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Helical CT for the Follow-up of Cervical Internal Carotid Artery Dissections

Xavier Leclerc, Christian Lucas, Olivier Godefroy, Henri Tessa, Pascal Martinat, Didier Leys, and Jean-Pierre Pruvo

PURPOSE: **The aim of this study was to assess the changes over time of internal carotid artery (ICA) dissections by using helical CT.**

METHODS: **Twenty-seven patients with 30 angiographically proved ICA dissections were followed up with helical CT at 7 to 62 months (median, 24 months) after conventional angiography. CT scans, analyzed independently by two radiologists in a blinded fashion, were evaluated for the presence of mural thickening, aneurysmal formation, and arterial occlusion. In cases without persisting occlusion or aneurysm, we measured the external diameter of the ICA at its upper segment.**

RESULTS: **The interobserver agreement was good. Mild mural thickening was observed in four cases of 30 previously dissected ICAs. All stenotic and nearly occlusive dissections without an aneurysm (n = 12) reverted to a normal or nearly normal diameter. Half the aneurysms resolved spontaneously (four of eight). Of the 10 occluded ICAs, nine were recanalized, but their external diameter was significantly smaller than that of normal carotid arteries, and a hypoplastic appearance was seen throughout the cervical segment of the ICA in three cases.**

CONCLUSION: **Most arterial lesions tend to improve or disappear spontaneously, but persisting ICA narrowing may be observed in the late course of occlusive-type dissections.**

Dissections of the extracranial internal carotid artery (ICA) are increasingly recognized as causes of stroke, accounting for up to 20% of ischemic strokes in young adults (1). They result from the penetration of blood into the arterial wall, leading to a narrowing or occlusion of the arterial lumen and an enlargement of the external diameter of the artery. Angiography has long been considered the standard of reference for the diagnosis (2, 3), but it carries a risk of complications and does not allow visualization of the external arterial wall. Noninvasive techniques have been used during the acute stage of ICA dissections, including magnetic resonance (MR) imaging (4), sonography (5), and computed tomography (CT) (6, 7); however, except for duplex doppler sonography (5), the value of these techniques for follow-up has not been ascertained.

Helical CT combines continuous movement of the patient with continuous rotation of the gantry, providing rapid data acquisition over a large area during peak contrast enhancement (8). This technique allows excellent visualization of the carotid arteries because of the contrast difference between the enhanced arterial lumen and the surrounding structures. Moreover, the data can be displayed by using a maximum intensity projection (MIP) algorithm, which provides angiogramlike images (9). Most previous studies have used this method to evaluate the degree of carotid stenosis (10–13). In a recent report (14), helical CT was found to be valuable in the diagnosis of extracranial ICA dissection in the acute stage, providing results in close agreement with those obtained at angiography. The presence of a narrowed eccentric lumen in association with enlargement of the overall diameter of the ICA was the best criterion for the diagnosis of acute carotid dissection. In that report (14), helical CT correctly depicted stenoses, occlusions, and pseudoaneurysms. The aim of the present study was to assess the long-term course of arterial abnormalities in extracranial ICA dissection by using helical CT.

Methods

Patients

Over a 58-month period (April 1991 through January 1996), 49 patients were admitted with the diagnosis of ICA dissection, as determined by angiographic criteria. Among the 49 patients, 22 were excluded from the study for the following reasons: lost

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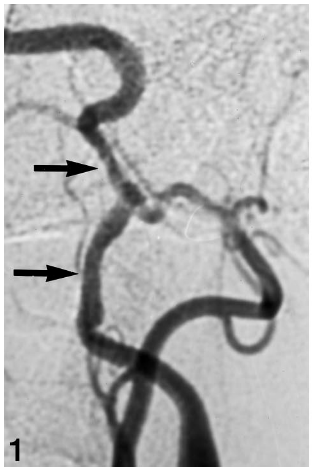

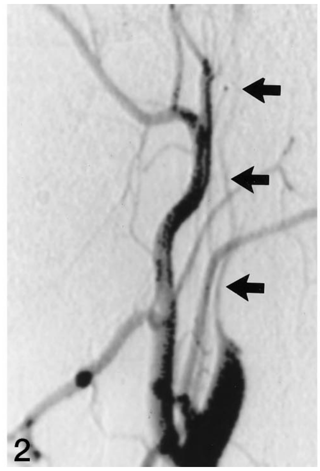

FIG 1. Stenotic dissection of the ICA on conventional angiogram with a moderate and irregular stenosis involving the upper segment of the ICA (*arrows*).

