Safety of Computed Tomographic Angiography in the Evaluation of Patients With Acute Stroke
A Single-Center Experience

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Background and Purpose—Noncontrasted head computed tomography (NCHCT) has long been the standard of care for acute stroke imaging. New guidelines recommending advanced vascular imaging to identify eligible patients for endovascular therapy have renewed safety concerns on the use of contrast in the emergent setting without laboratory confirmation of renal function.

Methods—We compared computed tomographic angiography (CTA) versus NCHCT alone during acute stroke evaluation with focus on renal safety and timeliness of therapy delivery. We reviewed data on all emergency department patients for whom the Acute Stroke Intervention Team was activated between December 2013 and September 2014. Primary outcomes included acute kidney injury and change in serum creatinine from presentation to 24 to 48 hours (Δ serum creatinine [Cr]). We assessed therapy delay using door-to-CT and door-to-needle times.

Results—Of 289 patients requiring Acute Stroke Intervention Team activation, 157 received CTA and 132 NCHCT only. There was no difference between groups in mean Cr at 24 to 48 hours (1.06 CTA; 1.40 NCHCT; P=0.059), ΔCr (−0.07 CTA, −0.11 NCHCT, P=0.489), or rates of acute kidney injury (5 CTA, 7 NCHCT, P=0.422). There was no significant difference in mean intravenous tissue plasminogen activator treatment times (68.11 minutes CTA, 81.36 minutes NCHCT; P=0.577). In the 157 patients who underwent CTA, 16 (10.2%) vascular anomalies and 55 (35.0%) high-grade stenoses or occlusions were identified.

Conclusions—CTA acquisition during acute stroke evaluation was safe with regards to renal function and did not delay appropriate therapy delivery. Acute CTA acquisition offers additional clinical value in rapid identification of vascular abnormalities. (Stroke. 2016;47:2045-2050. DOI: 10.1161/STROKEAHA.116.013973.)

Key Words: acute kidney injury ▪ cerebrovascular disorders ▪ quality assurance, health care ▪ stroke ▪ tissue-type plasminogen activator

During evaluation of patients with acute stroke, noncontrasted head computed tomographic (NCHCT) imaging serves as the standard of care because of wide availability, rapid acquisition, and convenience of use. NCHCT rules out intracerebral hemorrhage with high sensitivity,1 is able to identify potential stroke mimics, and informs the treatment decision for intravenous recombinant tissue-type plasminogen activator (r-tPA). Similarly, computed tomographic angiography (CTA) identifies cerebrovascular large vessel occlusion with a high degree of accuracy even when compared with the gold standard catheter-based digital subtraction angiography.2

Five recent acute stroke clinical trials demonstrated efficacy of endovascular therapy (EVT) with stent retrievers versus medical treatment alone in carefully selected patients with rapid intervention times.3–7 All 5 studies required demonstration of a proximal large vessel occlusion before randomization. A revised American Heart Association/American Stroke Association guideline now recommends noninvasive intracranial vascular imaging during the initial stroke evaluation, and notes that this imaging should be obtained as quickly as possible without delaying intravenous r-tPA administration.8

As a noninvasive vascular imaging modality, CTA is a logical choice to fulfill this new standard of care as an add-on to the NCHCT requiring little additional training and infrastructure. However, concerns linger over possible delays in treatment with intravenous r-tPA and potential risk from iodinated contrast exposure in patients with acute stroke with unknown renal function. Previous studies in this area9–14 investigated renal function after contrast administration without assessing impact on timely management and acute stroke therapy...
and were also small, uncontrolled, or used historical control groups. Therefore, we performed a study of CTA acquisition as a part of the acute stroke evaluation, hypothesizing that adding CTA imaging in this setting is both safe and efficient.

