The Egyptian Journal of Radiology and Nuclear Medicine (2016) 47, 991–997

Egyptian Society of Radiology and Nuclear Medicine

The Egyptian Journal of Radiology and Nuclear Medicine

www.elsevier.com/locate/ejrnm
www.sciencedirect.com

ORIGINAL ARTICLE

CT angiography collateral scoring: Correlation with DWI infarct size in proximal middle cerebral artery occlusion stroke within 12 h onset

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Received 8 January 2016; accepted 26 March 2016
Available online 13 April 2016

KEYWORDS

CT angiography;
Collateral score;
Infarct size;
Stroke

Abstract *Purpose:* It had been postulated that intra-cranial collateral flow can maintain penumbra and limit infarct growth in acute stroke patients. CT angiography is a frequently performed non-invasive modality for evaluation of intracranial collaterals. In this study, we sought to assess whether there is correlation between degree of collateral circulation as determined by CTA and admission DWI infarct size.

Patients and methods: We analyzed thirty patients with proximal middle cerebral artery occlusion within 12 h of onset. The grade of CTA intra-cranial collaterals was evaluated using Maas system and modified Tan scale. Admission DWI infarct volumes were calculated. Spearman correlation coefficient was used to assess relationship between CTA collateral score (CS) and DWI infarct size.

Results: Direct inverse correlation was found between CTA CS and infarct volume ($r = -0.5$, $p = 0.001$). ROC analysis showed CS as a good discriminator of DWI volume (AUC = 0.8, $p = 0.001$). Small infarct size was a significant predictor of good CS ($p = 0.01$).

Conclusions: In patients with major acute MCA occlusion strokes, CTA collateral grading is significantly correlated with admission DWI size. This finding may be relevant for clinical practice and helpful for guiding treatment decision and predicting clinical outcome.

1. Introduction

Acute anterior cerebral circulation occlusion is one of the most devastating clinical events, often causing severe neurologic deficit or death. Achieving well timed recanalization remains a main aim of acute stroke care (1) as it reduces tissue at risk and reverses neurologic deficits. The extent of revascularization depends not only on recanalization of the primary arterial occlusive lesion but also on reperfusion of the distal vascular bed (2,3). A lot of factors can impact success of recanalization, including clot composition, extent of clot burden, site of clot impaction, and collateral supply (4–7).

The collateral flow helps to maintain cerebral perfusion in the setting of arterial occlusion. Ischemic penumbra can remain viable because some degree of blood flow is sustained

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Peer review under responsibility of The Egyptian Society of Radiology and Nuclear Medicine.

http://dx.doi.org/10.1016/j.ejrnm.2016.03.013

through the collateral circulation that includes arterial communications between extracranial and intracranial circulation (8).

In acute ischemic stroke attributable to proximal anterior circulation occlusions, a smaller infarct volume at admission is an important predictor of functional outcome (9,10). Thus, recanalization therapy in acute MCA occlusion should ideally be guided by diagnostic methods capable of accurately identifying irreversible ischemia (9).

Multiple imaging modalities have been described for assessment and grading of intracranial collaterals as CTA and MRA. Detection of infarct core size is best accomplished with high accuracy and full anatomic coverage by using diffusion-weighted MRI (11–13).

Various scoring systems were used for grading of collateral circulations such as Miteff System (14), Maas System (15), Modified Tan Scale (3), Alberta Stroke Program Early CT Score Methodology using a 20-Point Grading Scale (16), and Careggi collateral score (17). However, there is no consensus on the best method to evaluate and grade collaterals (18).

In this study, we sought to assess whether there is any correlation between degree of collateral circulation and initial (admission) infarct core size.