FIG 2. Typical nearly occlusive dissection on conventional angiogram with a severe and long stenosis of the ICA from the bulb to the carotid canal (*arrows*).

FIG 3. Complete occlusion of the ICA on conventional angiogram with a gradually tapering segment (*arrow*) beyond the bulb.

FIG 4. Left ICA dissection on conventional angiogram with a mild and irregular stenosis (*short arrows) below a pseudoaneurysm at the skull base* (*long arrow*).

to follow-up (n = 8), informed consent not obtained (n = 4), inappropriate diagnostic angiography (n = 6), or incomplete workup (n = 4). Long-term follow-up was performed with helical CT in the 27 remaining patients (12 men, 15 women; median age, 44 years; range, 21 to 58 years). The acute clinical presentation consisted mainly of transient ischemic attacks (n = 7), stroke (n = 9), and headache or neck pain (n = 11). Two patients had Horner's syndrome, and three had cranial nerve palsies. Acutely, all patients were treated with heparin for 2 weeks and then received warfarin for a 3- to 6-month period. Angiography was performed within 2 weeks of presentation by the digital subtraction technique through a femoral approach.

The type of dissection present on conventional angiograms was established consensually by an experienced radiologist and neurologist, neither of whom participated in the interpretation of the CT scans. Anteroposterior and lateral views from each carotid injection were interpreted. In all, 30 ICA dissections were found (three patients had bilateral dissections). Each dissected artery was assigned to one of four categories: 1) mild or moderate stenosis with no apparent decrease in flow (Fig 1); 2) nearly occluded, with severe stenosis involving a long or short segment of the ICA, leading to decreased flow in the carotid siphon with opacification of intracranial branches by collaterals of the circle of Willis (Fig 2); 3) occlusion with a gradually tapering segment and loss of opacification of the arterial lumen on delayed films (Fig 3); and 4) an aneurysm in the upper portion of the cervical ICA associated with a narrowed arterial lumen (Fig 4). As usual in extracranial ICA dissections, abnormalities were located at the distal portion of the artery. A complete diagnostic work-up (blood tests, electrocardiography, 24-hour continuous electrocardiographic monitoring, duplex Doppler sonography, and transthoracic or transesophageal echocardiography) was performed to exclude a potential cardiac source of the embolism and atherosclerotic disease.

Helical CT

Helical CT was performed after conventional angiography at a median follow-up delay of 24 months (range, 7 to 62 months). To determine the level of carotid bifurcations, we obtained 5-mm sections without contrast injection from C-2 to C-6 after acquiring a lateral scout view. The gantry was tilted to avoid dental hardware. After selecting a starting point in the last 2 cm of the common carotid artery, we administered 120 mL of nonionic contrast material intravenously at a rate of 3 mL/s by using a power injector via a 20-gauge intravenous catheter inserted into the antecubital vein. Helical scanning, with 35-second continuous exposure, was started 15 seconds after injection of contrast material from the carotid bifurcations to the carotid canal (3-mm collimation, 3-mm/s table speed, 12-cm field of view, 120 kV, 280 mA, 512 × 512 matrix). The total coverage was 105 mm. Patients were instructed to breathe quietly without swallowing during the scanning period. Axial scans were reconstructed at 1.5-mm increments for a total of 70 sections. MIP reconstructions were then used to create angiographic projections. After adjusting the region of interest, we obtained several views of the ICA every 20°, rotated in the z-axis. Total examination time, including MIP reconstructions, was about 30 minutes per patient.