**Design/Methods**

**Study Design**

We conducted a retrospective review of prospectively collected data, in conjunction with additional chart review. The study included all patients presenting to the University of Virginia Medical Center Emergency Department between December 2013 and September 2014, for whom the Acute Stroke Intervention Team (ASIT) was activated. Inpatient acute stroke alerts were excluded. Beginning in late 2013, ASIT leaders (vascular neurology trained attendings, fellows, and senior neurology residents) were encouraged to consider obtaining CTA of the head and neck in addition to standard NCHCT during acute stroke evaluations. The decision to obtain CTA was left to the clinical discretion of the ASIT leader, which allowed for the use of those patients receiving only NCHCT as contemporary controls.

**Data Collection**

Demographic information, presenting clinical characteristics, and laboratory data for all individual patients were extracted on chart review of the electronic medical record and through the University of Virginia Clinical Data Repository.

**Imaging**

All imaging was performed per our institution’s standard acute stroke CT and CTA protocols on GE brand 64-section CT scanners (GE Healthcare, Little Chalfont, United Kingdom). For CTA of the head and neck, 70- to 100-mL contrast material (iohexol, Omnipaque 350 mg I/mL; GE Healthcare) is injected at a rate of 5 mL/second, and followed by a 25-mL saline bolus chase using a dual-head injector.

**Measures of Efficiency and Safety**

Measures of efficiency included any delay of appropriate therapy by door-to-CT read times (emergency department arrival time to recorded time of NCHCT: read by ASIT leader), door-to-needle times, and door-to groin puncture times.

Measures of safety included evidence of acute kidney injury (AKI) assessed using serum creatinine (Cr) as a marker of renal function. We analyzed baseline (presentation or time of admission) serum creatinine values, serum creatinine values 24 to 48 hours after presentation, and the difference between these 2 values ($\Delta$Cr). AKI is defined as a >25% increase in serum creatinine over presenting baseline value. Additional measures of safety included new need for hemodialysis during admission and any allergic contrast reactions.

Secondary outcome measures included other large vessel abnormalities relevant to patient care, such as the presence of extracranial or intracranial stenosis, cerebral artery dissection, intracranial aneurysm, arteriovenous malformation, or other vasculopathy. Radiological interpretation of the index CTA was used to identify pertinent abnormalities retrospectively. Chart review was also utilized to identify any patients undergoing carotid endarterectomy or carotid artery stenting during their acute stroke admission. As this study occurred before the completion of the recent positive endovascular trials, we did not systematically perform CT perfusion or formal assessment of collaterals.

**Statistical Analysis**

Patients were divided into 2 groups: CTA and NCHCT (CTA group) or NCHCT alone (control group). Two-sided, independent sample $t$ test was used for all comparison of means. Comparisons were made for categorical data including sex, race, presence of specific medical comorbidities, and frequency of intravenous r-tPA administration between groups using Pearson $\chi^2$ test. Alpha was set at 0.05. Statistical analysis was completed using SPSS, version 22 (IBM Corp.). All study procedures were considered exempt from review by the local institutional review board.

**Results**

**Demographics and Clinical Characteristics**

From December 2013 to September 2014, 289 patients were evaluated in the emergency department by the ASIT (Table 1). Of these, 157 (54.8%) were women and the mean age was 68.8 (range 14–96) years. Of 289 patients, 157 had CTA imaging and 132 had NCHCT only. Patients receiving CTA were generally younger than NCHCT only (mean age, 66.7 versus 71.4 years; $P = 0.017$). Fewer patients with a documented history of chronic kidney disease received CTA (n=24) compared with NCHCT only (n=52; $P<0.001$). The groups were otherwise similar with respect to sex, race/ethnicity, medical history, and previous stroke, or transient ischemic attack. The mean presenting NIHSS (National Institutes of Health Stroke Scale) was 7.7 (0–42) with no difference between groups ($P=0.980$).

**Outcomes**

There were no significant differences between the CTA and NCHCT-only groups with respect to intravenous r-tPA treatment (11.5% CTA, 8.3% NCHCT; $P=0.377$), mean door-to-CT read time (42.46 minutes CTA, 43.07 minutes NCHCT; $P=0.700$), or mean door-to-needle time (68.11 minutes CTA, 81.36 minutes NCHCT; $P=0.577$; Table 2).

