Spiral CT angiography and selective digital subtraction angiography of internal carotid artery stenosis.

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Spiral CT Angiography and Selective Digital Subtraction Angiography of Internal Carotid Artery Stenosis

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PURPOSE: To determine whether spiral CT angiography allows accurate, quantitative evaluation of anatomic abnormalities, including detection of additional lesions, delineation of plaque morphology, and estimation of degree of internal carotid artery stenosis. **METHODS:** Spiral CT angiography with a maximum intensity projection technique was compared with selective digital subtraction angiography (DSA) in 92 carotid arteries. The category of stenosis was determined according to the North American Symptomatic Carotid Endarterectomy Trial: mild (0% to 29%), moderate (30% to 69%), severe (70% to 99%), and occlusion (100%). **RESULTS:** In 78 (85%) of the 92 cases, spiral CT angiography and selective DSA demonstrated the same degree of stenosis. All occlusions (n = 19) were diagnosed correctly with spiral CT angiography. Spiral CT angiography agreed with selective DSA in the classification of stenosis in 59% of the group with mild stenosis, in 82% of the group with moderate stenosis, and in 90% of the group with severe stenosis. In the groups with mild (n = 13), moderate (n = 9), and severe (n = 27) stenosis, correlation of spiral CT angiography with selective DSA was significant. Calcified plaques were readily diagnosed with the use of spiral CT angiography but delineation of ulcers was poor. Tandem lesions were not visible owing to the limited coverage. **CONCLUSION:** Spiral CT angiography is useful for the detection of proximal internal carotid stenoses that are greater than 30%. Depiction of mild stenoses appears to be limited. CT is superior for the detection of calcified plaques but it is not useful for the detection of ulcers.

Index terms: Cerebral angiography, technique; Arteries, carotid, internal; Efficacy studies

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Spiral computed tomography (CT) angiography is a technique that can be used for the evaluation of carotid artery stenosis. Data from spiral CT angiography can be displayed by using a volume-rendering technique with maximum intensity projection (1–3). The maximum intensity projection technique presents an image similar to an angiogram, unlike that obtained with the surface-shaded display technique (4–6). In prior studies that used spiral CT angiography for the evaluation of carotid arteries, only a small number of cases were reported (1, 3, 4) or limited techniques were used (2). In another study (5), the angiographic technique was not standardized and intervals between spiral CT angiography and angiography varied from 30 to 90 days. The present study was designed to evaluate prospectively the accuracy of spiral CT angiography with maximum intensity projection technique as compared with selective intraarterial digital subtraction angiography (DSA). The degree of stenosis and its morphologic pattern were evaluated with spiral CT angiography and compared with the results of standardized selective angiography in a large group of patients. Collateral flow, tandem lesions, and anatomic abnormalities are discussed with reference to spiral CT angiography.

Materials and Methods

Patients

We prospectively studied 92 internal carotid arteries in 46 patients with symptomatic cerebrovascular disease (27

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men and 19 women; 42 to 80 years old; mean age, 63 years). Exclusion criteria were a history of allergic reaction to contrast material and renal disease. Informed consent for spiral CT angiography and DSA was obtained from all patients. DSA and spiral CT angiography were performed within 2 days of each other.

Selective DSA

All examinations were done with an Integris C 2000 system (Philips Medical Systems, Best, the Netherlands). The carotid studies consisted of selective common carotid angiograms via the femoral approach and included at least three projections (posterior-anterior, lateral, and 45° oblique view). For each projection a contrast bolus of 8 mL iopamidol (200 mg I/mL) (Solutrast, Byk Gulden, Konstanz, Germany) was injected manually. Additional vertebral angiograms were obtained in selected cases.

Spiral CT Angiography

Spiral CT angiography was performed on a Somatom Plus S Scanner (Siemens, Erlangen, Germany). Spiral data were acquired in 32 seconds with a slice thickness of 2 mm and a table speed of 2 mm/s (210 mA; 120 kV); the scanning volume was 62 mm. Scanning was started at the C5-6 disk space and continued cranially following mechanical injection of 100 mL of contrast material (270 mg I/mL) (Imagopaque, Nycomed, Oslo, Norway) into the antecubital vein with a flow of 3 mL/s. Scanning began after a delay of 12 seconds. Axial images were reconstructed every 1 mm. Image reconstruction was initially performed with a volume rendering technique to create angiographic projections from the spiral CT volume scans. On the reconstructed images, a region of interest was selected to eliminate bony structures (spine, calcifications of the larynx) and the internal jugular vein, if necessary. After adjusting the region of interest curve of the different image slabs, seven maximum intensity projection views of each artery were reconstructed every 15° (rotated in the z-axis) using a 256 × 256 matrix. Total postprocessing time was 20 minutes for each carotid artery.