Image Analysis

All CT axial source images were reviewed in a randomized order by two trained radiologists who were blinded to the results of the initial conventional angiography to determine the presence of mural thickening, aneurysmal formation, and arterial occlusion (14). To determine whether enlargement of the external diameter of the ICA, which is the best indicator of acute dissection (4), was still present at the follow-up examination, the external diameter of the dissected arteries without persisting aneurysm or occlusion (n = 25) was compared with the diameter of normal ICAs (n = 23). Orthogonal measurements were made in the last 3 cm below the carotid canal at the site of minimum diameter using magnified axial images and precise computer calipers. When wall thickening was detected, the external diameter included both the arterial lumen and the arterial wall. The window level was determined subjectively to obtain maximum definition of the vascular edge. The average level was preset to 150 Hounsfield units (HU) with a window between 400 and 500 HU. The measurement technique used is in accordance with a recent report by Dix et al (15)

TABLE 1: Comparison of helical CT findings with initial status as assessed at conventional angiography

Lesion Type at Conventional Angiography	No.	No. of Months (range) to Follow-up with Helical CT	Helical CT Findings		
			Mural Thickening	Aneurysm	Occlusion
Stenotic		24 (7–62)			
Without aneurysm	7		1	0	0
With aneurysm	7		0	4	0
Nearly occlusive		21 (9–41)			
Without aneurysm	5		2	0	0
With aneurysm	1		0	0	0
Occlusive	10	27 (7–60)	1	0	1
Total	30		4	4	1

FIG 5. *A*, Frontal view of left ICA on conventional angiogram shows a stenotic-type dissection of the upper portion of the ICA (*arrow*). *B* and *C*, Helical CT findings 9 months later (*B*) at the level of the initially dissected segment show mild mural thickening (*arrowhead*) (external diameter, 7 mm) without evidence of residual stenosis, as seen on MIP reconstruction (*C*).

assessing the accuracy of CT angiography in a model of ICA stenosis.

Statistical Assessment

The first analysis evaluated the interobserver agreement for the assessment of mural thickening, aneurysmal formation, and arterial occlusion by the use of the κ statistic (16), in which a κ value higher than 0.8 was judged to be excellent. Interobserver agreement for the measurement of the external diameter of the ICA was assessed by the method of limits of agreement (17). This test provides an index of the difference between each observer for 95% of observations (95% limits of agreement).

The second analysis consisted of a comparison of the external diameter of the ICA among the four groups defined according to the initial angiographic findings (normal, stenosed, nearly occluded, and occluded) with the Kruskal-Wallis *H* test and subsequent comparisons with the Mann-Whitney *U* test (18). *P* values lower than .05 were regarded as significant.

Results

Conventional angiographic findings during the acute stage showed a bilateral dissection in three patients. The narrowing was judged as mild or moderate in 14 cases and as nearly occlusive in six cases, including four patients with a long-segment hairline residual lumen and two with a short-segment severe stenosis. Complete occlusion of the ICA was observed in 10 cases and an aneurysm was detected near the skull base in eight dissected arteries (Table 1). Follow-up clinical evaluation showed no new neurologic event, and clinical findings were normal in 15 patients. A clinically persistent deficit was found in seven patients, including three with a severe disability. Residual headache or cervical pain was present in six patients.

Each segment of the ICA from the bifurcation to the carotid canal was clearly identified both on axial images and MIP reconstructions. A total volume of 120 mL of contrast material at a rate of 3 mL/s led to good contrast enhancement of the arterial lumen in all cases, despite a moderate opacification of the ICA in its proximal or distal portion in five patients. Artifacts due to dental hardware, motion, or swallowing were encountered in four cases. For these patients, image interpretations and measurements were made on the sections immediately above or below the sections with the artifacts.

Interobserver agreement was excellent for the evaluation of the presence of aneurysm and occlusion (κ = 1.00) and good for the presence of mural thickening (κ = 0.74, $P < .0001$). The assessment of mural abnormalities required a consensus reading because a discrepancy was observed in three cases owing to