2. Materials and methods

2.1. Patient selection

This study was approved by the ethics committee of our institution during the period between May 2014 and May 2015. The study included 30 consecutive patients with acute ischemic stroke syndrome. The inclusion criteria for the present study were as follows: (1) Time delay between acute stroke onset and imaging within 12 h; (2) CTA of the head showing proximal anterior circulation artery occlusion (i.e. terminal internal carotid artery (ICA) and/or proximal middle cerebral artery (MCA)); (3) DWI scan demonstrating area of true infarct with corresponding dark ADC. The exclusion criteria were as follows: (1) Intracranial hemorrhage or hemorrhagic infarction at non-contrast CT (NCCT); (2) no visible occlusion or small vessel occlusion at CTA; (3) poor CTA or DWI image quality.

National Institute of Health Stroke Scale (NIHSS), being a simple systematic tool providing a quantitative measure of stroke-related neurologic deficit was used to evaluate clinical severity of stroke. The patients were classified according to multi-item neurologic examination of NIHSS into having minor (1–4), moderate (5–15), moderate to severe (16–20) and severe (21–42) stroke (19).

2.2. Image acquisition

2.2.1. CT protocol

The CT scans were obtained with 16 multi-detector scanner (LightSpeed General Electric Medical Systems, USA).

2.2.1.1. Non Contrast CT. Standard NCCT scanning was performed with the following parameters: 120 kV, 180 mA, 2-s scan time, and 5-mm slice thickness.

2.2.1.2. Computed Tomography Angiography. CT angiography was performed from the vertex to the aortic arch following injection of 80–120 ml of Omnipaque 350 (GE Healthcare Inc., Princeton, NJ) at a rate of 3.5 mL/s. SmartPrep was used with a region of interest 1 cm below the carina covering the entire lumen of the ascending aorta. Scanning began with a 10-s delay after the region of interest reached 75 HU. The parameters were 1.25-mm slice thickness, 0.625-mm reconstruction interval, 120 kV, 350–800 mA, and 0.516:1 pitch.

2.2.2. MRI protocol

MR imaging was performed on a 1.5 T Signa whole body scanner (General Electric Medical Systems, USA) with echo planar capabilities. Axial DWI images were obtained using single shot, spin echo planar imaging with the following parameters: TR 5000 ms; TE 80–110 ms. The high b value was 1000 s/mm^2 and the low b value was 0 s/mm^2; field of view 22 × 22 cm; matrix size 128 × 128, and slice thickness of 5 mm with a 1-mm inter-slice gap.

2.3. Post processing image analysis

2.3.1. CTA

CTA axial source images were processed to obtain sagittal, coronal, and 3D reformatted images as well as Maximum Intensity Projection (MIP) images, which were used all together with axial source images for evaluation of vessel patency/occlusion, site, size and extent of occlusion.

The CTA images were reviewed and evaluated by two radiologists (Mahmoud M. Higazi and Enas A Abdel Gawad) who had 10 years and 15 years of experience "respectively" in the field of diagnostic radiology, for intracranial collaterals according to two collateral scoring systems: Maas system and Modified Tan Scale. This was done blinded to results of MR DWI to avoid bias.

2.3.1.1. Maas System. The system of Maas et al. (15) is a 5-point score which compares collaterals on affected hemisphere against those on contralateral side using Sylvian fissure vessels as internal controls. The score ranges are 5 (exuberant), 4 (more than those on the contralateral side), 3 (equal to those on the contralateral side), 2 (less than those on the contralateral side), and 1 (no vessel opacification).

2.3.1.2. Modified Tan Scale. The modified scale of Tan et al. (3) is the simplest system that classifies the collaterals as "good" if seen in ⩾50% of the MCA territory and "poor" when they are seen in 50% of the territory. This system allows a rapid assessment and is less prone to differences in opinion.

2.3.2. MRI

Apparent diffusion coefficient (ADC) maps were generated from the diffusion-weighted images for each slice using commercially available software (Functool, General Electric Medical Systems, USA).

The areas of restricted diffusion at DWI with corresponding dark ADC maps were semi-automatically outlined and traced to obtain infarct volume at admission DWI for all patients. Image segmentation and volume measurements were done using a semi-automated commercially available image analysis software program (Image J, Version 1.5 for Windows).