ASPECTS on CTA Source Images Versus Unenhanced CT Added Value in Predicting Final Infarct Extent and Clinical Outcome

Shelagh B. Coutts, MBChB; Michael H. Lev, MD; Michael Eliasziw, PhD; Luca Roccatagliata, MD; Michael D. Hill, MD; Lee H. Schwamm, MD; J.H. Warwick Pexman MBChB; Walter J. Koroshetz, MD; Mark E. Hudon, MD; Alastair M. Buchan, MD; R. Gilberto Gonzalez, MD, PhD; Andrew M. Demchuk, MD

Background and Purpose—The Alberta Stroke Program Early CT Score (ASPECTS) is a grading system to assess ischemic changes on CT in acute ischemic stroke. CT angiography–source images (CTA-SI) predict final infarct volume. We examined whether the final infarct ASPECTS and clinical outcome were more related to acute CTA-SI ASPECTS than to the acute noncontrast CT (NCCT) ASPECTS.

Methods—ASPECTS was assigned by 2 raters on the acute NCCT, CTA-SI, and follow-up imaging. The mean baseline ASPECTS of acute NCCT and CTA-SI was compared with the follow-up ASPECTS. Rate ratios (RRs) were used to quantify the relationship between the dichotomized baseline ASPECTS (categorized as 0 to 7 versus 8 to 10) and favorable patient outcome.

Results—Thirty-nine patients were recruited. Proximal occlusion (internal carotid artery or middle cerebral artery) was seen in 62%, M2 occlusion in 18%, and no occlusion was seen in 20% of patients. The median time between symptom onset and imaging was 1.9 (1.2 to 2.5) hours. There was a significantly larger difference of 1.4 between the mean baseline NCCT and CTA-SI ASPECTS in patients who had more ischemic changes (follow-up ASPECTS = 0 to 3) than a difference of 0.6 in patients who had near-to-normal CT scans (follow-up ASPECTS = 8 to 10). The rate of favorable outcome for acute NCCT ASPECTS of 8 to 10 was 51.8% versus 25.0% for 0 to 7 (RR, 2.1, 95% CI: 0.7 to 5.9, \(P = 0.12\)). For acute CTA-SI ASPECTS of 8 to 10, the rate of favorable outcome was 58.8% versus 31.8% for 0 to 7 (RR, 1.8, 95% CI: 0.9 to 3.8, \(P = 0.09\)).

Conclusions—CTA-SI ASPECTS provides added information in the prediction of final infarct size. (Stroke. 2004;35:2472-2476.)

Key Words: computed tomography stroke, acute thrombolysis

CT is currently the modality of first choice for imaging patients with acute stroke. Although MRI has uncovered considerable information on the process of ischemic infarction, most patients with a stroke present to community hospitals without readily available MRI.1 Although noncontrast CT (NCCT) was initially used to exclude intracranial hemorrhage and other nonstroke pathologies, advanced CT techniques are increasingly recognized as a modality to characterize early signs of ischemia.2,3 With the use of multislice CT scanners, the potential information available from a CT scan has increased.4 CT angiography and CT perfusion techniques can refine the current clinical criteria for patient selection for thrombolysis.5 Source images from CT angiography (CTA-SI) can be rapidly obtained with minimal delays after a NCCT in the emergency room.6,7,8 Although CT has been shown to have value in identifying vessel occlusion, CTA-SI may also aid in the assessment of tissue status. Schramm et al found that the combination of CT, CTA, and CTA-SI was comparable to that of a magnetic resonance diffusion-weighted imaging.9 CTA-SI can also be useful in predicting final infarct volume.10,11 Brain tissue with a low cerebral blood volume appears as a region without enhancement on CTA-SI, effectively delineating the regions of ischemia.11 The Alberta Stroke Program Early CT Score (ASPECTS) was developed as a grading instrument to assess early ischemic changes on pretreatment CT scans in patients with acute ischemic stroke of the middle cerebral artery (MCA).12,13 The ASPECTS divides the MCA territory into 10 regions of interest. With training and experience, the early changes of acute ischemia

Received February 11, 2004; final revision received July 29, 2004; accepted July 30, 2004.