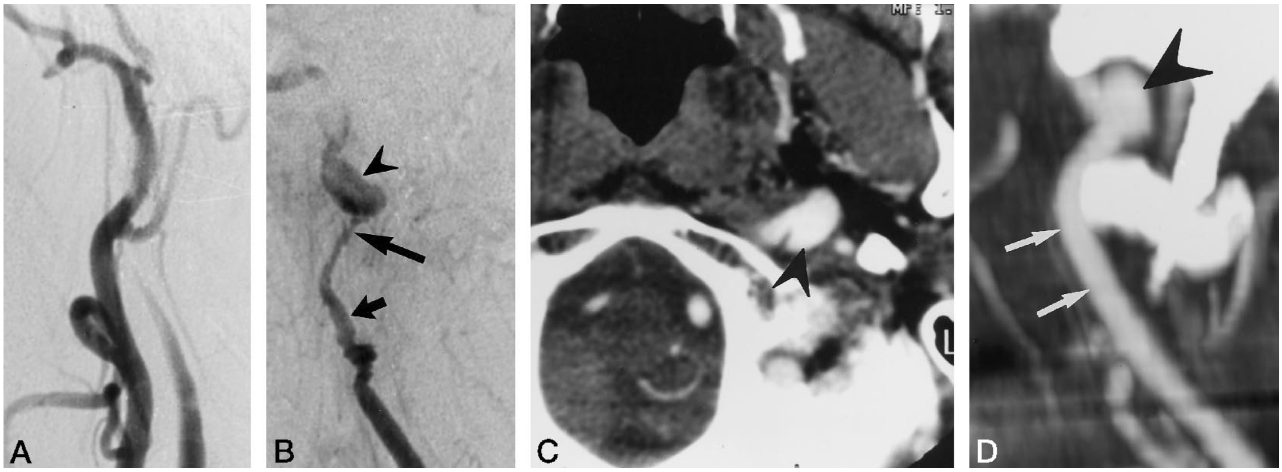

FIG 6. *A* and *B*, Right ICA dissection on conventional early (*A*) and delayed (*B*) angiograms. Nearly complete occlusion is seen, with a moderate and irregular stenosis (*short arrow*) below a severe stenosis (*long arrow*) and an aneurysm (*arrowhead*).

C and *D*, Helical CT study 18 months later shows a persisting aneurysm (*arrowhead*) on both the axial source image (*C*) and the MIP reconstruction (*D*), with a normal diameter of the ICA below the aneurysm (*arrows*).

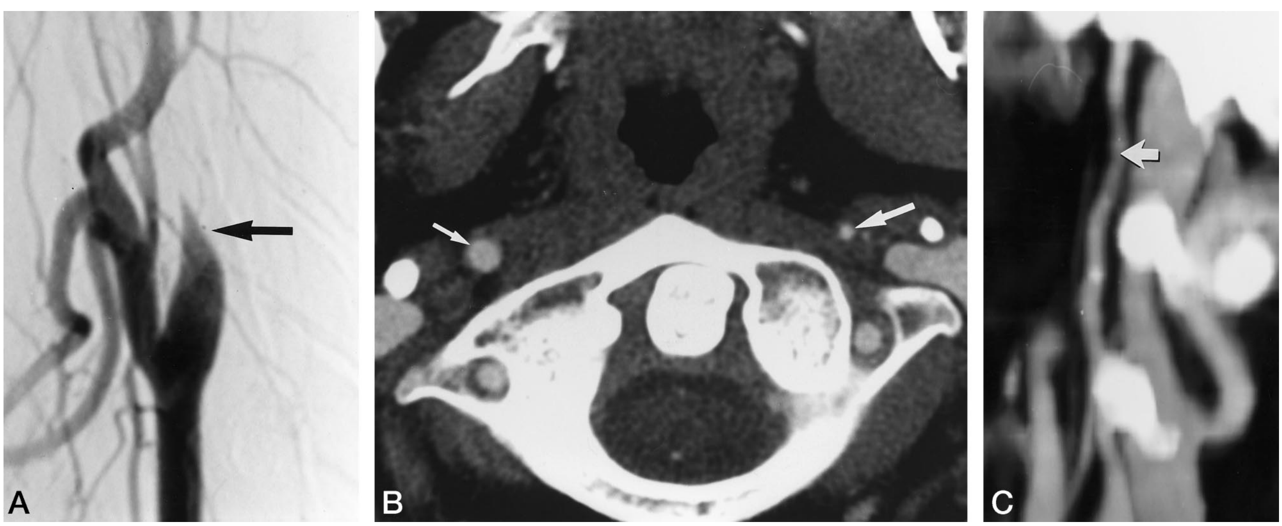

FIG 7. *A*, Conventional angiogram 2 days after onset of symptoms reveals complete occlusion of the left ICA with tapered lumen just beyond the bulb (*arrow*).