Image Analysis

All studies for each imaging technique were performed by one investigator who was blinded to the results of the other studies. All angiographic projections and all reconstructed views of the spiral CT angiograms were used in the assessment of the degree of stenosis. The degree of internal carotid artery stenosis was expressed as the ratio of the diameter of the narrowest point to the diameter of the internal carotid artery well beyond the bulb according to the North American Symptomatic Carotid Endarterectomy Trial (NASCET) (mild = 0% to 29%; moderate = 30% to 69%; severe = 70% to 99%; occlusion = 100%) (7, 8). The individual arteries were evaluated qualitatively for the presence of calcification, thrombus formation, ulcer, dissection, or other anatomic abnormalities with both imaging techniques. Evaluation for calcification in the DSA studies included review of the unsubtracted images. The categories of stenosis were correlated with the Spearman rank sum test.

Results

Selective DSA

Of a total of 92 selective carotid angiograms, 10 showed normal findings, 22 showed mild stenoses, 11 showed moderate stenoses, and 30 showed severe stenoses. Nineteen internal carotid arteries were occluded. Eighteen arteries (20%) had anatomic abnormalities such as carotid loops (n = 5) and kinking of the internal carotid artery (n = 13). In 23 patients with severe stenosis or occlusion, DSA showed collateral flow via the ophthalmic artery (n = 9), the anterior communicating artery (n = 17), and the posterior communicating artery (n = 6). Tandem lesions were present in seven (9%) of the 82 stenotic arteries (two stenoses in the upper cervical portion of the internal carotid artery and five siphon stenoses). One patient had an additional stenosis of the A1 portion of the anterior cerebral artery. In nine cases of stenosis, a small ulcer was present in the internal carotid artery; in one case, a large ulcer was present. In one vessel a small thrombus was detected in a patient with preocclusive disease.

Spiral CT Angiography

All spiral CT angiograms were technically acceptable. Motion or swallowing artifacts were seen on eight angiograms but did not interfere with the evaluation of stenosis. The bifurcation was always within the scan volume. With the use of multiple reconstructed views, we were able to visualize the region of stenosis in 89 of 92 carotid arteries. Because of circumferential plaques, it was impossible to determine the degree of stenosis on the maximum intensity projection images of three severely stenosed carotid arteries. Additional review of cross-sectional images allowed estimation of the stenosis in two of these three vessels, but no further information was available in the remaining artery.

There was an overall agreement between spiral CT angiography and selective DSA in 78 (85%) of the 92 carotid arteries. All 10 carotid angiograms with normal findings were correctly identified with spiral CT angiography. In the

A B

Fig 1. *A*, Digital subtraction angiogram shows preocclusive stenosis of the internal carotid artery.

B, Spiral CT angiogram with maximum intensity projection technique shows preocclusive stenosis with small calcification in the bifurcation region of the internal carotid artery.

A B

Fig 2. *A*, Digital subtraction angiogram shows coiling of the internal carotid artery with additional severe stenosis.

B, Spiral CT angiogram with maximum intensity projection technique shows coiling of the internal carotid artery with severe stenosis and calcified plaque.

group with stenoses, there was agreement between the methods in 68 (83%) of the 82 carotid arteries (r = .95; P = .0001) as to the degree of stenosis. Among the arteries with mild stenosis, 13 (59%) of 22 (r = .61; P = .0054) were correctly identified with spiral CT angiography, as were 9 (82%) of 11 arteries with moderate stenosis (r = .77; P = .0143) and 27 (90%) of 30 arteries with severe stenosis (r = .86; P = .0001) (Table). Nineteen internal carotid arteries appeared occluded by both spiral CT angiography and DSA. There were no false-positive occlusions diagnosed by using spiral CT angiography.