From the Seaman Family MR Research Centre (S.B.C., A.M.B., A.M.D.), Foothills Medical Centre, Calgary Health Region; the Departments of Clinical Neurosciences (S.B.C., M.E., M.D.H., J.H.W.P., M.E.H., A.M.B., A.M.D.), Medicine and Community Health Sciences (M.E., M.D.H.), and Radiology (M.E.H.), University of Calgary, Alberta, Canada; and the Departments of Radiology (M.H.L., L.R., R.G.G.) and Neurology (L.H.S., W.J.K.), Massachusetts General Hospital, Harvard Medical School, Boston.

Correspondence to Dr Shelagh Coutts, Seaman Family MR Centre, Foothills Hospital, 1403 29th ST NW, Calgary, Alberta T2N 2T9. E-mail shelagh.coutts@calgaryhealthregion.ca

© 2004 American Heart Association, Inc.

Stroke is available at http://www.strokeaha.org DOI: 10.1161/01.STR.0000145330.14928.2a

2472
can be reliably detected. One advantage of ASPECTS is that it combines a semiquantitative estimate of volume along with localization. It weights smaller volumes in the basal ganglia and internal capsule equally with larger volumes of brain designated M1 through M6. This approach is useful because lesion volume alone on NCCT is only weakly correlated with neurological outcome.

In this study, we sought to assess whether the final infarct ASPECTS and clinical outcome were associated with the acute CTA-SI ASPECTS.

Subjects and Methods

Subjects
We assessed the clinical and imaging information of consecutive patients with acute ischemic stroke from 2 institutions, who had NCCT and CTA. Stroke onset was defined as the time the patient was last seen well. Exclusion criteria were CT scan evidence of hemorrhage or tumor; hypoglycemia (serum glucose <2.0 mmol/L); serious comorbid illness that would result in the patient being unlikely to survive 3 months, or contaminate evaluation scales, or a patient who did not complete any follow-up imaging due to severe neurological deterioration; <18 years old, premorbid status Rankin >3; or symptoms suggestive of a posterior circulation event. Exclusion criteria specific for CTA were a known history of contrast medium allergy or any degree of renal failure. Patient demographics and clinical characteristics were recorded at the time of admission to the emergency department. All patients received intravenous or intra-arterial thrombolysis if indicated. ASPECTS on MRI was assigned in a similar manner to NCCT as previously described.

Statistical Analyses

The unit of analysis was the mean of the 2 readers’ ASPECTS. Two-factor repeated measures ANOVA was used to compare the mean baseline ASPECTS of acute NCCT and CTA-SI. In the analysis of variance, the between-subject factor was the follow-up ASPECTS, categorized as 0 to 3, 4 to 7, and 8 to 10. The within-subject factor was the baseline ASPECTS, because the NCCT and CTA-SI scores were obtained from the same patient’s CT scan. Rate ratios (RRs) were used to quantify the relationship between the dichotomized baseline ASPECTS (categorized as 0 to 7 versus 8 to 10) and favorable patient outcome. The chosen cut point has been previously used for acute ischemic stroke patients.

Interrater agreement in assigning ASPECTS was estimated using an intraclass correlation coefficient, computed from 1-way ANOVA.

Results

A total of 39 patients were recruited. There were no adverse events related to the use of the contrast medium. Demographic results are described in this section as median, and the interquartile range is shown. The median age of the patients was 74 (62 to 81) years, and 54% were female. The median baseline National Institutes Of Health Stroke Scale was 16 (9 to 22), and 90% of the patients were treated with tissue plasminogen activator (tPA). Four patients were treated with...
IV/intra-arterial (IA) therapy, 13 were treated with IV alone, and 18 were treated with IA tPA alone. The median time between symptom onset and imaging was 1.9 (1.2 to 2.5) hours, with 41% of the scans performed within 90 minutes of symptoms. Proximal occlusion (internal carotid artery or MCA) on CT was identified in 62% of the patients, M2 occlusion in 18%, and no large vessel occlusion in 20%. The follow-up scan was performed at a median time of 10 (4 to 34) days. T2-weighted MRI was substituted for follow-up NCCT in 14 patients.