The CTA group had lower mean Cr values on presentation compared with NCHCT-only (1.06 mg/dL CTA, 1.39 mg/dL NCHCT; $P=0.004$). However, there was no difference between the groups’ mean Cr at 24 to 48 hours (1.06 CTA; 1.40 NCHCT; $P=0.059$) or in $\Delta$Cr ($-0.07$ CTA, $-0.11$ NCHCT; $P=0.489$). Overall, 12 patients (6.3%) developed AKI, with no significant difference between the groups (5 CTA, 7 controls; $P=0.422$). Ninety-eight patients included in the study did not have a 24- to 48-hour creatinine value recorded in the electronic medical record and therefore were excluded from the relevant analyses. No patients in either group developed a new need for hemodialysis although 8 (2.7%) were receiving pre-existing chronic hemodialysis at the time of the acute stroke presentation.

CTA imaging revealed vascular anomalies in 16 of 157 patients (10.2%), and severe stenosis or occlusion of a major intracranial or extracranial artery in 55 patients (35.0%); internal carotid artery, middle cerebral artery M1 or M2 segments, vertebral artery, basilar artery, or posterior cerebral artery P1 division; Table 3). The remaining 102 patients who received CTA imaging had no such stenosis or occlusion. One patient in the CTA group and none in the control group received EVT, and one patient from the CTA group underwent carotid endarterectomy during the presenting stroke admission.

**Discussion**

Before the results of the 5 recent positive acute stroke endovascular trials, there was already significant interest in the addition of advanced imaging in selecting patients for acute treatment at our institution. In analysis of our advanced imaging protocol, acquired before the publication of positive endovascular trials, we found that CTA acquisition...
during acute stroke evaluation was safe with regards to renal function and did not delay evaluation or appropriate therapy delivery.

When the new EVT trial data were published, American Heart Association guidelines were updated to include a recommendation for noninvasive vascular imaging as a part of the

### Table 1. Patient Demographics

<table>
<thead>
<tr>
<th></th>
<th>NCHCT Only (n=132)</th>
<th>CTA (n=157)</th>
<th>P (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Age, y</strong></td>
<td></td>
<td>71.4 (16–96)</td>
<td>66.7 (14–96)</td>
</tr>
<tr>
<td><strong>Sex</strong></td>
<td></td>
<td></td>
<td>0.866</td>
</tr>
<tr>
<td>Female</td>
<td>71 (53.8)</td>
<td>86 (54.8)</td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>61 (46.2)</td>
<td>71 (45.2)</td>
<td></td>
</tr>
<tr>
<td><strong>Race</strong></td>
<td></td>
<td></td>
<td>0.084</td>
</tr>
<tr>
<td>White</td>
<td>86 (65.2)</td>
<td>121 (58.5)</td>
<td></td>
</tr>
<tr>
<td>Black</td>
<td>42 (31.8)</td>
<td>34 (44.7)</td>
<td></td>
</tr>
<tr>
<td>Asian</td>
<td>2 (1.5)</td>
<td>0 (0)</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>2 (1.5)</td>
<td>2 (1.3)</td>
<td></td>
</tr>
<tr>
<td><strong>Medical history</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dyslipidemia</td>
<td>90 (68.2)</td>
<td>118 (75.2)</td>
<td>0.188</td>
</tr>
<tr>
<td>Hypertension</td>
<td>116 (87.9)</td>
<td>128 (81.5)</td>
<td>0.138</td>
</tr>
<tr>
<td>Obesity</td>
<td>40 (30.3)</td>
<td>39 (24.8)</td>
<td>0.299</td>
</tr>
<tr>
<td>Diabetes mellitus</td>
<td>61 (46.2)</td>
<td>66 (42.0)</td>
<td>0.476</td>
</tr>
<tr>
<td>CAD/previous MI</td>
<td>52 (39.4)</td>
<td>59 (37.6)</td>
<td>0.808</td>
</tr>
<tr>
<td>Heart failure</td>
<td>45 (34.1)</td>
<td>40 (25.5)</td>
<td>0.109</td>
</tr>
<tr>
<td>Atrial fibrillation/flutter</td>
<td>42 (31.8)</td>
<td>56 (35.7)</td>
<td>0.491</td>
</tr>
<tr>
<td>Previous stroke</td>
<td>48 (36.4)</td>
<td>44 (28.0)</td>
<td>0.130</td>
</tr>
<tr>
<td>Previous TIA</td>
<td>14 (10.6)</td>
<td>19 (12.1)</td>
<td>0.690</td>
</tr>
<tr>
<td>Smoking</td>
<td>64 (48.5)</td>
<td>78 (49.7)</td>
<td>0.839</td>
</tr>
<tr>
<td>Chronic renal insufficiency</td>
<td>52 (39.4)</td>
<td>24 (15.3)</td>
<td>&lt;0.001*</td>
</tr>
<tr>
<td>Presenting NIHSS</td>
<td>7.7 (0–39)</td>
<td>7.7 (0–42)</td>
<td>0.980 (−2.077 to 2.024)</td>
</tr>
</tbody>
</table>

