Multi-Slice CT Angiography in Diagnosing Total Versus Near Occlusions of the Internal Carotid Artery
Comparison With Catheter Angiography

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**Background and Purpose**—To determine the accuracy of multislice computed tomographic (CT) angiography in diagnosing total versus near occlusions of the internal carotid artery (ICA).

**Methods**—Fifty-seven ICA total or near occlusions identified by catheter angiography were studied with multislice CT angiography 1 to 3 days after catheter angiography. CT angiography in diagnosing total versus near occlusions was analyzed by 2 radiologists independently. The results were compared with those of catheter angiography.

**Results**—Catheter angiography depicted 31 total occlusions, including 10 without a stump, 19 with a stump 2 cm, and 2 with a stump >2 cm. Among them, 22 had a downward extent of the retrograde ICA flow at or above the carotid siphon, 8 at the carotid canal, and 1 at the distal cervical ICA. Catheter angiography depicted 26 near occlusions, including 21 with a tight stenosis at the proximal third cervical ICA, 1 at the middle third, and 4 at the carotid canal or siphon. CT angiography correctly depicted all total and near occlusions. In total occlusions, the length of the stump and the retrograde flow were all accurately described by CT angiography. In near occlusions, the sites of tight stenoses were also correctly identified by CT angiography.

**Conclusions**—Multislice CT angiography had an excellent correlation with catheter angiography in diagnosing total versus near occlusion of the ICA. It may be considered as a substitute of catheter angiography in confirming the ultrasonographic results in diagnosing total versus near occlusions of the ICA. (**Stroke.** 2004;35:83-85.)

**Key Words:** angiography, computed tomographic ■ carotid arteries ■ carotid stenosis ■ computed tomography

An exact differentiation between total and near occlusions of the internal carotid artery (ICA) is important for the therapeutic approach. Patients with occlusive lesions are usually treated medically, whereas patients with near occlusions may benefit from surgery. In the initial workup, these patients are usually examined by color-coded carotid duplex ultrasonography (US). A sensitivity of 86% to 94% for near occlusions and 100% for total occlusions has been reported. In respect of magnetic resonance (MR) angiographic techniques, gadolinium-enhanced 3-dimensional MR angiography was found to be the best MR technique, with a sensitivity of 100% for near occlusions and 100% for total occlusions. With regard to CT angiography, a review of the literature did not reveal any CT angiographic study focusing on the subject. The aim of this study was to evaluate the accuracy of the multislice CT angiography in diagnosing total versus near occlusions of the ICA.

**Subjects and Methods**

**Patients**
Between July 2000 and February 2003, 512 patients with clinical suspicion of ischemic stroke were selected for catheter angiography. A total of 276 of these who had ICA diameter stenosis >60% were selected as potential candidates for multislice CT angiography on the next 1 to 3 days after catheter angiography. Patients were excluded if they declined to enter this study (n=6) or did not have an accessible large intravenous line (n=4). The study protocol was approved by the local medical ethics committee and all patients gave their informed consent. A total of 266 patients were enrolled. Among them, 57 were identified with total or near occlusion of the ICA. Thirty-one of them had totally occluded ICAs (2 women and 29 men; age range, 34 to 83 years; mean, 65.3±12.0 years) and 26 had nearly occluded ICAs (5 women and 21 men; age range, 37 to 84 years; mean, 67.4±11.8 years).

**Catheter Angiography**

Digital subtraction angiography (DSA) of the aortic arch was obtained, followed by selective catheterization of the common carotid arteries (CCA) and vertebral arteries. At least frontal and lateral views were obtained. Delayed imaging was performed in all patients. The images were retrospectively reviewed by 1 neuroradiologist blinded to any clinical and prior imaging results. A near occlusion was defined by the following angiographic criteria: severe stenosis with delayed cranial arrival of ICA compared with the external carotid artery, collateral flow toward the ipsilateral cerebral hemisphere from other arterial territories, and evidence of narrowing

**Comparison With Catheter Angiography**

Multi-Slice CT angiography 1 to 3 days after catheter angiography. CT angiography had an excellent correlation with catheter angiography in diagnosing total versus near occlusions of the ICA. It may be considered as a substitute of catheter angiography in confirming the ultrasonographic results in diagnosing total versus near occlusions of the ICA.
of the poststenotic ICA. For total occlusions, the stump’s length and the downward extent of the retrograde ICA flow were evaluated. The stump was classified into 3 groups: (1) no stump, (2) stump <2 cm, and (3) stump >2 cm. The retrograde ICA flow was divided into (1) at or above the carotid siphon, (2) at the carotid canal, and (3) at the distal cervical ICA groups. For near occlusions, the stenotic site was grouped into (1) at the proximal third cervical ICA, (2) at the middle third, (3) at the distal third, and (4) at the carotid canal or siphon.

