Noninvasive Imaging of Carotid Arteries in Stroke

Emerging Value of Real-time High-Resolution Sonography in Carotid Occlusion Due to Cardiac Embolism

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Objective. Comprehension of the pathophysiologic characteristics of atherosclerosis has focused its attention on the study of dynamic and metabolic processes involving the vessel wall as possible causes of stroke. When compared with conventional radiologic techniques, sonography has the main advantage of being a real-time imaging modality. We report 2 acute stroke cases in which carotid sonography showed some dynamic features that could not be identified with computed tomography (CT) and magnetic resonance angiography (MRA).

Methods. Carotid sonography with high-resolution probes (9–14 MHz) was compared with CT and MRA findings showing carotid axis occlusion in 2 patients with acute stroke.

Results. In case 1, the internal carotid artery occlusion observed on CT and MRA was interpreted as a dissection on a clinical basis, but sonography showed a mobile embolus originating from the heart in the internal carotid artery. In case 2, the occlusion of the whole carotid axis observed on CT and MRA was instead related to a heart-originating embolus floating in the common carotid artery.

Conclusions. The evaluation of dynamic aspects of atherosclerosis is fundamental to understanding the pathophysiologic characteristics of stroke. Sonography is fundamental in carotid artery imaging for its possibility of showing dynamic processes that could be misdiagnosed with “static” imaging. The correct identification of the pathophysiologic characteristics of stroke in these cases could have led to different diagnostic and therapeutic algorithms. Key words: acute stroke; carotid artery imaging; high-resolution sonography.

Abbreviations
CT, computed tomography; CTA, computed tomographic angiography; NIHSS, National Institutes of Health Stroke Scale; MRA, magnetic resonance angiography; MRI, magnetic resonance imaging

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Recent advances in comprehension of the pathophysiologic characteristics of atherosclerosis have focused their attention on the study of dynamic and metabolic processes involving the arterial vessel wall as causes of cerebrovascular diseases: inflammation, intimal and plaque neoangiogenesis, and plaque motion have all been considered as mechanisms involved in the transformation of an atheroma into a vulnerable unstable plaque.

Nowadays, several conventional noninvasive radiologic techniques are available for the imaging of carotid arteries. The use of magnetic resonance angiography (MRA), with or without contrast agents, and computed tomographic angiography (CTA) in the evaluation of carotid disease has been largely described in the literature.1-6
Nonetheless, the evolution of radiologic imaging has also focused on the development of a technique that would be able not only to visualize the vessel from its flow but also to characterize the vessel wall disease and functional pathophysiologic characteristics in vivo. In these regards, several new advanced techniques are the objects of study for vessel wall characterization, such as high-resolution magnetic resonance imaging (MRI), single-photon emission computed tomography, positron emission tomography, and near-infrared fluorescence. As a matter of fact, evaluation of the vessel lumen by only indirect visualization of the inward blood flow is no longer considered sufficient to evaluate the stroke risk and, moreover, may lead to misinterpreting results when the images considered are “static.”

The power of sonography in carotid artery imaging is represented by the possibility to perform a “triplex” scan: the B-mode to evaluate the vessel wall, the color and power modes to visualize the blood flow, and the pulsed wave Doppler mode to evaluate hemodynamics. Moreover, all of these features are available in real time so that the sonographer can directly assess the structures during physiologic movements and adjust the visualization while performing the scan to obtain a better image and interpretation. On the other hand, this high operator dependency has caused the sensitivity of sonography to be strictly related to the examiner’s skills and experience, thus reducing its overall sensitivity in clinical studies when compared with conventional radiologic imaging. In recent-generation echographic systems specific to vascular imaging, the availability of high-frequency, high-resolution probes with advanced signal-processing technologies that ameliorate B-mode visualization, such as tissue harmonics and spatial compounding, and the increased quality of color modes, which provide better visualization of inward flow, have greatly increased the diagnostic accuracy of sonography with the advantage of being a relatively low-cost and repeatable bedside technique. Furthermore, the use of sonographic contrast agents for carotid imaging gives the possibility of studying plaque microvascularization, thus making it possible to explore even the pathophysiologic functional aspects of atherosclerosis with sonography.

We report 2 cases of patients with acute stroke in whom sonography showed particular dynamic features that could not be identified by conventional CTA and MRA. The detection of these aspects could have led to a different interpretation of the pathophysiologic characteristics of stroke in these patients, with consequent different diagnostic and therapeutic algorithms.

Case Descriptions

Case 1: The Internal Carotid Artery “Pseudo” Dissection

A 52-year-old man, in an apparent general good state of health and without known vascular risk factors, was admitted to our department for acute onset of dysarthria and left hemiplegia. On admission, the patient was conscious with mild right Bernard-Horner syndrome and dysarthric, with left upper arm hemiplegia and grade 4/5 paresis of the left lower limb. Clinically, he recalled the occurrence of moderately intense neck pain on the right side before symptom onset without a history of traumatic neck injury.

