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Technical Note

Safety and Feasibility of a CT Protocol for Acute Stroke: Combined CT, CT Angiography, and CT Perfusion Imaging in 53 Consecutive Patients

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Summary: By combining non–contrast-enhanced CT imaging, CT perfusion imaging, and cranial-to-chest CT angiography (CTA), the entire cerebrovascular axis can be imaged during acute stroke. To our knowledge, the safety and feasibility of this technique have not been previously reported. In a consecutive series of 53 patients with suspected acute stroke, renal failure was not observed. Median imaging time was 27 minutes (range, 9–67 minutes). Image quality was degraded by motion in 1.3% of vessels studied. Dynamic CT perfusion data were successfully obtained in 52 patients (98% of patients). High-speed, multisection, helical CT scanners allow rapid, safe imaging of the entire neurovascular axis in patients with acute stroke by use of combined CT imaging, CT perfusion imaging, and CTA.

In the routine diagnosis and treatment of a patient with stroke, the treating physician often orders a battery of tests after the patient undergoes non–contrast-enhanced cranial CT imaging to determine patency of extra- and intracranial vessels. Because treatment decisions such as hospital admission, peripheral or intraarterial thrombolysis, or endarterectomy may be based on these findings, it is desirable to have these data available as soon as possible. Prognostic data obtained by using perfusion imaging would be of additional value. We instituted an imaging protocol whereby non–contrast-enhanced cranial CT imaging, multisection CT perfusion imaging, and CT angiography (CTA) of the entire cerebrovascular axis can be accomplished during acute stroke. We report the safety of this protocol in the first 53 patients imaged at our institution and the feasibility of obtaining all three sequences during a single examination.

Methods

We instituted a CT stroke protocol for all patients with suspected stroke or transient ischemic attack (TIA) at a major urban university hospital beginning April 2000. Patients were placed on IV-infused half–normal saline or normal saline at 1.5 mL/kg/h and transported to the CT suite. Application of the protocol was allowed without prior ascertainment of serum creatinine with the following exceptions: 1) known history of renal failure or recent serum creatinine measurement that exceeded 2.0; 2) history of kidney disease as an adult, including tumor or transplant surgery; 3) family history of kidney failure; 4) insulin-dependent diabetes mellitus of ≥2-year duration; paraproteinemia syndromes or multiple myelomas; 5) collagen vascular disease; and 6) current usage of metformin, aminoglycosides, or nonsteroidal anti-inflammatory drugs (1).

The head and neck were imaged by using a multidetector helical CT scanner (GE Lightspeed; GE Medical Systems, Milwaukee, WI) with the following protocol: non–contrast-enhanced transaxial CT of the brain (contiguous, 3.75-mm-thick sections), dynamic CT perfusion imaging by use of the toggling table technique (2) during the infusion of 400 mL of contrast material (3–4 mL/s, 9-second delay before imaging), and CTA from vertex to aortic arch (110 mL of contrast material with 18–20 gauage IV at 3–4 mL/s; 20-second delay before imaging, 3:1 pitch, section thickness 1.25 mm, 120 kV, 170 mAs).

The first 53 consecutive patients imaged by using this protocol are included in this analysis to accurately report the duration of each study as technologists and physicians became comfortable performing the protocol. Demographic information was obtained from record review. Hospital charts were reviewed by a neurologist (W.S.S.) to determine the hospital discharge diagnosis. The institutional review board approved this retrospective review of patient information. Ischemic stroke diagnosis was further classified as small-vessel (lacunar) stroke or large-vessel stroke on the basis of findings on clinical examination and subsequent imaging studies. TIAs were classified as large-vessel or small-vessel on the basis of presenting signs and symptoms.

Total imaging duration was defined as the time between patient arrival and discharge from the CT suite, and scanning duration was defined as the time between the acquisition of the first and last cross-sectional image. Timing information regarding patient transport to and from the CT suite was not available.

The first, maximum, and hospital discharge creatinine levels were recorded to confirm evidence of renal failure. The time of initial blood draw and the time the serum creatinine findings were available to the treating physician were abstracted to determine which CT scans were obtained before knowledge of creatinine levels.

Results

Patient Demographics

Fifty-three consecutive patients underwent imaging by use of the stroke CT protocol. In all cases, CT scans were obtained to confirm suspected clinical stroke or TIA. Mean age was 71 years ± 14.7

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(mean ± SD); 22 patients were male and 31 female. Upon hospital discharge, 40 (75%) of patients had stroke (n = 37) or TIA (n = 3), and 13 (25%) did not; one patient had an intracranial hemorrhage.

Effect on Renal Function

The average serum creatinine for all patients before imaging was 1.13 mg/dL ± 0.89 (mean ± SD) and at hospital discharge was 1.26 mg/dL ± 1.56 (*P* = .60, *t* test). Two hemodialysis-dependent patients with end-stage renal disease were included; neither had an adverse event. Of the remaining 51 patients, no renal failure was observed. In 28 (53%) of 53 cases, the stroke CT protocol was performed before serum creatinine findings were available, and in five cases, initial creatinine was analyzed after IV administration of contrast medium. On average 73.3 minutes ± 51 elapsed between blood drawing and availability of serum creatinine findings.