Calcifications were seen on spiral CT angiograms in 38 (60%) of all 63 stenoses (Figs 1–3). In 56% of these calcified stenoses, calcification was correctly diagnosed by using DSA. One thrombus and nine small ulcers were missed by spiral CT angiography. In two patients there was a dissection of the cervical portion of the internal carotid artery with a long string sign distal to the bifurcation, which extended to just below the petrosal bone. Both were correctly diagnosed by means of spiral CT angiography. Spiral CT angiography missed carotid loops in three of five cases, owing to the limited scan volume.

Discussion

The NASCET and the European Carotid Surgery Trial have shown that symptomatic patients with severe stenosis can benefit from carotid endarterectomy (8, 9). Therefore, preoperative diagnosis requires a technique that is able to depict accurately the degree of stenosis. In accordance with the literature (1, 4–6), our study showed a good (85%) overall agreement between spiral CT angiography and selective DSA for evaluation of internal carotid artery stenosis. Castillo (2) achieved an agreement of only 50%, but his study was limited by the amount of contrast material used (60 mL), the injection flow rate (2 mL/s), and the section thickness used (5 mm).

Differentiation of preocclusive disease from occlusion was possible in all patients studied with spiral CT angiography. Only in the group

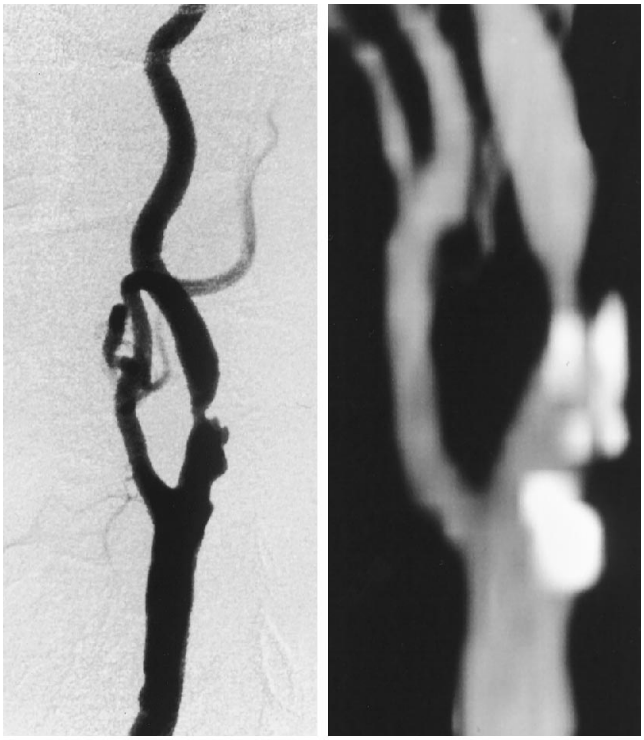

Fig 3. *A*, Digital subtraction angiogram shows severe stenosis of the internal carotid artery with ulcer.

B, Spiral CT angiogram with maximum intensity projection technique shows severe stenosis of the internal carotid artery with calcifications; the ulcer is missed.

with mild stenosis was correlation poor (59%). In two patients, spiral CT angiography overestimated the DSA classification of mild stenosis by two categories; all other estimations were only one category apart. Use of spiral CT angiography allowed us to identify patients who could benefit from carotid endarterectomy, but patients with mild stenosis who should be treated conservatively were missed in 41% of our cases. The inability of spiral CT angiography to depict stenoses with circumferentially calcified plaques was observed in three cases of severe stenosis. Additional analysis of the axial CT scans, as recommended by Marks et al (1), was successful in only two cases. In one of the three patients with circumferential plaques, a reasonable estimation of stenosis was not possible owing to the inability to differentiate calcification from contrast material. Napel et al (3) suggest electronic removal of calcification to judge the degree of stenosis; however, removal of calcification inevitably involves removal of neighboring pixels, which could result in overestimation of stenosis (4).

Spiral CT angiography allows better visualization of calcification than does DSA; calcified plaques were correctly interpreted with DSA in only 56% of our patients. In case of a thrombus, additional observation of cross-sectional images may be useful for detecting a large thrombus, although the one thrombus in our study was missed. As in the study of Schwartz et al (4), delineation of plaque ulceration was very poor by spiral CT angiography, which depicted only 1 of 10 ulcers. Plaque ulceration may have a clinical relevance (10) and may affect surgical therapy, because plaque with ulcer and thrombus may cause cerebral embolism (11). As with sonography and MR angiography (10, 11), detection of plaque ulcerations is limited with spiral CT angiography.

