guideline recommended angiography assessment only for selecting mechanical thrombectomy (MT) eligibility, and treatment should not be delayed by additional perfusion imaging [14]. Previous studies reported that CTP needed more time to acquire,

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process and interpret, and hold high rate of post-processing failure. These disadvantages might contribute to the recommendation not to use CTP for imaging assessment for patients within the time window [15, 16]. However, Olivot *et al*. recently reported that twenty-nine percent of the AIS patients with onset time less than 6 h had no target mismatch. Using CTP to evaluate target mismatch for patients within the time window was also important for identifying patients had potential to respond favorably to reperfusion therapy [17]. Therefore, there was still no consensus on how to establish the imaging assessing strategy for the AIS patients in different time window. In our opinion, full understanding of the time usage and failure rate of CTA- and CTP- based imaging assessment strategies was of great importance for making the most reasonable imaging protocol for AIS patients.
Therefore, the purpose of our study was to compare the time usage and success rate between CTA- and CTP based imaging assessment strategy for the AIS patients, and to clarify the risk factors potentially associated with CTP scan failure.

Methods

The study was approved by our center's ethical committee. The requirement for a written informed consent was waived due to the retrospective nature of the study. We included consecutive patients admitted to our emergency department with a diagnosis of AIS for the period of 6 months. Among 400 patients enrolled in our study, 300 (75%) patients underwent CTA- based, while 100 (25%) patents underwent CTP- based imaging assessment strategy.
We selected patients who (1) were older than 18 years; (2) presented to the emergency department with symptoms consistent with AIS; (3) underwent NCCT + CTA or NCCT + CTP for pre-treatment evaluation; (4) were treated by endovascular treatment (EVT) or intravenous thrombolysis (IVT).

Image protocol

Baseline CT was performed using a 128-section CT scanner (Optima CT 660, GE Medical Systems). For AIS patients with an onset time less than 5 h, imaging protocol included NCCT (120 kVp, 100–350 auto-mAs, and contiguous 5-mm axial sections ranging from the vertex to the skull base) and multiphase CTA (mCTA). The mCTA generated time-resolved cerebral angiograms of brain vasculature from the skull base to the vertex in three phases after contrast agent injection. Aortic arch vertex CT angiography made up the first phase. Image acquisition was timed to occur during the peak arterial phase in the healthy brain and was triggered by bolus monitoring. The remaining two phases are from the skull base to the vertex in the equilibrium/peak venous and late venous phases in the healthy brain. Images were acquired with a 0.625-mm section thickness. The second phase was acquired after a delay of 8 s that allows for table repositioning to the skull base. Scanning duration for the first phase was 5.1 s and for each additional phase was 2.6 s. A total of 50-mL nonionic iodinated contrast (iopromide, Ultravist 370, Bayer Schering Pharma) was administered at a flow rate of 4 mL/s, followed by a 40-mL saline chaser at a rate of 4 mL/s. The CT dose indexes (CTDIvol) were 8.14 mGy, 5.70 mGy, and 5.71 mGy for mCTA scan in three phases, respectively. The average total dose-length products (DLP) were 326.78 ± 0.10 mGy*cm, 117.63 ± 0.07 mGy*cm, and 117.73 ± 0.05 mGy*cm, respectively.
For AIS patients in whom the onset time ≥ 5 h or with unclear time, imaging protocol included NCCT and CTP. CTP scan was conducted using the cradle table technique, allowing a coverage of whole brain. The imaging parameters for CTP scan were as follows: 4-dimensional adaptive spiral mode, periodic spiral approach, 80 mm in z-axis, 1.7 s temporal resolution, 30 consecutive spiral scans, 100 kVp, 200 mAs, rotation time of 0.4 s and 0.984 maximum pitch. A scan delay of 2 s was applied after injecting 50-mL (flow rate 5 mL/s) nonionic iodinated contrast (iopromide, Ultravist 370, Bayer Schering Pharma, Germany), followed by a 30-mL saline at the same rate. As a standard scan model, the CTDIvol was 315.68 mmGy, and the total DLP was 2998.96 mmGy*cm for each CTP scan. CTP data were analyzed retrospectively in a commercial software (Advantage Workstation 4.7; GE Healthcare, Milwaukee, WI, USA), using singular value deconvolution algorithms. Simulated CTA source image was reconstructed from the peak arterial phase in the normal distal ICA of the source CTP images for detecting vessel occlusion, based on the arterial input function (AIF). CTP data were reconstructed with a thickness of 5 mm for perfusion analysis, and with a slice thickness of 0.625 mm for CTA analysis.