B, Axial CT scan 3 years later shows a smaller diameter of the left ICA (*large arrow*) as compared with the contralateral side (*small arrow*).

C, MIP reconstruction shows a severe narrowing throughout the cervical left ICA (*arrow*).

confusion between mural thickening and a node close to the carotid artery. Interobserver agreement for the measurement of ICA diameters was judged as good (the 95% range for agreement was −0.67 to 0.85 mm).

In arteries with initially stenotic or nearly occlusive dissections (n = 12), the follow-up helical CT study was normal in nine cases and showed a mild mural thickening in three cases (Table 1 and Fig 5), with blurred outlines in one case, leading to a poor delineation of the ICA. Among the eight aneurysms seen at initial angiography, only four persisted on helical CT studies (Fig 6). In the occlusive-type dissections (n = 10), a reopening occurred in nine cases on the follow-up CT study, with a mild mural thickening in one case. Among these nine reopened arteries, a diffuse narrowing of the ICA was observed in three cases from its initial portion just beyond the bulb to the skull base, with luminal irregularities on MIP reconstructions (Fig 7).

The external diameter of the ICA measured on follow-up helical CT scans was significantly decreased ($P = .005$) in the group of occluded ICAs seen in the acute stage as compared with the other three groups (normal, stenosed, nearly occluded) (Table 2). This statistic was attributed to five cases in which the diameter was less than 3.5 mm (mean of the normal ICA group, −2 SD).

To illustrate the evolution of CT findings in dissected arteries over time, we provide the CT studies obtained during the acute stage of ICA dissection (14) and during the present, follow-up study in two patients (Figs 8 and 9). These figures show the complete resolution of early CT signs (narrowed eccentric lumen and mural wall thickening in one case and pseudoaneurysm in another case).

Discussion

Heparin is used in most institutions to obviate the risk of ischemic stroke in carotid dissection, although the benefit of such treatment has never been proved in a randomized trial. Anticoagulation is given for 3 to 6 months and, after 6 months, usually no additional treatment is prescribed when the artery reverts to normal. In cases of residual aneurysm, persisting severe stenosis, or underlying arteriopathy, long-term aspirin therapy is often used (19). Thus, knowledge of the time course of a carotid dissection may influence the therapeutic strategy, even if this strategy is not based on randomized trials and remains somewhat empirical.

Noninvasive techniques need to be evaluated as alternatives to the iatrogenic risk posed by conventional angiography in the follow-up of ICA dissections. In this regard, helical CT seems to be the most valuable method for imaging both the arterial lumen and the arterial wall. Moreover, a previous study in a group of patients examined during the acute stage of ICA dissection has shown very good agreement between findings at helical CT and those at angiography (14).

The present study showed that stenotic-type and nearly occlusive dissections tended to heal with only minor residual mural abnormalities, and that disappearance of the aneurysm was observed in half the cases. These findings are in accordance with previous angiographic studies (2, 3, 20) showing that stenoses improve of resolve completely in more than 80% of patients, whereas aneurysms resolve or decrease in size in about two-thirds of cases. No residual stenosis was found in our patients examined by CT, but we cannot exclude the presence of "angiographic residuum," described in 25% of healed dissections in a study by Houser et al (2), since conventional angiography provides higher resolution of the arterial lumen. These residual abnormalities include luminal irregularities related to fibromuscular dysplasia, tortuosities, atheroma, or scar.

The presence of an aneurysm may be the only finding in long-term follow-up of dissection (2). In our study, half the dissecting aneurysms that were present at the acute stage spontaneously disappeared. In one case (Fig 2A), an early angiogram showed apparently complete occlusion, but delayed angiograms revealed a severe stenosis, with an aneurysm at the upper portion of the ICA (Fig 2B). It may be that some aneurysms were already present during the acute stage but not detected because of hemodynamic factors.