CAD indicates coronary artery disease; CI, confidence interval; CTA, computed tomographic angiography; MI, myocardial infarction; NCHCT, noncontrast head computed tomography; NIHSS, National Institutes of Health Stroke Scale; and TIA, transient ischemic attack.

*Significant at P<0.05.

### Table 2. Outcome Measures

<table>
<thead>
<tr>
<th></th>
<th>NCHCT Only (n=132)</th>
<th>CTA (n=157)</th>
<th>P (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>tPA administered</td>
<td>11 (8.3)</td>
<td>18 (11.5)</td>
<td>0.377</td>
</tr>
<tr>
<td>Door-to-CT read, min</td>
<td>43.07</td>
<td>41.46</td>
<td>0.700 (−9.83 to 6.61)</td>
</tr>
<tr>
<td>Door-to-needle, min†</td>
<td>81.36</td>
<td>68.11</td>
<td>0.577 (−63.67 to 37.17)</td>
</tr>
<tr>
<td>Creatinine on arrival, mg/dL</td>
<td>1.39</td>
<td>1.06</td>
<td>0.004* (−0.56 to −0.11)</td>
</tr>
<tr>
<td>Creatinine at 24–48 h, mg/dL‡</td>
<td>1.40</td>
<td>1.06</td>
<td>0.059 (−0.71 to 0.01)</td>
</tr>
<tr>
<td>Delta creatinine, mg/dL</td>
<td>−0.11</td>
<td>−0.07</td>
<td>0.489 (−0.07 to 0.15)</td>
</tr>
<tr>
<td>Acute kidney injury‡</td>
<td>7 (7.8)</td>
<td>5 (5.0)</td>
<td>0.422</td>
</tr>
</tbody>
</table>

CI indicates confidence interval; CT, computerized tomography; CTA, computed tomographic angiography; NCHCT, noncontrast head computed tomography; and tPA, tissue-type plasminogen activator.

*Significant at P<0.05.

†Among tPA-treated patients.

‡Ninety-eight patients had no 24- to 48-hour creatinine measure; NCHCT only n=90, CTA n=101.
Table 3. Vascular Occlusions, Stenoses, and Abnormalities on Computed Tomographic Angiography