Data collection

All the time information was retrospective obtained from the picture archiving and communication system equipped in our center. In CTA scan, failure was defined as poor visualization of vascular structure which would influence subsequent imaging evaluation. For CTP scan, failure was defined as abnormal perfusion curves. If perfusion curve showed as a typical wash-in and wash-out pattern, we would define the CTP scan as successful. If the perfusion curve was chaotic or wash-out phases were not finished, we would define it as a failure.
The potential causes of CTP or CTA scan failure included severe motion, streak artifact, and poor arrival of contrast bolus due to poor basic condition of vessel. Two raters (both with more than 5 years of experience in neuroradiology) who were blinded to the clinical data assessed whether failures occurred or

not. In case of disagreement between two raters, consensus was reached by discussion with a senior radiologist.

Demographic, clinical and imaging information such as age, gender, baseline National Institute of Health Stroke Scale (NIHSS) score, onset time and occlusion site were collected for univariate analysis between CTP success group and failure group.

Statistical analysis

All statistical analyses were performed using MedCalc (version 12.3.0) or SPSS (version 23.0). A two-sided P value less than 0.05 was considered significant.

Results

Table 1: Demographic and clinical characteristics of patients in CTA and CTP group

Variables [Median (IQR) or N (%)]	CTA group (N = 300)	CTP group (N = 100)
Age, years	70 (61–77)	67 (60–75)
Sex, male	120 (60%)	60 (60%)
Baseline NIHSS	12 (7–19)	13 (9–17)
Time interval from onset to imaging, hours	2.5 (1.5–3.5)	6 (5–8.5)
Patients awakened with stroke symptoms	0	25 (25%)
Treatment		
Intravenous tPA	150 (50%)	24 (24%)
EVT	90 (30%)	65 (65%)
Intravenous tPA + EVT	60 (20%)	12 (12%)
Occlusion site		
ICA or MCA	204 (68%)	72 (72%)
Basilar	24 (8%)	7 (7%)
Other site	75 (25%)	20 (20%)

The mean age of the patients in CTA group was 70 (IQR 61–77) years, and 60% were male. The median age of the patients was 67 (IQR 60–75) in CTP group, and 61% were male. The median baseline NIHSS score was 12 (IQR 7–19) for CTA group, and 13 (IQR 9–17) for CTP group. The median time interval from stroke onset to CT scan was 2.5 (IQR 1.5–3.5) hours for CTA group, and 6 (IQR 5–8.5) hours for patients in CTP group with clear onset time. Among them 24 (24%) patients in CTP group had awakened from sleep with symptoms of a stroke and with unclear onset time, and the onset time was the time they were last seen well. The number of patients with occlusion in internal carotid artery or MCA, basilar and other sites was 204 (68%), 7 (7%) and 75 (25%) respectively for the CTA group, while 72 (72%), 7 (7%) and 20 (20%) for the CTP group. In the CTA group, 61 (20%) patients were treated with EVT after intravenous tPA, 150 (50%) patients were treated with intravenous tPA alone, and 90 (30%) patients were treated with EVT alone. While in the CTP group, 12 (12%) patients received EVT after intravenous tPA, 24 (24%) patients received intravenous tPA alone, and 87 (64%) patients received EVT alone.

Table 2: Comparison of time consumption between CTA and CTP group

Variables [Median (IQR)]	Time of NCCT scan	Time of CTA/CTP scan and reconstruction	Total time consumption
CTA group, seconds	47 (43–52)	263.5 (97–652.5)	312.5 (148-711)
CTP group, seconds	49 (44–54)	775 (465–1369)	828 (503-1413)
P value	0.055	< 0.001	< 0.001

There was no significant difference in the time usage of NCCT can between CTA and CTP group [IQR, 47 (43–52) sec vs 49 (44-54) sec, P = 0.055]. However, CTP needed significantly longer time for scan and imaging reconstruction than CTA [IQR, 263.5 (97–652.5) sec vs 775 (465–1369) sec, P < 0.001]. Total time duration for NCCT + CTP assessment strategy was significantly longer than that of NCCT + CTA strategy [828 (503–1413) sec vs 312.5 (148–711) sec, $p< 0.001$].