Mural thickening is one of the best CT criteria for the diagnosis of carotid dissection in the acute phase (14). Only a few cases of mild thickening were found in the present study, which is in agreement with disappearance of stenosis reported in most previous studies (2, 3), since improvement in stenoses is related to resolution of hematoma.

The long-term course of occlusive dissections remains unclear. In the study by Bogousslavsky et al (21), Doppler sonography showed reopening of the occluded artery in 57% of the patients who survived. In the Mayo Clinic study (3), seven occlusions were reevaluated by intravenous (n = 3) or intraarterial (n = 4) angiography, and reopening was found in two cases (29%). Pozzati et al (22) described 10 patients with occlusive cervical carotid dissection who underwent angiographic follow-up within 6 months; recanalization was demonstrated in eight patients and the

TABLE 2: Comparison of external diameter of the internal carotid artery as measured on helical CT scans with the initial appearance of the carotid artery at conventional angiography

Angiographic Findings	No.	External Diameter, mm	
		Median	Range
Normal	23	4.4	3.5–5.7
Stenotic	10	4.3	3.2–7.4
Nearly occlusive	6	4.7	3.1–6.3
Occlusive	9	3.2	2.4–4.7

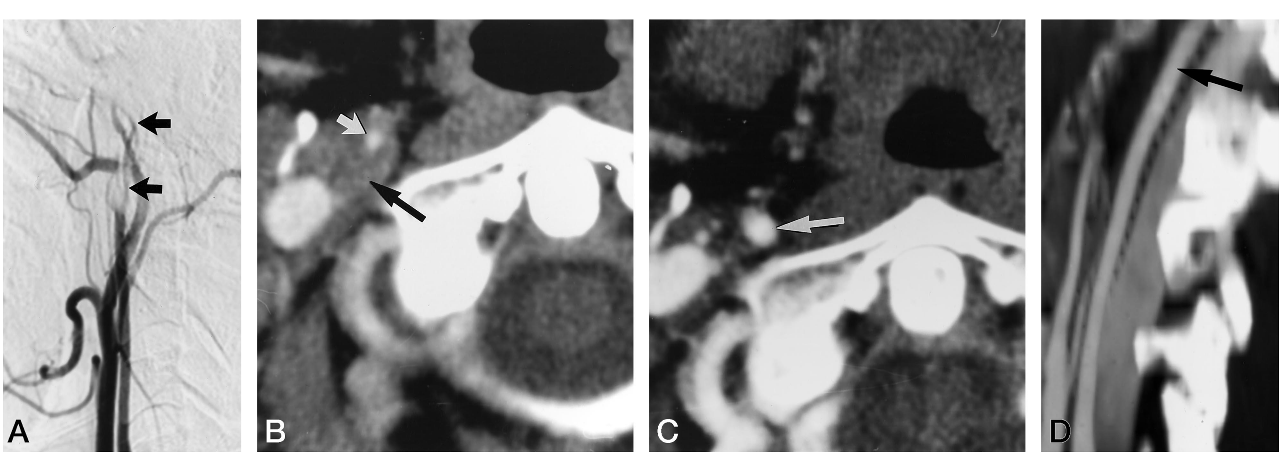

Fig 8. *A*, Conventional angiogram reveals a carotid dissection with a severe short stenosis at the upper segment of the ICA (*arrows*).

B, Axial CT scan at an early stage shows arterial wall thickening (*long arrow*) with an eccentric residual lumen (*short arrow*) leading to enlargement of the overall diameter of the ICA.

C and D, Follow-up CT angiography 2 years later shows complete resolution of the wall abnormalities with a normal arterial lumen on both the axial scan (*C*) and the MIP reconstruction (*D*) (*arrow*).