<table>
<thead>
<tr>
<th>Abnormality</th>
<th>No. of Patients*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anterior circulation occlusion or severe stenosis</td>
<td>39</td>
</tr>
<tr>
<td>Posterior circulation occlusion or severe stenosis</td>
<td>16</td>
</tr>
<tr>
<td>Arteriovenous malformation/fistula</td>
<td>4</td>
</tr>
<tr>
<td>Aneurysm</td>
<td>4</td>
</tr>
<tr>
<td>Vertebral artery dissection</td>
<td>1</td>
</tr>
<tr>
<td>Aortic ectasia</td>
<td>1</td>
</tr>
<tr>
<td>Intracranial vasculitis</td>
<td>1</td>
</tr>
<tr>
<td>Vascular web (carotid)</td>
<td>1</td>
</tr>
<tr>
<td>Developmental venous anomaly</td>
<td>1</td>
</tr>
<tr>
<td>Multiple intracranial stenoses (mult. territories)</td>
<td>1</td>
</tr>
<tr>
<td>Fibromuscular dysplasia</td>
<td>1</td>
</tr>
<tr>
<td>Hypoplastic vertebral arteries with fetal PCAs bilateral</td>
<td>1</td>
</tr>
</tbody>
</table>

PCA indicates posterior cerebral artery.

*A single patient could have multiple abnormalities included.

acute stroke evaluation. These studies used CTA (preferably multiphase), magnetic resonance angiogram, or less frequently digital subtraction angiography to identify patients with large vessel, anterior circulation thrombus. For many institutions, CTA remains the most easily and rapidly obtained modality.

These data overwhelmingly support the need for this imaging, yet laboratory tests to evaluate renal function would be far too time consuming for appropriate clinical decision making and delays in onset-to-tPA treatment can reduce the benefit of therapy. In addition, the iodinated contrast bolus required for CTA raises concern for potential allergic or idiosyncratic reactions. Although the risk of contrast-induced nephropathy (CIN) from radiographic tests is generally low, in some subsets of patients, the risk can reach up to 20%. The highest risk of CIN is in those who are diabetic, have underlying kidney dysfunction, or have a combination of both and likely represents a large overlap with patients at high risk for stroke. Other risk factors for developing CIN include cardiovascular disease, collagen vascular disease, nonsteroidal anti-inflammatory drug use, dehydration, paraproteinemia, aminoglycoside antibiotics, and advanced age.

The pathophysiology of CIN probably involves a combination of direct tubular toxicity and renal ischemic injury but remains incompletely understood. There is also evidence suggesting renal dysfunction at admission in patients with stroke is associated with poor outcomes. During emergent stroke evaluation and treatment, patients often have unknown medical histories and are unable to provide this history or history about the aforementioned CIN risk factors. Few studies exist in the literature examining the safety of contrast dye used in this emergent setting. Much of what is available is described in the periprocedural period of cardiac catheterization for myocardial infarction and those studies evaluating stroke patients are small, retrospective, and uncontrolled or use historical control groups. One larger retrospective, uncontrolled study by Ang et al showed a low risk of CIN in their population, in which 16 of 623 cases developed CIN. They additionally showed that these 16 patients all had confounding risk factors for CIN including dehydration, nephrotoxic medication use, and concurrent urinary tract infections.

Our study was devised primarily to evaluate the safety of CT contrast use in our stroke-alerted patient population. As it was retrospective, there was no randomization of patients to receive or not to receive intravenous contrast although ASITs were encouraged to use CTA when there was no clear contra-indication. This allowed for the use of those patients receiving only NCHCT as contemporary controls.

In our population, using intravenous contrast for CTAs during acute stroke evaluations was safe with regard to renal function. There was no statistical difference in renal function 24 to 48 hours after contrast administration, and no statistical difference in the change in creatinine values over this time. Importantly, there was no difference in the percentage of patients developing AKI between controls and of those receiving intravenous contrast for CTA. Interestingly, the overall rate of AKI was slightly higher than in other studies, at 6.3%, although the definition of AKI or CIN varied between studies. This may be the result of differences in contrast agent, technique, and population comorbidities and, therefore, predisposition to developing AKI.