Cerebral computed tomography (CT) and MRI revealed extensive ischemic damage in the right middle cerebral artery territory (Figure 1A). Computed tomographic angiography was performed in the emergency department with an Aquilion 16 multidetector scanner (Toshiba Medical Systems, Co, Ltd, Tokyo, Japan) on a multissection at 135 kV and 250 mAs with a 0.5-mm section thickness. The CT protocol consisted of dynamic helical scanning during contrast agent bolus infusion. Computed tomographic angiography showed the absence of a signal in the right internal carotid artery just after its origin (Figure 1, B–D). On a clinical basis, because the patient was young with no vascular risk factors and considering the neck pain and Bernard-Horner syndrome, the internal carotid artery occlusion was interpreted as consequent to vessel dissection, but considering the lesion extension, anticoagulation was contraindicated and surgical procedures for revascularization were not considered. The patient was treated with aspirin, low-molecular-weight heparin to prevent deep venous thrombosis, and angiotensin-converting enzyme inhibitors.
Carotid sonography (S2000; Siemens Medical Solutions, Mountain View, CA; 9L4 and 14L4 probes, tissue harmonics, and spatial compounding) performed shortly thereafter showed normal common carotid artery intima-media thickness and a mobile clot in the right internal carotid artery with a large hyperechoic head and a thin hypoechoic tail. The thrombus head was attached to the posterior wall of the internal carotid artery just after the origin, and the tail was completely occluding the vessel in the distal tract (Figure 2 and Video 1). This image was clearly suggestive of an embolus originating from the heart. Transcranial Doppler imaging showed asymmetry between the middle cerebral arteries, vasodilated on the right side and with compensation through the anterior communicating and right posterior communicating arteries, activated toward the right anterior circulation. The right carotid siphon was clearly visible and identifiable on transcranial color-coded duplex imaging but with low flow. Echocardiographic findings were within normal limits, with minimal left atrial dilatation and mitral valve regurgitation and prolapse, but accurate patient anamnesis revealed episodes of tachycardia that are still under diagnostic evaluation at present after the first Holter electrocardiographic findings were reported as normal.

**Case 2: The Common Carotid Artery “Pseudo” Occlusion**

An 82-year-old woman affected by arterial hypertension and chronic atrial fibrillation, who was receiving aspirin and antihypertensive treatment, was admitted to our hospital for the sudden onset of left hemiparesis 2 hours previously. On admission, her National Institutes of Health Stroke Scale (NIHSS) score was 10, and she was conscious with mild dysarthria, grade 2/5 paresis of the left upper limb, and grade 3/5 paresis of the left lower limb. She had noncontrolled hypertension (blood pressure, 180/110 mm Hg) and atrial fibrillation with tachycardia (heart rate, 160 beats per minute).

Cerebral CT findings were normal, and MRI showed multiple small areas of altered signal in the right basal ganglia on diffusion-weighted images (Figure 3A). Magnetic resonance angiography was performed with a 1.5-T scanner.
(Gyroscan NT15; Philips Healthcare, Best, the Netherlands) by using a standard contrast MRA protocol. A standard 20-mL dose of 1.0-mol gadolinium was administered with an angiography pump at a flow rate of 3 mL/s. T1-weighted fast-field echo time-of-flight sequences were acquired with a slice thickness of 1.2 mm, number of signal averages of 1, field of view of 250 mm², and matrix of 512 × 512, with the orientation plane parallel to the carotid plane. Raw data were processed in the 2-dimensional maximum-intensity projection mode (15-mm slab). Computed tomographic angiography of the supra-aortic vessels was also performed in the emergency department with the technique described above. Both CTA and MRA revealed the absence of a signal in the complete right carotid axis, occluded 1 cm after the origin of the common carotid artery and extending to the homolateral siphon and M1 middle cerebral artery tract (Figure 3, B–D).

Carotid sonography (S2000; Siemens Medical Solutions; 9L4 and 14L4 probes, tissue harmonics, and spatial compounding) performed 3 hours later showed diffuse common carotid artery intimal thickening and a floating mobile clot in the lumen of the right common carotid artery. The head of the thrombus, which was hyperechoic, was located in the proximal part of the vessel, and the thin tail, attached to the posterior wall of the common carotid artery, extended 3 cm over the bifurcation, floating in the internal carotid artery and occluding the external carotid artery (Figure 4A and Video 2).

Pulsed wave Doppler imaging revealed that flow had a “stop” signal in the proximal common carotid artery (Figure 4B), which, in disagreement with the CTA, was clearly patent and visible. Minimal flow reversal with “backflow” was present in the distal tract of the internal carotid artery, which was however visible with an increase in the color gain (Figure 4C). This image was clearly indicative of an embolus originating from the heart, indicating that the common carotid artery occlusion did not originate locally and was not consequent, for example, to a complicated unstable atheroma. Transcranial sonography was not possible because of an inadequate temporal bone window, and sonographic contrast agents were contraindicated because of the presence of the mobile clot. Both ophthalmic arteries were orthodromic with right-less-than-left asymmetry.

