Effects of Carotid Endarterectomy or Stenting on Arterial Diameters in the Circle of Willis

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Background: In patients with internal carotid artery (ICA) stenosis, the circle of Willis (CoW) is the primary collateral pathway. We compared luminal diameters in the CoW before and after carotid revascularization and compared the effects of carotid endarterectomy (CEA) and stenting on these diameters. *Methods:* At a single center in the International Carotid Stenting Study, 139 patients with symptomatic ICA stenosis of 50% or more were randomized to stenting (n = 81) or CEA (n = 58). The diameters of all segments of the CoW were assessed on computed tomography angiography (CTA), before and 30 days after revascularization. All evaluations were performed blinded to treatment allocation and order of CTA. *Results:* A .10-mm increase (95% confidence interval [CI], .02-.17; 7%; $P = .01$) in diameter after revascularization occurred in the ipsilateral precommunicating anterior cerebral artery (A1), whereas both the ipsilateral and contralateral posterior communicating arteries decreased in diameter by .12 mm (95% CI, .04-.21; 14%; $P = .01$) and .08 mm (95% CI, .00-.17; 10%; $P = .05$), respectively. The increase in diameter of the A1 was larger after stenting (.15 mm; 95% CI, .07-.24; $P = .001$) than after CEA (.02 mm; 95% CI, −.11 to .15; $P = .79$). Only in patients treated with CEA, the diameters of the contralateral A1 and ipsilateral precommunicating posterior cerebral artery were reduced after revascularization. *Conclusions:* Carotid revascularization improves anterior collateralization and reduces reliance on posterior collateral pathways via the CoW. Carotid stenting and endarterectomy appear to have different early effects on collateralization. **Key Words:** Stroke—circle of Willis—carotid endarterectomy—stents—randomized clinical trials.

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Received March 24, 2013; revision received May 16, 2013; accepted June 10, 2013.

The International Carotid Stenting Study was funded by the Medical Research Council (and managed by the National Institute for Health Research on behalf of the Medical Research Council–National Institute for Health Research partnership), the Stroke Association, Sanofi-Synthélabo, and the European Union. M.M.B.'s Chair in Stroke Medicine is supported by the Reta Lila Weston Trust for Medical Research. This work was partly done at the University College London Hospital and University College London, which received a proportion of funding from the Department of Health's National Institute for Health Research Biomedical Research Centre funding schemes. H.B.v.d.W. is supported by a grant from the Dutch Heart Foundation (2010T075).

Disclosure: A.A. has received funding for travel and speaker honoraria from Boehringer Ingelheim. L.J.K. has received funding for travel and speaker honoraria from the Netherlands Heart Foundation and Boehringer Ingelheim. H.B.v.d.W. has received speaker's honoraria from Servier, GlaxoSmithKline, and Sanofi Aventis and served as a consultant to Bristol-Myers Squibb. The other authors have no disclosures.

Conflict of interest: None.

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1052-3057/$ - see front matter

http://dx.doi.org/10.1016/j.jstrokecerebrovasdis.2013.06.020

Introduction

In patients with symptomatic internal carotid artery (ICA) stenosis, the risk of stroke increases with increasing severity of the stenosis[1] and compromised ipsilateral cerebral perfusion.[2-5] In these patients, the circle of Willis (CoW) is the primary collateral pathway to redistribute blood from the contralateral ICA or basilar artery to the territory of the affected ICA.[6] Collateral flow via the CoW can be provided via the anterior communicating artery (ACoA) and the right and left precommunicating anterior cerebral arteries (A1 segments) and also via the ipsilateral posterior communicating artery (PCoA) and precommunicating posterior cerebral arteries (P1 segments).[6] The collateral ability of the CoW is determined by the presence and the luminal caliber of these segments.[6,7] Several studies have suggested that in patients with ICA stenosis, the risk of stroke is increased if these collateral pathways are impaired.[8,9]

Luminal diameters of segments of the CoW have been demonstrated not to be static. The diameter of all segments of the CoW, as assessed with magnetic resonance angiography (MRA), was smaller several months after carotid endarterectomy (CEA) than before.[10] Studies with transcranial Doppler or MRA have also shown considerable changes in collateral flow through the CoW in the first day or week after carotid artery stenting (CAS),[11,12] but changes in luminal diameters have not been studied after CAS.

The aim of the present study was to compare luminal diameters of segments of the CoW before and after carotid revascularization and to compare the effects of CEA and CAS on these diameters.

Materials and Methods

Patients

All patients in the present study are participants in the International Carotid Stenting Study (ICSS; ISRCTN25337470) at the University Medical Center Utrecht (UMCU), The Netherlands. The ICSS is an international, multicenter, randomized, controlled, open, clinical trial comparing the risks, benefits, and cost-effectiveness of CAS and CEA in patients with a recently symptomatic ICA stenosis of 50% or more. Patient criteria, randomization, and the results of an interim safety analysis have been described elsewhere.[13] Baseline demographic, clinical, and carotid imaging data were collected as part of the ICSS. From October 2003 to September 2007, computed tomography angiography (CTA) of the neck and brain before and 30 days after revascularization was performed in the ICSS participants randomized to CAS at the UMCU and from April 2004 also in patients randomized to CEA. During this period, 206 patients were enrolled in the ICSS at the UMCU, of whom 139 were included in this study. Fifty-eight had been randomized to CEA and 81 to CAS. Reasons for exclusion are shown in Figure 1. In 18 cases (8.7%), the reason for not performing CTA at both time points was unknown. Because of the absence of a medical reason for not performing CTA in these 18 patients, the most likely reason for their exclusion was logistical as well, but this was not reported in the patient charts.

The Medical Ethics Review Board of Zuidwest Holland and the Medical Ethics Review Board of the UMCU had approved the study protocol, and written informed consent was obtained from each patient.

Carotid Revascularization

Patients underwent CEA under general anesthesia or CAS under local anesthesia. Surgery was performed by an experienced vascular surgeon or vascular fellow under supervision. Two experienced neurointerventional radiologists performed all stenting procedures. In patients randomized to stenting, clopidogrel in a daily dose of 75 mg was started at least 4 days before stenting and was continued for 4 weeks thereafter, in addition to standard antithrombotic treatment. The peak systolic velocity (PSV) in the ipsilateral ICA was assessed with duplex ultrasonography before and 30 days after revascularization.

The CTA

CTA was performed before revascularization and at 30 days thereafter with a 16-, 40-, or 64-detector row scanner (Philips Medical Systems, Cleveland, OH), as described elsewhere.[14]

CTA was performed after intravenous injection of 80 mL of contrast material at 5 mL/s, followed by a saline chaser bolus of 50 mL injected at the same flow rate. The delay before computed tomography (CT) data acquisition was determined from a test bolus that consisted of an injection of 40 mL contrast material that was used for a brain perfusion study.[14]

We used 16 × .75-mm, 40 × .625-mm, or 64 × .625-mm collimation with a pitch between .77 and .85 (dependent on the CT system options) and a rotation time of .42 seconds. To keep the differences between CT systems as small as possible, we reconstructed overlapping sections of 1.0 mm slice thickness (16 detector rows) or .9 mm thickness (40- and 64-detector rows) at a reconstruction interval of .5 mm and a field of view of 160 mm. The resulting pixel size on axial images was .31 mm^2. A moderately smoothing filter was applied (filter B) on all CT systems. We employed 120 kVp tube voltage and 180 mA (effective) with all CT system scanners.

CT Analysis

The CTA images were sent to a dedicated CT workstation (Extended Brilliance Workspace; Philips, Best, The Netherlands) for evaluation. For each patient, the