There was, notably, a difference between mean Cr values on presentation (1.39 mg/dL NCHCT, 1.06 mg/dL CTA; P = 0.004) and likewise history of chronic kidney disease between groups (39.4% NCHCT; 15.3% CTA; P < 0.001). These differences are likely because of an innate selection bias because of the lack of randomization in this retrospective study. It is probable that some patients were known to our institution and therefore previous kidney function or medical history was already in the electronic medical record and available to the treating physicians at presentation. In addition, some patients may have been able to relate a history of renal dysfunction, thus prompting avoidance of intravenous contrast. Interestingly, despite these differences on presentation, there was no statistical significance in Cr at the 24- to 48-hour time point.

In treatment of acute ischemic stroke, longer delays mean worse outcomes. Acquisition of advanced imaging requires additional time, planning and skill, increasing risk of human error. In our study population, door-to-needle times for intravenous tPA administration were not affected by the addition of CTA imaging. At the authors’ institution, a final decision to treat with thrombolytics is made after rapid evaluation of the patient and the noncontrasted head CT is obtained, allowing the tPA to be mixed and delivered from the pharmacy during the CTA portion of the examination. In our study, the average door-to-needle time was faster for those who had CTA imaging than for those who did not (68.11 versus 81.36 minutes, respectively). Although these averages were not statistically different in this small population, 13 minutes may be clinically significant when it comes to tPA administration.

CTA revealed 55 instances of high-grade stenosis or occlusions pertinent to the patients’ stroke cause. Of note, only 1 patient in the CTA group with a large vessel occlusion underwent thrombectomy, reflecting practice before publication of positive EVT trials and updated treatment guidelines favoring EVT in...
addition to intravenous tPA for eligible patients. We also identified 16 vascular anomalies, including aneurysms, arteriovenous malformations, evidence of fibromuscular dysplasia, vertebral artery dissections, and an arterial web (Table 3). Although the majority of these abnormalities were not thought to be causative of the patients’ presenting stroke, early identification may help inform their management in the acute stroke setting.

Furthermore, obtaining CTA during the acute evaluation eliminated the need for additional vascular imaging later in the patients’ evaluation. At the authors’ institution, acute CTA acquisition replaced a future magnetic resonance angiogram, likely reducing cost. Adding CTA imaging to the initial evaluation does add radiation exposure although this is difficult to quantify for a given patient or a given scanner and is generally considered acceptable in the setting of acute stroke evaluation.

There are limitations to this study, including those inherent to its retrospective nature. As noted, patients were not randomly assigned to the treatment groups, which probably resulted in the difference in presenting creatinine values and rates of chronic kidney disease as described previously. The decision to obtain a CTA with a particular encounter was at the discretion of the ASIT leader, which likely introduced selection bias. However, clinical decision making based on prestroke renal function is likely to be similar at other large medical centers maintaining the generalizability of our results in real world practice. In addition, creatinine values were recorded at 24 to 48 hours from admission although CIN may present later; this was a limitation in the availability of data, retrospectively.

Conclusions

Overall, CTA acquisition during acute stroke evaluation was safe with regards to renal function and did not delay evaluation or appropriate therapy delivery. Advanced vessel imaging in the acute stroke evaluation has become standard of care after multiple clinical trials supporting its use to identify EVT candidates. Acute CTA acquisition offered additional clinical value in rapid identification of vascular abnormalities, and any additional cost was negligible given it replaced magnetic resonance angiogram typically performed later as standard vessel imaging. This adds to the growing body of knowledge supporting the safety of CTA use in the acute stroke setting.

Disclosures

Dr Worrall serves Associate Editor for Neurology. Dr Southerland: Provisional US Patent 61/867,477; research support from HRSA GO1RH27869-01-00, the American Academy of Neurology, American Board of Psychiatry and Neurology, and the UVA Neuroscience Center of Excellence; speaker honorarium from America’s Essential Hospitals, Palmetto Care Connections, and the Virginia College of Emergency Physicians; Dr Southerland also serves as Deputy Section Editor for the Neurology Podcast. The other authors report no conflicts.

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