Two dissections of the internal carotid artery in typical locations (12) extending from the bifurcation to the upper cervical portion of the internal carotid artery were well demonstrated with spiral CT angiography. In one patient, the string sign was partially obscured by beam hardening of the teeth, although diagnosis of dissection could be made.

Carotid loops, especially in combination with bifurcation stenosis, may also require a surgical

Correlation of Spiral CT Angiography Maximum Intensity Projections and Digital Subtraction Angiography in Grading Degree of Stenosis

Digital Subtraction Angiography (n = 92)	Spiral CT Angiography (n = 89)*				
	Direct Correlation	Overestimated by One Category	Overestimated by Two Categories	Underestimated by One Category	Underestimated by Two Categories
Normal (n = 10)	10	0	0	0	0
Mild (n = 22)	13	3	2	4	0
Moderate (n = 11)	9	0	0	2	0
Severe (n = 30)	27	0	0	0	0
Occlusion (n = 19)	19	. . .	. . .	0	0

* In three patients with severe stenosis, it was impossible to grade the stenosis by means of spiral CT angiography with a maximum intensity projection technique.

procedure (5). In our study, two such anatomic abnormalities were missed with spiral CT angiography because they were not included in the 6.2-cm-long scan volume. A scan volume of at least 9 to 12 cm in length would have been necessary, and could have been achieved by a larger collimation or a pitch of 1.5 or 2.0. Compared with MR angiography, which suffers from flow artifacts in kinks and loops (13, 14), spiral CT angiography might allow an accurate delineation of kinks and loops when they are in the covered range. No false stenotic lesions were described in kinks and loops by spiral CT angiography.

Collateral flow cannot be evaluated with spiral CT angiography. The impact of collateral flow is of great clinical importance. Poor collateral flow in patients with hemodynamic infarctions may require surgery, even if the stenosis is less than 70%. Carotid occlusion and poor collateral flow in case of hemodynamic infarctions may indicate extracranial or intracranial bypass procedures. Lack of information about collateral flow is a disadvantage of spiral CT angiography that might be compensated for by also performing transcranial Doppler sonography. Recently published studies have not addressed this point (1–6). A major disadvantage of spiral CT angiography as compared with angiography is the lack of information about tandem lesions caused by the limited coverage. Tandem lesions were detected by DSA in 9% of our cases. Tandem lesions may have a higher intraoperative and perioperative risk for cerebrovascular events (15). The main advantage of cerebral angiography is its ability to display the whole vessel, which at present cannot be achieved with any other imaging technique.

A future step for spiral CT angiography could be in allowing the acquisition of unenhanced and enhanced spiral scans with the now available DXP mode, which allows two consecutive spiral scans of 40 seconds. Subtracting these two examinations from each other is possible; however, our first efforts in this direction were disappointing as a result of motion artifacts between the two examinations. This problem could be improved by application of a three-dimensional pixel shift. The postprocessing time of 20 minutes for each artery for removal of calcifications, bones, and sometimes veins seems too long for routine use.

There is controversy about the replacement of DSA for examination of cervical vessels (16–19). Quantification of stenosis is only one important factor in the diagnosis of cerebrovascular disease. Noninvasive techniques like MR angiography, spiral CT angiography, and duplex sonography show a high correlation for accurately depicting the degree of stenosis, with only minor differences among them (12, 14). In our study, however, spiral CT angiography was not successful in delineating mild stenoses. In addition to plaque morphology, the presence of tandem lesions and the impact of collateral flow have to be considered. Taking into account the limitations of the various noninvasive techniques in relation to these points, in addition to the low rate of neurologic complications (0.09% to 0.5%) (20–22) encountered with selective cerebral angiography using a digital subtraction technique, DSA remains the standard for diagnosis of symptomatic patients with suspected stenosis of the internal carotid artery.

Spiral CT angiography may be an alternative technique to DSA for use in high-risk patients who require high doses of heparin. However, in comparison with MR angiography, spiral CT angiography must prove its value. One advantage of spiral CT angiography may be its good differentiation between moderate and severe stenoses, which is a problem with MR angiography along with attendant flow artifacts. Spiral CT angiography may become an additional tool for delineation of the extent of calcification in patients who require interventional therapy for internal carotid artery stenosis.

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