Figure 1. Seventy-five year old man with left hemiplegia and hemineglect syndrome caused by a right MCA occlusion. Unenhanced CT scanning was performed 62 minutes after symptom onset; National Institutes Of Health Stroke Scale was 15 at baseline. A, Possible subtle right lentiform/subinsular ischemic hypodensity; this scan received an ASPECTS rating of 10 from 1 of the experts and 9 from the other. B, Corresponding CTA-SI images, obtained immediately after the NCCT, showed unequivocal hypocontrastation involving the caudate nucleus, lentiform nucleus, M2 territory, and insula. This scan received an ASPECTS rating of 6 from 1 of the experts and 2 from the other. C, Follow-up CT reveals progression to infarction in the territory of the CTA-SI lesions, despite successful vessel recanalization after IV and IA rt-PA. The raters scored the follow-up scan as having ASPECTS of 6 and 5, respectively.

The overall mean baseline ASPECTS differed by 1.1 (P <0.001). Figure 2 summarizes the mean differences at each follow-up ASPECTS category. There was a significantly larger difference of 1.4 between the mean baseline NCCT and CTA-SI ASPECTS in patients who had more ischemic changes (follow-up ASPECTS=0 to 3) than a difference of 0.6 in patients who had near-to-normal CT scans (follow-up ASPECTS=8 to 10). There were no cases of CTA-SI overestimating the final infarct size. There were 10 cases in which the NCCT was rated as having an ASPECTS of 10 by at least 1 rater. In 3 cases, the NCCT, the CTA-SI, and the follow-up CT were rated by both observers as having an ASPECTS of 10. In 7 of the cases that ultimately had a stroke, (follow-up ASPECTS <10) 1 reader interpreted the NCCT as normal (ASPECTS 10), but interpreted the CTA-SI as showing at least some ischemic change (ASPECTS <10). There was no evidence of reversibility of CTA-SI seen in this study. Figure 3 shows a scatter plot of mean ASPECTS scores for CTA-SI and NCCT as compared with final ASPECTS scores on follow-up imaging.

The rate of favorable outcome for NCCT ASPECTS of 8 to 10 was 51.8% versus 25.0% for 0 to 7 (RR, 2.1; 95% CI, 0.7 to 5.9; P=0.12). For CTA-SI ASPECTS of 8 to 10, the rate of favorable outcome was 58.8% versus 31.8% for 0 to 7 (RR, 1.8; 95% CI, 0.9 to 3.8; P=0.09).

The interrater agreement for baseline ASPECTS using NCCT was 0.71 versus 0.73 for CTA-SI.

Discussion

Acute ischemic stroke requires urgent assessment of the clinical and radiological features of the brain insult. The ability to identify an acute infarct on CT is helpful in confirming the diagnosis of acute stroke.17 A completely normal NCCT scan seems ideal in terms of potential benefit (because no damage is currently seen) from any possible therapies but may introduce diagnostic uncertainty for the stroke neurologist. Normal CT scans are relatively common if the scans are performed very early into the stroke symptoms. The European Cooperative Acute Stroke Study (ECASS II) experienced reviewers did not detect early ischemic changes in ≈1/3 of infarcts that later appeared on follow-up CT,17 and the National Institute of Neurological Disorders and Stroke

Figure 2. A comparison of mean ASPECTS score at baseline between NCCT and CTA-source images (CTA-SI) according to 3 categories of ASPECTS scores at follow-up. The 95% CI about the mean score (vertical lines) and the P values (along the horizontal axis) were computed from 2-factor repeated measures ANOVA. The P values correspond to comparing the mean scores (reported above the P values) between NCCT and CTA-SI for each category of follow-up ASPECTS. In general, the baseline ASPECTS for CTA-SI was lower than for NCCT and was closer to the midpoint of the category for the follow-up ASPECTS.
(NINDS) investigators reported that only 31% of patients in the NINDS tPA trial had evidence of early ischemic changes.\(^1\)\(^8\) Our results suggest that CTA-SI ASPECTS has a greater sensitivity to ischemic changes and more accurately identifies the volume of tissue that will ultimately infarct compared with NCCT alone. The cases where 1 rater scored the scan as 10 show the potential advantage of using CTA-SI. In 7 of these cases, the ischemia would have been totally missed by 1 of the expert raters. It is in this setting (ASPECTS = 10 of the NCCT) where CTA-SI is most likely to be helpful.