CT Angiography
CT angiography was obtained with a 4-slice scanner (LightSpeed; GE Medical Systems). Helical acquisition starting from the aortic arch to the circle of Willis was initiated 20 seconds after the start of injecting 120-mL nonionic contrast medium at a rate of 3 mL/sec. A helical protocol was performed by using a 1.25-mm nominal section thickness, a table speed of 7.5 mm per rotation, and a 0.8-second gantry rotation period. Two radiologists blinded to clinical information were asked to reformat and analyze these images independently. Disagreements were resolved by consensus. All CT angiograms were processed into maximum intensity projections (MIP) and curved planar reformations (CPR). The time invested in each case was 30 minutes. Total occlusion was considered if a long segment of nonenhanced lumen was noted along the cervical ICA. Near occlusion was considered if a continuously enhanced lumen or only a tiny segment of nonenhanced lumen (due to a very tight stenosis) was seen along the cervical ICA. For total occlusions, the stump’s length and the downward extent of the retrograde flow were recorded. For near occlusions, the stenotic site and the thickness of the vascular wall were recorded. Interobserver agreement for lesion detection was evaluated by κ statistics.

Results
Catheter angiography depicted 31 ICA total occlusions, including 10 without a stump, 19 with a stump <2 cm, and 2 with a stump >2 cm (Figure 1). Among them, 22 had a downward extent of the retrograde ICA flow at or above the carotid siphon, 8 at the carotid canal, and 1 at the distal cervical ICA. Catheter angiography also depicted 26 ICA near occlusions, including 21 with a tight stenosis at the proximal third cervical ICA, 1 at the middle third, and 4 at the carotid canal or siphon.

CT angiography correctly depicted all the 31 total occlusions and 26 near occlusions. The sensitivity and specificity of CT angiography in diagnosing total and near occlusions were both 100%. With regard to the stump measurement and the retrograde ICA flow, CT angiography showed 100% correlation with catheter angiography. With respect to identifying the site of tight stenosis, CT angiography also showed...
100% correlation with catheter angiography. The $\kappa$ value (95% CI) for interobserver agreement in evaluating total versus near occlusion, the stump’s length, the retrograde ICA flow, and the stenotic site was 1.000 (1.000 to 1.000), 0.936 (0.814 to 1.000), 0.859 (0.681 to 1.000), and 0.891 (0.670 to 1.000), respectively. In 2 near occlusions, CT angiography demonstrated a hypoplastic carotid canal on axial and reformatted images (Figure 2). With regard to depicting the vascular wall, 2 out of the 26 near occlusions had a diffusely thick and irregular distal wall (Figure 3) and the others had only a focal stenosis along the course of the ICA.

Discussion

Several single-slice CT studies have reported excellent correlation with catheter angiography in depicting high-grade ICA stenoses and total occlusions.4–6 Four-slice CT provides the advantage of speed, which enables imaging of the entire cranio cervical vessels in approximately one third of the time with 1.12 times the spatial resolution of that of single-slice CT.7 The results of our study showed that multislice CT angiography had 100% accuracy in diagnosing total versus near occlusions, classifying stump or retrograde flow of total occlusions, and recognizing stenoses of near occlusions. In addition, multislice CT angiograms helped distinguish the underlying pathology such as dissection or diffusely subtotal thrombosis. Another advantage of CT angiography is to allow observation of the bony structures. Catheter angiography can hint at a hypoplastic ICA, while CT angiography can confirm the diagnosis by finding a hypoplastic carotid canal.

There are disadvantages to CT angiography. One disadvantage shared by catheter angiography is the use of ionizing radiation as well as intravenous contrast and its inherent risks. Another disadvantage is that in contrast to US, catheter, and MR angiographies, CT angiography cannot give information about flow velocity and directionality of flow. Therefore, it is better to conjoin with other modalities if the above information is critical.

In conclusion, multislice CT angiography may be considered as a substitute for catheter angiography in diagnosing total versus near occlusions of the ICA.

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