Adverse Events

One patient had dye extravasation into the forearm and reported pain at the injection site. No allergic reactions to contrast material were observed.

Duration of Stroke CT Protocol

A median of 27 minutes (range, 9–67 minutes) elapsed from time of patient entry into the CT suite to time of patient exit. Scanning time (from first to last axial image) lasted a median of 22 minutes (range, 6–67 minutes), and 25% of patients were imaged in less than 19 minutes. In no case was thrombolytic treatment prevented by imaging.

Feasibility

The stroke protocol was attempted in 53 consecutive patients. All three series of data (non–contrast-enhanced CT, CT perfusion, and CTA) were obtained in all patients except one in whom CT perfusion imaging was not performed (protocol was not followed by the technician). Dental or other metal artifact impeded visualization in 2.5% of the vascular segments reviewed (46 of 1855; average of two reviewers). Dental artifact most commonly obscured images of the middle and distal carotid segments and the V2 or V3 segments. In no case did dental artifact obscure visualization of the carotid bifurcation or intracranial vessels. Motion artifact degraded the image quality in 1.2% of segments (23 of 1855), and calcification obscured interpretation of stenosis in 0.5% of segments (10 of 1855).

Discussion

CT imaging of the brain is the currently recommended imaging technique for establishing the diagnosis of stroke and TIA because of speed, ability to exclude hemorrhage, wide availability, and clinician familiarity with the procedure (3, 4). Following initial imaging and treatment, patients often undergo a series of imaging procedures to determine the cause of stroke. This usually includes imaging the carotid arteries and echocardiography to reveal potential sources of thrombosis or embolus (3).

These studies are usually performed the same or next day and often are coupled with inpatient admission to expedite the diagnostic evaluation. In addition, some physicians administer heparin until large-vessel occlusive disease is excluded by these studies. Patients may further undergo MR angiography of the intracranial vessels or conventional angiography if suspicion for intracranial atherosclerosis or dissection is present. Thus, many patients who have minor stroke or TIA, who could otherwise avoid inpatient hospitalization, undergo admission to eliminate concern over significant carotid disease or intracranial atherosclerosis. Recent data suggest that one can stratify patient risk for stroke following TIA by careful attention to patient history, which facilitates the decision of whether to expedite patient evaluation (6). In addition to patient history, it seems prudent to offer an imaging sequence that can eliminate the concern for large-vessel stenosis (internal carotid or intracranial vessels) during initial cranial imaging.

The imaging protocol described here provides all of this information in one setting, thus reducing examination time. The protocol is highly feasible in that it took a median of 27 minutes of imaging time (time from entering to exiting the CT suite), and the entire imaging sequence was obtained in 98% of patients. Calcification and motion did not significantly impair interpretation of vascular patency. CTA offers details of the entire relevant neurovascular axis by excluding significant carotid disease (7, 8) and potentially intracranial disease (9). Using no postprocessing images, CTA partition images can be interpreted with high accuracy within the carotid bifurcation (10). The CT perfusion study offers four axial sections centered on the region of clinical interest by using the toggling table technique (2). CT perfusion has been shown to predict stroke location, stroke size, and appears to augment the sensitivity for detecting infarction compared with that of non–contrast-enhanced CT (11, 12). Others have shown that reduced cerebral blood volume, indicating the absence of vascular collaterals, predicts eventual infarction (13). Furthermore, CT perfusion may be an excellent technique to document the presence or absence of vascular collaterals, which may ultimately determine whether a brain tissue infarct will occur (14).

In the emergency acute stroke situation, contrast-enhanced CT imaging can be problematic because of the extra time required to perform additional imaging and the potential for renal failure. For example, in the series reported here, it took on average 73 minutes to obtain the serum creatinine level. If one were to wait this period before performing imaging, patients would undergo excessive delays and the opportunity to treat with thrombolytics might be missed. In the 53 consecutive patients in this series, the administration of iodinated contrast material resulted in no adverse effects beyond one patient who had dye extravasation within the forearm. In more than half of the patients, by using the proper exclusions against IV contrast material listed in the Methods section, IV contrast material was administered before laboratory findings of renal function were established, and no renal failure occurred. Including these additional imaging sequences did increase imaging time, but no patient was precluded from receiving thrombolytics because of this delay. Clinician discretion needs to be applied so that the acquisition of the perfusion and CTA images does not delay treatment.

Conclusion

Coupling non–contrast-enhanced cranial CT imaging with CT perfusion imaging and CTA of the entire crebrovascular axis is safe and feasible. Provided that certain conditions in patient history are met (see exclusion criteria in Methods), emergency administration of IV contrast material is not associated with renal failure. This protocol can expedite patient triage to intraarterial therapy for acute stroke and provide specific information to exclude large-vessel stenosis in patients with TIA or suspected stroke. Implementation of this protocol as the routine imaging protocol for suspected stroke will likely reduce the use of additional imaging studies and may provide a powerful tool to identify patients at high risk for further stroke.

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