JACC: CARDIOVASCULAR INTERVENTIONS
VOL. 7, NO. 11, 2014

ISSN 1936-8798/$36.00
PUBLISHED BY ELSEVIER INC.
http://dx.doi.org/10.1016/j.jcin.2014.05.021

# Predictors of Carotid Occlusion Intolerance During Proximal Protected Carotid Artery Stenting

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## ABSTRACT

**OBJECTIVES** The aim of this study was to identify predictors of occlusion intolerance (OI) developing during proximal protected carotid artery stenting (CAS).

**BACKGROUND** The use of proximal embolic protection devices, such as endovascular occlusion, during CAS has been demonstrated to be particularly safe and effective. However, endovascular occlusion can expose the ipsilateral hemisphere to hypoperfusion and produce transient neurological symptoms (OI).

**METHODS** From March 2010 to March 2012, 605 consecutive patients underwent proximal protected CAS at our institution. To identify independent predictors of OI, a multivariate logistic regression model was developed that included all patients' clinical/angiographic and procedural characteristics.

**RESULTS** OI developed in a total of 184 patients (30.4%). Compared with patients in whom OI did not develop, those who experienced OI had lower occlusion pressure (OP) (42.3 ± 12.7 mm Hg vs. 61.9 ± 15.4 mm Hg, $p < 0.001$). Receiver-operating characteristic curve analysis demonstrated that OP was the most consistent predictor of OI with a C-statistic of 0.85 (95% confidence interval [CI]: 0.82 to 0.88) with best cutoff being ≤40 mm Hg (sensitivity, 68.5%; specificity, 93.3%). By logistic regression analysis, the most powerful independent predictor of OI developing was an OP ≤40 mm Hg (odds ratio: 33.2, 95% CI: 19.1 to 57.7) and the most powerful clinical predictor of such OP was the presence of contralateral internal carotid artery occlusion (odds ratio: 3.1, 95% CI: 1.5 to 6.2).

**CONCLUSIONS** OI may occur in as many as one-third of the patients undergoing proximal protected CAS. This event is more common in those patients with an OP ≤40 mm Hg. Patients presenting with concomitant occlusion of the contralateral internal carotid artery more frequently have an OP ≤40 mm Hg. (J Am Coll Cardiol Intv 2014;7:1237–44)


Current guidelines recommend use of an embolic protection device (EPD) during carotid artery stenting (CAS) (1). Among the EPDs that are in clinical use, proximal EPDs have the advantage to provide cerebral embolic protection during all phases of the endovascular intervention (2). The use of endovascular occlusion, a proximal EPD, during CAS has been demonstrated to be particularly safe and effective in large registries and clinical trials (3,4). Moreover, the use of a proximal EPD has been associated with a reduced amount of cerebral embolization signals compared with distal protection devices (5).

Proximal EPDs act through the occlusion of the common carotid artery (CCA) and expose the ipsilateral cerebral hemisphere to the risk of hypoperfusion

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Manuscript received March 8, 2014; accepted May 8, 2014.

**ABBREVIATIONS AND ACRONYMS**

**ACT** = activated clotting time
**CAS** = carotid artery stenting
**CCA** = common carotid artery
**CI** = confidence interval
**ECA** = external carotid artery
**EPD** = embolic protection device
**ICA** = internal carotid artery
**MACE** = major adverse cardiac event(s)
**OI** = occlusion intolerance
**OP** = occlusion pressure
**OR** = odds ratio

with consequent transient neurological symptoms (occlusion intolerance [OI]) (2,4).

The ability to predict in advance the risk of OI, which is relatively frequent (3,4), might help the operators to be ready to deal with this event.

Thus, the aim of the present study was to identify the predictors of developing carotid OI during proximal protected CAS.

