Embolic Stroke after Carotid Stenting

Microscopic Computed Tomography Analysis of En Bloc Surgical Specimen Demonstrating Ulceration

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The precise sequence of events leading to carotid plaque vulnerability is as yet unknown, and the majority of ischemic strokes seem to result from atherosclerotic plaque rupture or thrombus propagation at the carotid bifurcation.\(^1\) Traditionally, the surgical approach of carotid endarterectomy is well accepted for the treatment of symptomatic and severe asymptomatic carotid stenosis.\(^2,3\) More recently, carotid artery stenting has arisen as the preferred, less invasive technique for the treatment of symptomatic and asymptomatic severe stenosis in patients with anatomically or physiologically high-risk features.\(^4,5\) To date, the mechanisms of recurrent stroke after carotid artery stenting have not been well characterized.

A 79-year-old woman with a history of recurrent left hemispheric strokes underwent surgical resection of her left carotid artery 3 years after its stenting. The patient initially presented with recurrent ischemia after a left hemispheric stroke. Carotid ultrasound revealed a severe unilateral left internal carotid stenosis (peak systolic velocities were measured to be 408 cm/s with an internal carotid artery/common carotid artery ratio of 8.87). The patient was enrolled in the Carotid Revascularization Endarterectomy versus Stent Trial and randomized to receive a stent.\(^6\) A tapered 8 mm to 6 mm×40 mm open cell self-expanding stent (Acculink, Abbott Vascular, Abbott Park, IL) was implanted and postdilated to 4.5 mm without complication. The patient did well for 26 months, at which time she presented with transient aphasia. Magnetic resonance imaging revealed acute infarcts in the left postcentral gyrus, frontoparietal, and insular regions. Carotid duplex doppler, carotid computed tomographic angiography, and transesophageal echocardiography did not identify a source of embolus. Clopidogrel was added to her existing medical regimen of aspirin, atorvastatin, and lisinopril. Ten months later, the patient again presented with recurrent aphasia and evidence of extension of her left parietal cerebral infarction on magnetic resonance imaging. Images from cervical radiography and computed tomographic angiography of the neck were interpreted as representing stent fracture with an ulcerated plaque. On the basis of these findings, left carotid artery resection with the placement of a 6-mm polytetrafluoroethylene interposition graft (Gore Propaten, W.L., Gore & Associates, Inc., Flagstaff, Ariz) between the common and internal carotid arteries with ligation of the external carotid artery was performed.

The explanted carotid artery was formalin fixed, infused with a bismuth gelatin solution, and scanned using a GE eXplore SP MicroCT scanner (GE Healthcare, London, Canada) with 2-dimensional and 3-dimensional reconstruction at 38-μm resolution. The 3-dimensional reconstruction revealed a complex calcified eccentric plaque opposite the external carotid artery origin extending proximally (~8.9 mm) and distally (~14.2 mm) from the carotid bifurcation (Figure 1). Two discrete ulcerations within the plaque, 1 at the level of the common carotid (~2.0 mm proximal to the bifurcation) and the other in the internal carotid artery (~9.6 mm distal to the bifurcation) were also noted (Figure 1). The spatial relationship between the plaque ulcerations, the stent, and the lumen can be better appreciated in the rotating 3-dimensional reconstruction (Movie 1 of the online-only Data Supplement). Tomographic slices (Figure 1 and online-only Data Supplement Movie II) confirmed the presence of 2 discrete complex ulcers with filling defects extending proximally and distally within the plaque. Covering the ostia of these ulcers were stent struts that were not incorporated into the vessel. No stent strut fractures were observed.

After scanning, the specimen was embedded in methyl methacrylate, sawed, ground, and polished by an EXAKT grinder (EXAKT Technologies, Inc., Oklahoma City, Okla) for histological evaluation. A total of 24 serial sections (40 to 50 μm at 2-mm intervals) were prepared and stained with toluidine blue and basic fuchsin.\(^7\) Histological evaluation confirmed a complex fibroatheroma with ulcerations at the level of the common and the
internal carotid arteries corresponding to the microscopic computed tomographic findings (Figure 1). Figure 2 shows the ulceration of the plaque at the level of the common carotid with 5 stent struts overlaying the ostium of the ulcer that are not covered by endothelium. Thrombus at varying stages of organization is present within the ulcer and adjacent to 3 noncovered stent struts. The remainder of the stent is covered by neointimal tissue consisting of

Figure 1. En bloc resection of stented carotid artery: microscopic computed tomography (composite 3-dimensional and segmental axial tomograms) with histological correlates. Microscopic computed tomography (3-dimensional reconstruction and axial tomograms) in black box along with corresponding histological sections (right column) of resected carotid artery. The 3-dimensional reconstruction reveals a complex calcified eccentric plaque opposite the external carotid artery origin. Two discrete ulcerations are seen within the plaque, one at the level of the common carotid (orange solid arrow) and the other in the internal carotid artery (orange dashed arrow). The extravascular calcification is reconstructed in blue, the luminal fill in red, and the stent in white. Microscopic computed tomographic section and histological correlates are shown at level of the internal carotid (A), bifurcation (B), distal common carotid (C) and proximal common carotid (D).

Figure 2. Histological cross-section of the stented common carotid plaque ulceration. Histological cross section of the distal common carotid artery (Figure 1C) stained with toludine blue and basic fuchsin, demonstrating plaque ulceration. The ulcer is in direct communication with the lumen of the artery; across its mouth are 5 bare struts not covered by endothelium, 3 of which are associated with thrombus (*). Thrombus is also noted deep in the ulcer crater, likely representing the source of the patient’s recurrent strokes. The amorphous homogenous material attached to the bare struts within the lumen and the ulcer is a remnant of the bismuth fill remaining after processing.
smooth muscle cells in a proteoglycan-collagen matrix. These images of a stented carotid artery with underlying plaque ulceration demonstrate a novel mechanism for recurrent stroke after carotid artery stenting.

Disclosures
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