Journal of Neuroradiology (2015) 42, 261—268

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ORIGINAL ARTICLE

Computed tomography angiography source images closely reflect the integrity of collateral circulation

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Available online 6 November 2014

KEYWORDS
Stroke;
Computed tomography angiography source images;
Thrombolysis;
Collateral circulation;
Middle cerebral artery occlusion

Summary
Background: We studied the interplay between collateral circulation, the location of the thrombus and infarct extent based on evaluation of CT angiography source images (CTA-SI) in predicting the clinical outcome of patients treated with intravenous thrombolytic therapy (< 3 h) in a retrospective cohort.
Methods: Anterior circulation occlusion was detected with CTA in 105 patients. The site of the occlusion was recorded, collaterals were assessed with Collateral Score (CS) and Alberta Stroke Program Early CT Score (ASPECTS) was evaluated from CTA-SI, and entered into logistic regression analysis to predict favorable clinical outcome (three-month modified Rankin Scale 0—2).
Results: CTA-SI ASPECTS was highly correlated with CS (Spearman's rho = 0.63, $P = 0.01$). Not a single patient with good collaterals (CS 2—4) had a poor CTA-SI scan (ASPECTS 0—7). The mean CTA-SI ASPECTS score became progressively lower when the status of the collateral circulation deteriorated (ANOVA $P < 0.001$). In univariate analysis a good CTA-SI scan at the admission predicted favorable three-month outcome ($P < 0.001$). In a multivariate model containing CTA-SI ASPECTS, CS and the site of the occlusion along with significant clinical parameters, CTA-SI ASPECTS was rendered non-significant ($P = 0.43$) in the presence of CS.
Conclusions: CTA-SI and CS convey overlapping information. CTA-SI is not a significant predictor of the clinical outcome three months after intravenous thrombolysis when the other CTA-based parameters, CS and the clot location, are considered simultaneously. CTA-SI may have a role in the assessment of the extent of irreversible ischemic changes at admission if contrast injection and image acquisition protocols are designed suitably.

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http://dx.doi.org/10.1016/j.neurad.2014.06.001
0150-9861/

Introduction

The volume of irreversibly damaged brain parenchyma at the time of the admission to the emergency department has been identified as a major determinant of clinical and imaging outcome of acute ischemic stroke (AIS) and thus an important parameter that guides treatment decision making, especially the selection of diverse revascularization therapies [1—5]. AIS is most often evaluated using non-contrast-enhanced computed tomography (NCCT) and CT angiography (CTA) that are sometimes complemented with a CT perfusion study (CTP) [1,2,4]. As the sensitivity, accuracy and interobserver agreement of NCCT in the detection of irreversible ischemic damage are suboptimal [6,7], assessment that utilizes CTA source images (CTA-SI) was recognized as a potential improvement [8]. Consequently a number of reports have established that CTA-SI is superior to NCCT in the detection of brain parenchyma destined to become or already infarcted and that the findings in CTA-SI predict both short term and three-month clinical outcome [9—17]. Most of these studies characterized the extent of the ischemic changes by employing the semi-quantitative Alberta Stroke Program Early CT Score (ASPECTS) [12]. However, the sensitivity of CTA-SI in the detection of irreversible ischemic changes and the accuracy in the prediction of clinical outcome are less than ideal [11,13,15].

Other parameters easily obtainable from a CTA or MRA study include the site of the vessel occlusion and the integrity of the leptomeningeal collateral circulation. Both of these have been shown to be independent predictors of clinical outcome and response to treatment [18—23].

Recently concern has been raised on how image acquisition parameters influence whether CTA-SI reflects the cerebral blood volume or whether it is more flow-weighted [24,25]. This phenomenon may lead to overestimation of the extent of irreversible ischemia with faster scanners and thus decreased utility for CTA-SI.

The purpose of our study was to analyze the interplay and interactions between CTA-SI ASPECTS, the status of the collateral circulation (as depicted by Collateral Score [CS] [26]) and the location of the clot with respect to the findings in admission NCCT, the 24 h imaging outcome and the three-month clinical outcome of AIS patients treated with intravenous thrombolysis (IVT) in less than 3 h from the onset of symptoms. These three CTA-based parameters reflect different aspects of stroke pathophysiology. Thus, potentially all of them may be useful in devising a prognostic model.

Methods

Study population

This retrospective observational cohort study was approved by Tampere University Hospital ethics committee. From January 2004 to December 2007, 313 anterior or posterior circulation AIS patients were treated with IVT and had a three-month follow-up after thrombolysis at the department of neurology of the Tampere university hospital. CTA had been successfully performed at the admission to 283 (90%) of these patients. The remaining 10% were not studied with CTA because of previously known contrast agent hypersensitivity, chronic renal failure, impending closure of the 3 h time window or movement artifacts that prohibited reliable interpretation. Inclusion criteria for the study were acute anterior circulation vessel occlusion confirmed with CTA and treatment with standard IVT administration scheme. One hundred and five (37%) of the 283 patients met these criteria. No clot was detected in 140 (50%) cases, and 38 (13%) patients had a posterior circulation occlusion. The thrombolytic therapy protocol used was in line with the American Heart Association (AHA) guidelines [27].

Participants and variables

Baseline clinical characteristics were collected from the patient records. National Institutes of Health Stroke Scale (NIHSS) score at the time of administration of IVT had been prospectively stored. Follow-up NCCT and NIHSS scoring were performed for all patients 24 h after the administration of the thrombolytic therapy. Modified Rankin Scale (mRS), scored three months after the stroke, was the primary outcome measure. The three-month mRS score was prospectively recorded based on a follow-up visit to neurologist or a phone interview by neurologist.

Imaging parameters

Computed tomography scans were obtained using two different multidetector scanners: General Electrics LightSpeed 16-row (GE Healthcare, Milwaukee, WI) and Philips Brilliance 64-row (Philips, Cleveland, OH). CTA was imaged from the C2-vertebra to the vertex. The imaging parameters were 120 kV, 212 mAs (dynamic tube current modulation), collimation 64×0.625 mm, rotation 0.75s, pitch factor 0.923 (64-row) or 120 kV, 160 mAs, collimation 16×0.625 mm, rotation 0.8 s, pitch factor 0.938 (16-row). Contiguous slices were reconstructed to 0.9 mm-thickness using 0.45 mm overlap (64-row) or 1.25 mm-thickness (16-row). The contrast agent (iobitridol, Xenetix 350 mgI/ml, Aulnay-sous-Bois, France) was administered through an antecubital 18 G cannula using a double piston power injector with a flow rate of 4 ml/s using 70 ml of contrast agent followed by a 50 ml saline flush. The contrast bolus was tracked visually using repetitive (1s interval) scanning of a single slice at the level of the C2-vertebra. The scanning was triggered 3s after the appearance of the contrast agent in the vertebral arteries. NCCT and CTP were performed as described in our previous report [28].

Image analysis

ASPECTS was assessed from admission and follow-up NCCT images and CTA and CTP studies were post-processed and interpreted as described in our previous study [28]. The location of the clot was recorded based on the most proximal position of the occlusion. The M1 segment of the middle cerebral artery (MCA) was divided in two parts of equal length: the proximal and the distal half (designated as M1P and M1D). The status of the collateral circulation was evaluated using the scoring system devised by Souza et al. [29]. In short, CS was determined from maximum intensity