## METHODS

**STUDY POPULATION.** From January 2010 to March 2012, 605 consecutive patients underwent CAS using endovascular occlusion with a proximal EPD at our institution. Inclusion criteria were the degree of internal carotid artery (ICA) stenosis, determined by angiography according to the North American Symptomatic Carotid Endarterectomy Trial Criteria (3): 1) asymptomatic stenosis ≥80% and 2) symptomatic stenosis ≥50%. Symptomatic was defined a carotid stenosis occurring within 6 months before the intervention, with amaurosis fugax, ipsilateral hemispheric transient ischemic attack, or ipsilateral ischemic stroke not resulting in a major residual neurological deficit (stroke scales: Barthel score ≤60; National Institutes of Health Stroke Scale score ≥15, or Rankin Scale score >3).

Patients with the following criteria were excluded: 1) presence of a critical stenosis of the ipsilateral CCA; occlusion of the ipsilateral external carotid artery (ECA); 3) contraindication to thienopyridines; and 4) refused to provide informed consent before enrollment.

**CLINICAL ASSESSMENT.** In each patient, clinical history and risk factors were assessed. Smokers included current and former smokers. Hypertension was diagnosed if the systolic arterial pressure was >140 mm Hg and/or diastolic arterial pressure was >90 mm Hg on repeated measurements or if the patient used antihypertensive drugs. Hypercholesterolemia was diagnosed if plasma total cholesterol was >200 mg/dl, plasma low-density lipoprotein cholesterol was >130 mg/dl, or if the patient used lipid-lowering drugs because of a history of hypercholesterolemia. Diabetes mellitus was diagnosed if plasma fasting glucose was >126 mg/dl or if the patient used hypoglycemic agents. Hospital records documented previous cardiovascular events or other comorbid conditions.

**TECHNIQUE OF THE CAS PROCEDURE.** All procedures were performed percutaneously with the patient under local anesthesia. At the procedure start, an 8- to 9-F, 25-cm long introducer sheath (Terumo, Tokyo, Japan) was inserted in the infrarenal aorta via the common femoral artery. After aortic arch angiography, selective bilateral carotid artery catheterization was performed using a 5-F JR4 diagnostic catheter advanced over a 0.035-inch soft hydrophilic wire (Standard Glidewire, Terumo). Once diagnostic angiography was completed, the wire was advanced into 1 of the ECA distal branches, the diagnostic catheter was advanced in the distal ECA, and then the hydrophilic wire was exchanged for a 300-cm, 0.035-inch stiff wire (Hi-Torque Supracore, Abbott Vascular, Abbott Park, Illinois). The endovascular occlusion device (Mo.Ma system, Medtronic Inc., Santa Rosa, California) was guided over the stiff wire until the radiopaque marker of the distal balloon was located in the ECA, at ~1 cm beyond bifurcation and in proximity to or at the superior thyroid artery (6). Then the distal balloon was inflated in the ECA and the proximal balloon in the CCA, thus blocking the antegrade and the retrograde flow across the target vessel. A 0.014-inch wire was then navigated through the ICA stenosis. Lesion pre-dilation was left to the operator's discretion, and self-expanding carotid stents were deployed (Carotid Wallstent, Boston Scientific, Natick, Massachusetts; X-Act, Abbott Vascular; Precise, Cordis, Miami Lakes, Florida; Acculink, Abbott Vascular; Cristallo Ideale, Medtronic). After post-dilation, at least 60 ml of blood was aspirated and filtered through sieves, checking for visible plaque debris. Blood flow was restored only after 3 consecutive aspirations free of debris, deflating first the distal balloon and then the proximal balloon. The final angiography included ipsilateral biplane carotid and intracranial views (3).

**CONCOMITANT THERAPY.** All patients received aspirin (75 to 160 mg/day) and should have been on ticlopidine (250 mg twice daily) for at least 7 days. Alternatively, patients received clopidogrel preload (300 mg) 24 h before the procedure. After the procedure, thienopyridines were continued for at least 3 months, whereas aspirin was continued for life. For anticoagulation, 70 to 100 IU/kg of heparin was administered before wiring the ECA, with the intention to achieve an activated clotting time (ACT) >250 s. Additional heparin was administered at the operator's discretion according to ACT values (7).

**POST-PROCEDURAL PATIENT MANAGEMENT.** Femoral sheaths were removed when the ACT was <150 s. Access site hemostasis was achieved by manual compression in all patients. If clinical signs of limb