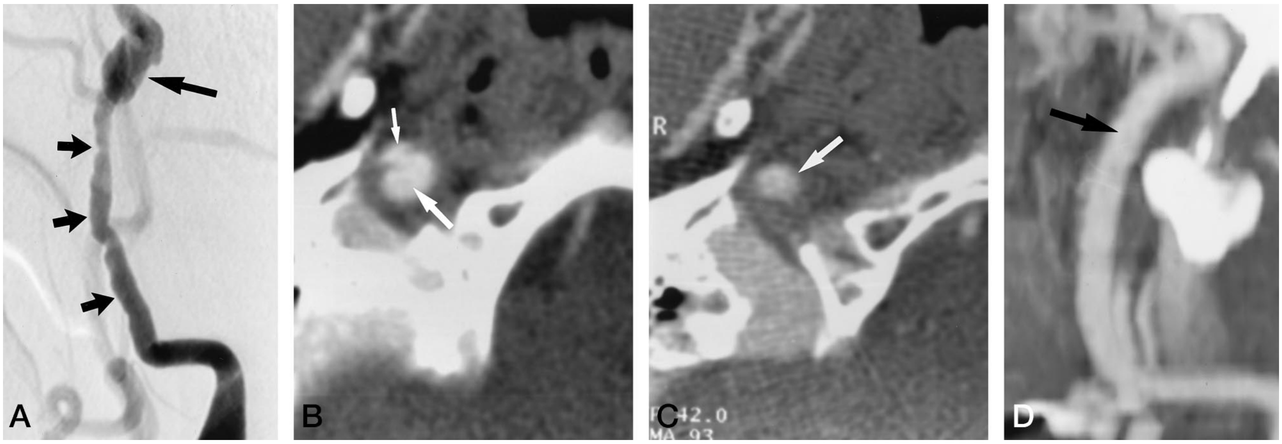

FIG 9. *A*, Dissection of a right ICA on conventional angiogram, showing an association between a long and irregular mild stenosis (*short arrows*) and an aneurysm below the skull base (*long arrow*).

B, Axial CT scan 1 day after conventional angiography shows both narrowed eccentric lumen (*small arrow*) and aneurysm (*large arrow).*

C and D, CT follow-up 29 months later shows resolution of the aneurysm and a normal arterial lumen (arrow) on both the axial scan (*C*) and the MIP reconstruction (*D*).

occlusion persisted in the other two. In our study, recanalization was found in nine of 10 patients. This high reopening rate can be explained by the long interval between conventional angiography and CT follow-up. Despite this reopening, arterial changes remained. The external diameter of the carotid artery was often smaller both in its proximal and distal segment as compared with the normal contralateral ICA. Moreover, a diffuse severe narrowing of the cervical ICA was observed in three cases. Such an appearance contrasts with the ICA enlargement observed during the acute stage and remains poorly documented in the follow-up of carotid dissections. Previous studies have not described in detail residual arterial abnormalities after recanalization, although a partial reopening with persisting luminal narrowing has been reported (1). The smaller ICA diameter observed in the present study shows that partial reopening is not related to a persisting stenosis of the extracranial ICA; instead, it might reflect a fibrous change of the arterial wall resulting from a significant pressure drop over a long period of time. The possibility of a residual stenosis of the ICA in the carotid canal, leading to reduced blood flow and adaptive narrowing of the cervical ICA, cannot be excluded. Another explanation would be a major reduction of hemispheric blood flow due to a large infarct, but no patient with ICA narrowing on helical CT suffered from a widespread infarct. Although the exact mechanism awaits documentation, the present results suggest that the presence of a diffuse narrowing of the cervical ICA may reflect an undiagnosed old dissection.

Conclusion

Helical CT is useful for depicting arterial luminal patency after carotid dissection and for showing residual arterial abnormalities—findings that allow physicians the flexibility to alter the treatment of ICA dissections as appropriate. Previous studies (10–14) as well as the present investigation show that helical CT scans afford good interobserver agreement, and that occlusion, stenosis, and pseudoaneurysm of the cervical ICA are correctly identified. The present follow-up study provides results close to those reported for conventional angiography (2, 3, 20, 22) and demonstrates the value of helical CT in monitoring the alterations of extracranial ICA dissections over time. Despite the ability of Doppler sonography to show recanalization and to enable analysis of residual flow abnormalities (5), its reliability in the assessment of the upper portion of the ICA might be a limiting factor. Helical CT is theoretically superior to MR imaging in the evaluation of aneurysms because of its higher resolution and the absence of flow-related artifacts, but MR imaging might be better for the evaluation of the arterial segment near the skull base because of artifacts on CT scan. Further studies comparing the advantages of these techniques are required.

Acknowledgments

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