CTA is 1 method of quickly and accurately identifying vessel occlusion and ischemia. Using a follow-up ASPECTS as the final infarct size, CTA-SI gives a more accurate estimate of tissue that is at risk of infarcting than does a NCCT alone. The value of a combined CTA, CTA-SI over NCCT in predicting clinical outcome has also been demonstrated using a scale that differs from ASPECTS.\(^1\)\(^9\)

It is important to recognize that hypointensituation on NCCT and CTA-SI hypointensitation probably imply different pathophysiological abnormalities. These may not always represent core of infarction. A CTA-SI region showing a lack of enhancement provides an estimate of cerebral blood volume,\(^1\)\(^0\),\(^1\)\(^1\) whereas NCCT measures shifts in brain tissue water content. It is the net uptake of water in brain regions with \(<12 \text{ mL/100 g} \times \text{minutes}^{2}\)\(^0\),\(^2\)\(^1\) that causes hypointensitation. Large shifts of water are needed for the human eye to visualize hypointensitation. Animal studies have shown that a 1% increase in brain water content results in an x-ray attenuation decrease of 2 to 3 Hounsfield units.\(^2\)\(^2\) Optimal window width and leveling\(^2\)\(^3\) can help with reliably identifying such changes in water content. Recent work confirms that the volume of abnormality on CTA-SI at baseline is a very close match to the volume of final infarct on follow-up scanning if there is prompt recanalization.\(^2\)\(^4\) Further work is needed on this subject.

Both NCCT and CTA-SI showed a trend toward a better clinical outcome for baseline ASPECTS of 8 to 10. This is consistent with observations from the Prolyse in Acute Cerebral Thromboembolism Trial (PROACT II) where an ASPECTS of 8 to 10 was found to differentially predict response to thrombolytic treatment.\(^2\)\(^5\) Larger numbers of patients will be needed to assess and confirm the relationship of ASPECTS on CTA-SI with clinical outcome.

The possibility of CT fogging effect is a relative limitation of our study. The timing and degree of fogging is variable, and has mostly been studied in small series, on older generation CT scanners.\(^2\)\(^6\),\(^2\)\(^7\) More recent studies suggest that fogging can start as early as 5 to 10 days post ictus, but that it may also occur months after stroke onset, coincident with the time period of poststroke hyperemia\(^2\)\(^8\) (a potential mechanism of fogging). The timing and degree of fogging likely varies with factors such as infarct size as well as the severity of the initial deficit.\(^2\)\(^9\) Importantly for our results, previous work suggests that fogging of large infarcts is typically not complete.

The reliability of assessing ASPECTS on the CTA-SI was very good and similar to that on NCCT. Larger studies are needed very early from stroke onset to compare both techniques. NCCT changes are particularly difficult to appreciate in such patients and may be greatly aided by CTA-SI information.

Acknowledgments

AMB was supported by the Heart and Stroke Foundation of Canada (HSFC), Canadian Institutes for Health Research, and The Canadian Stroke Network. SBC was supported by HSFC fellowship and Alberta Heritage Foundation for Medical Research Fellowship (AHFMRF). AMD was supported by AHFMRF and Canadian Institutes for Health Research. MDH was supported by Heart and Stroke Foundation of Alberta/North West Territories (NWT) and the Nunavut and Canadian Institutes for Health Research. ME was supported by AHFMRF and by the Natural Sciences and Engineering Research Council of Canada. WJK and MHL were supported by the Agency for Healthcare Research and Quality (AHRQ), a division of the US Health and Human Services.
References


ASPECTS on CTA Source Images Versus Unenhanced CT: Added Value in Predicting Final Infarct Extent and Clinical Outcome

*Stroke*. 2004;35:2472-2476; originally published online October 14, 2004; doi: 10.1161/01.STR.0000145330.14928.2a

*Stroke* is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231
Copyright © 2004 American Heart Association, Inc. All rights reserved.
Print ISSN: 0039-2499. Online ISSN: 1524-4628

The online version of this article, along with updated information and services, is located on the World Wide Web at:

http://stroke.ahajournals.org/content/35/11/2472

Permissions: Requests for permissions to reproduce figures, tables, or portions of articles originally published in *Stroke* can be obtained via RightsLink, a service of the Copyright Clearance Center, not the Editorial Office. Once the online version of the published article for which permission is being requested is located, click Request Permissions in the middle column of the Web page under Services. Further information about this process is available in the Permissions and Rights Question and Answer document.

Reprints: Information about reprints can be found online at:
http://www.lww.com/reprints

Subscriptions: Information about subscribing to *Stroke* is online at:
http://stroke.ahajournals.org//subscriptions/