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Translational

Effect of the Endothelial Shear Stress Patterns on Neointimal Proliferation Following Drug-Eluting Bioresorbable Vascular Scaffold Implantation

An Optical Coherence Tomography Study

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Objectives This study sought to investigate the effect of endothelial shear stress (ESS) on neointimal formation following an Absorb bioresorbable vascular scaffold (BVS) (Abbott Vascular, Santa Clara, California) implantation.

Background Cumulative evidence, derived from intravascular ultrasound–based studies, has demonstrated a strong association between local ESS patterns and neointimal formation in bare-metal stents, whereas in drug-eluting stents, there are contradictory data about the effect of ESS on the vessel wall healing process. The effect of ESS on neointimal development following a bioresorbable scaffold implantation remains unclear.

Methods Twelve patients with an obstructive lesion in a relatively straight arterial segment, who were treated with an Absorb BVS and had serial optical coherence tomographic examination at baseline and 1-year follow-up, were included in the current analysis. The optical coherence tomographic data acquired at follow-up were used to reconstruct the scaffolded segment. Blood flow simulation was performed on the luminal surface at baseline defined by the Absorb BVS struts, and the computed ESS was related to the neointima thickness measured at 1-year follow-up.

Results At baseline, the scaffolded segments were exposed to a predominantly low ESS environment (61% of the measured ESS was <1 Pa). At follow-up, the mean neointima thickness was 113 ± 45 μm, whereas the percentage scaffold volume obstruction was 13.1 ± 6.6%. A statistically significant inverse correlation was noted between baseline logarithmic transformed ESS and neointima thickness at 1-year follow-up in all studied segments (correlation coefficient range −0.140 to −0.662). Mixed linear regression analysis between baseline logarithmic transformed ESS and neointima thickness at follow-up yielded a slope of −31 μm/ln(Pa) and a y-intercept of 99 μm.

Conclusions The hemodynamic microenvironment appears to regulate neointimal response following an Absorb BVS implantation. These findings underline the role of the ESS patterns on vessel wall healing and should be taken into consideration in the design of bioresorbable devices. (J Am Coll Cardiol Intv 2014;7:315–24) © 2014 by the American College of Cardiology Foundation

Neointimal formation is modulated by several local factors, including the vessel wall trauma caused during stent deployment, the plaque burden, and the composition of the underlying plaque, as well as local endothelial shear stress (ESS) patterns (1–5). Several clinical and experimental studies have provided evidence that local hemodynamic factors, in particular low ESS, promote neointimal formation in bare-metal stents, whereas in drug-eluting stents, the association between ESS and neointimal proliferation is weak and appears to be affected by the mechanisms of action and probably the release kinetics of the eluted drug (6–8).

Bioresorbable scaffold is a new technology introduced to overcome the long-term implications of metallic caging, because these devices have the unique ability to disappear after implantation, allowing restoration of vessel physiology (9). The first clinical studies provided evidence about the safety and efficacy of these devices and revealed a gradual increase of the neointima tissue, which, however, was accommodated by the expanding scaffold and did not appear to affect luminal dimensions (10). We have recently demonstrated that neointima tissue has an asymmetric distribution around the circumference of the vessel wall, indicating that local factors (i.e., vessel wall trauma, increased plaque inflammation, and local hemodynamics) are likely to be involved and regulate this process (11).

Abbreviations and Acronyms

3D = 3-dimensional

ESS = endothelial shear stress

IVUS = intravascular ultrasound

NT = neointimal thickness

OCT = optical coherence tomographic/tomography

The aim of the present analysis was to investigate the impact of ESS on neointima proliferation following an Absorb bioresorbable vascular scaffold (BVS) (Abbott Vascular, Santa Clara, California) implantation. In contrast to previous reports, we utilized optical coherence tomographic (OCT) data to reconstruct the surface of the scaffolded segment at baseline, simulate blood flow, and assess vessel wall healing. The high resolution of this imaging technique allows more detailed reconstruction of luminal morphology and evaluation of the hemodynamic microenvironment and its impact on neointimal growth.

Methods

Included patients and study design. We analyzed data from the patients recruited in the second group of the ABSORB Cohort B Trial (A Clinical Evaluation of the Everolimus Eluting Bioresorbable Vascular Scaffold System in the Treatment of Patients With De Novo Native Coronary Artery Lesions; NCT00856856). The study design has already been described in detail by Serruys et al. (12). In brief, 101 patients with single- or 2-vessel de novo coronary disease implanted with an Absorb BVS (dimensions 3.0 × 18 mm) were included in this prospective multicenter trial. The studied population was divided into 2 groups. Both groups had serial angiographic, grayscale intravascular ultrasound (IVUS), IVUS virtual histology, and OCT evaluation at 3 time points. The first group (B1) had these tests at baseline post-device implantation and at 6 months and 2 years follow-up, whereas the second group (B2) had these investigations at baseline, 1-year, and 3-year follow-up. Thus the current analysis included only the patients from Cohort B2 who had received an Absorb BVS in a relatively straight coronary segment and had undergone OCT evaluation at baseline and 1-year follow-up.

The ABSORB Cohort B study was approved by the human research committee of the institutions that participated. Informed consent was obtained from all patients.

Computation of vessel angulation. Biplane coronary angiographic imaging that would allow accurate reconstruction of coronary geometry was available only in 1 patient at 1-year follow-up. Thus, coronary reconstruction was performed using only the OCT data neglecting the vessel curvature. To minimize the error introduced by this approximation, we analyzed relatively straight arterial segments. The angulation of the treated segments was assessed using a previously described methodology (13). In brief, an expert observer reviewed the angiographic images acquired at 1-year follow-up and selected an end-diastolic projection where there was minimal foreshortening and overlapping of the scaffolded segment. The angulation of the scaffolded segment was defined as the angle formed by the tangents of the centerlines of the 5-mm proximal and distal parts of the segment. To classify the scaffolded segments as straight or curved, we estimated the curvature of the segments treated in the Absorb Cohort B study during balloon inflation, assuming that the balloon straightened the treated artery. The mean ± 2 SD (29°) of the angulations measured during balloon inflation was used as a cutoff value (13).

Optical coherence tomography. OCT image acquisition was performed at baseline (immediately after scaffold implantation) and at 1-year follow-up using a C7XR Fourier Domain

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