Table 3: Characteristics and differences between patients with CTP failure and CTP success

Variables [Median (IQR) or N (%)]	CTP Failure (N = 10)	CTP Success (N = 90)	P value
Age, years	75 (56–79)	67 (60–74)	0.450
Sex, male	5 (50%)	55 (61.11%)	0.220
Baseline NIHSS	17 (13–20)	13 (8–16)	0.007
Time from symptom onset to CTP, hours	6 (5–8.5)	7 (5–9)	0.633
Treatment			0.322
-Intravenous tPA	3 (30%)	22 (24.44%)	
-EVT	7 (70%)	60 (66.66%)	

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-Intravenous tPA + EVT	0	12 (13.33%)	
Occlusion site			0.730
-ICA or MCA	12 (80%)	65 (72.22%)	
-Basilar	1 (10%)	5 (5.55%)	
-Other site	1 (10%)	20 (22.22%)	

The scan failure rate of CTP group was 10% (10/100), while that of CTA group was 1% (3/300). The scan failure rate of CTP group was significantly higher than CTA group ($P < 0.001$). Causes of CTP scan failure included severe motion (n = 12, 80%), streak artifact (n = 5, 5.55%) and poor arrival of contrast (n = 2, 13.33%).

Discussion

Magnetic resonance perfusion (MRP) imaging has been used in several past and current clinical trials [18]. The role of MRP is to triage patients for reperfusion treatment by quantifying the acute ischemic lesion and classifying mismatch pattern. More recently, computed tomographic perfusion (CTP) has been applied in a similar manner [19]. In the interest of timely recruitment, several studies now include both MRP and CTP in their protocols [20].

Ischemic stroke results from occlusion of a cerebral artery, and it is the leading cause of disability and the fifth leading cause of death in the United States [21]. Cerebral artery occlusion results in irreversible death of a component of cerebral tissue, which is referred to as the core infarction. There is an additional component of brain tissue that is ischemic, but viable, which is commonly referred to as the penumbra. The penumbra is at risk of irreversible infarction if timely restoration of blood flow is not achieved, and the preservation of the penumbra by restoration of arterial blood flow is the target of reperfusion therapy in the treatment of ischemic stroke.

Currently, CTP and CTA were two main imaging techniques commonly used for assessing the patients with AIS. Besides differential diagnosing stroke mimics and improving the detection rate of medium vessel occlusion [27], CTP could provide an objective and quantitative assessment of the volume of ischemic core and penumbra, and subsequently had been wide used to selected patients with anterior LVO in both early and extended window for EVT [10, 24, 18]. However, a relative longer time consumption which might potentially result in reperfusion delay and relative larger dose of radiation for CTP scan must be taken into consideration [15]. The main role of CTA scan was to clarify whether a LVO existed or not. Beside the well-known advantage of speediness, several researchers recently reported that there was close relationship between CTP- derived and CTA- derived diagnostic information, especially when mCTA used [22, 23].

In our study, CTP- based imaging assessment strategy showed relatively longer time consumption than CTA based strategy. Multiphase CTA included a three-time phases scan, while CTP scan contained 30 consecutive spiral scans of the brain. More images raw data would be obtained from CTP scan, and subsequent transform of raw data from scan workstation to reconstruction workstation might be one reason of time delay in CTP based strategy. Besides that, compared with reconstruction of vascular image from CTA, reconstruction of CTP parametric maps seemed to be a more complicated process. This situation might also be associated the time delay of CTP- based strategy. Considering the potential association between the longer time delay and the poorer clinical outcome, effectively shortening the time usage of CTP- based strategy had important clinical significance. Recently, increasing large comprehensive stroke centers have applied the automated perfusion analysis software to process the perfusion data. It may dramatically shorten the time usage of CTP reconstruction and subsequent analysis [24-26].

Besides longer time consumption, CTP also showed higher failure rate than CTA in our study. Kauw *et al*. reported a CTP failure rate of 11%, and they found that motion was the leading cause, followed by streak artifacts and poor contrast bolus arrival, which was in line with our study. The main reason for the higher failure rate of CTP might be that it was difficult for the patients to remain stationary during the relatively longer scan time. In consistent with the prior study, we found that baseline NIHSS was the risk factor that significantly associated with CTP failure [28]. Patients with higher baseline NIHSS would be neurologically more severe, more restless, and more likely to be mobile in the scanning process. We recommended to take caution on the patients with high NIHSS score, and to take effective measures such as fixed band and sedation drugs to keep them static during CTP scan. According to our result, we would recommend the sedative medication before CT scan for the stroke patients with a NIHSS higher than 11. Certainly, we admitted that the optimal threshold value of NIHSS should be derived based on further study with larger sample size. When CTP scan failure occurred, repeated CTP scan was usually not suggested because of that waiting the clearance of the contrast retention within the brain would increase the time consumption. Therefore, some previous studies tried to find fungible imaging biomarkers.

Conclusion

In summary, our study found that CTP- based imaging assessment strategy needed more time consumption, and showed higher failure rate than CTA- based strategy. High baseline NIHSS score might be a risk factor associated with the CTP scan failure in AIS patients.

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