Because of occlusion located in the proximal common carotid artery, and considering the extension of the process to the whole carotid axis, including the homolateral siphon as indicated by CTA, carotid recanalization was not considered possible by the vascular surgeons. Moreover, the patient was not even considered eligible for intravenous thrombolysis and received an aspirin bolus and antihypertensive treatment with angiotensin-converting enzyme inhibitors. Eighteen hours from symptom onset, she showed minimal recovery: her dysarthria was partially improved; she had grade 3/5 hemiparesis of the left upper limb and grade 4/5 hemiparesis of the left lower limb; and her NIHSS score was 6. Her blood pressure was controlled (160/90 mm Hg), and her heart rate was reduced (100 beats per minute), but she was highly arrhythmic. She then started receiving anticoagulants.

The patient was considered for eventual acute mechanical thrombus retrieval but 19 hours later, ie, 37 hours from symptom onset, a right forced head gaze and complete left hemiplegia developed, and her NIHSS score was 19. Cerebral MRI showed extensive ischemic damage in the entire right middle cerebral artery territory (Figure 5A) with occlusion of the middle cerebral artery. A new carotid sonographic scan was performed. The embolus in the common carotid artery was now less evident (Figure 5B); the distal
tail was visible for 2 cm in the internal carotid artery; and the distal part of the vessel was now detectable in a tract longer than 1.8 cm (Figure 5C). Flow was increased in the common carotid artery and, in particular, the distal part of the internal carotid artery with disappearance of the backflow (Figure 5D). Anticoagulants were at this point discontinued, considering the size of the lesion.

Discussion

In the past, digital subtraction angiography was considered a reference standard imaging technique for carotid stenosis evaluation because of its capability of imaging the arterial lumen through direct visualization of contrast agent flow in the vessel, thus helping in the understanding of even functional hemodynamics. Nevertheless, apart from its invasiveness, a limitation with this technique is the impossibility of simultaneously visualizing the vessel wall along with the vessel lumen, thus missing important information on plaque structure. Moreover, contrast agent injection under pressure in selective angiography can alter the nominal flow characteristics of an otherwise impaired vessel, making the vessel appear normal. The development of imaging technologies, first with B-mode sonography, then with CT and MRI, and then with more recent functional imaging, brought more relevance to evaluation of the vessel wall: since the 1990s, evaluation of carotid plaque morphologic characteristics has been considered, along with degree of stenosis, a fundamental predictor of stroke risk. In this regard, CT and MRI have very high potential, but their interpretation may sometimes be difficult because part of the image is derived from the signal of the blood movement in the vessel, and low-flow conditions as well as turbulence may hamper correct vessel visualization, with the consequent well-known limit of MRA, which may overestimate the degree of vessel narrowing or occlusion. Moreover, conventional radiologic imaging with CT and MRI is static and interpreted on images processed from an already acquired signal. On the contrary, sonography offers the unique possibility of visualizing vessels in real time and to couple a morphologic study with evaluation of hemodynamics, which is fundamental for completely understanding vascular pathophysiologic characteristics.

Two cases of acute ischemic stroke have been presented here, in which the conventional radiologic imaging was suggestive of “large artery disease,” ie, occlusion of the internal carotid artery due to dissection in the former and of the common carotid artery due to atherosclerotic disease in the latter. High-resolution carotid sonography showed that the occlusion was not provoked locally by the rupture of an unstable atherosclerotic plaque or by dissection but was due to an arterial embolus with morphologic characteristics (the large hyperechoic head with the thin floating mobile hypoechoic tail) that clearly identified an embolus originating from the heart, in the absence of a relevant local atherosclerotic burden.

Although in case 1 the extensive cerebral damage per se, along with the occlusion of the complete extracranial segment of the internal carotid artery, did not allow any kind of surgery, in case 2 it may be argued that urgent surgery with, for
example, intra-arterial mechanical embolectomy could have prevented further deterioration of the clinical state, as also described in other case reports for other vascular regions as well as for cerebrovascular diseases,22–24 but, unfortunately, the patient’s clinical condition deteriorated before this solution could be done. Mechanical embolectomy with thrombus-retrieving devices is indeed a well-defined emergent surgical indication in peripheral arteries because of the occurrence of distal limb ischemia and necrosis.22 With regard to cerebrovascular diseases, in the Mechanical Embolus Removal in Cerebral Ischemia trial,24,25 thrombus retrieval with a mechanical device was shown to be useful in terms of vessel recanalization in cases of terminal internal carotid artery occlusion, when coupled with thrombolytic pharmacologic therapy, even though such an approach is feasible only in highly specialized centers. Early identification of intra-arterial floating emboli, with respect to thrombosis originating locally on a ruptured unstable plaque, may identify subgroups of patients that could benefit more from this invasive approach.

In conclusion, sonographic technology shows high potential because of the possibility of investigating hemodynamics in real time. The diagnostic accuracy in vascular diagnoses can be increased by a multimodal approach with conventional radiologic imaging, including CT and MRI, but also considering highly specific and sophisticated sonographic devices with high-resolution probes from the very beginning. Integration of the results from several imaging techniques, each carrying its own advantages and disadvantages, can be more useful than a single approach in defining the pathophyslogic characteristics of stroke, with consequent appropriate diagnostic and therapeutic approaches.

References


