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Late Stent Recoil of the Bioabsorbable Everolimus-Eluting Coronary Stent and its Relationship With Plaque Morphology

Shuzou Tanimoto, MD,* Nico Bruining, PhD,* Ron T. van Domburg, PhD,* David Rotger, BSc,† Petia Radeva, PhD,† Jurgen M. Ligthart, BSc,* Patrick W. Serruys, MD, PhD, FACC*

Rotterdam, the Netherlands; and Bellaterra, Spain

Objectives This study sought to evaluate late recoil of a novel bioabsorbable everolimus-eluting coronary stent (BVS), which is composed of a poly-L-lactic acid backbone, coated with a bioabsorbable polymer containing everolimus.

Background Little is known about the mechanical behavior of bioabsorbable polymer stents after deployment in diseased human coronary arteries.

Methods The study population consisted of 16 patients, who were treated with elective BVS implantation for single de novo native coronary artery lesions and were followed at 6 months. All patients underwent an intravascular ultrasound examination at post-procedure and follow-up. A total of 484 paired cross-sectional areas (CSAs) were acquired and analyzed. Late absolute stent recoil was defined as stent area at post-procedure (X) − stent area at follow-up (Y). Late percent stent recoil was defined as $(X - Y)/X \times 100$. In each CSA, plaque morphology was assessed qualitatively and classified as calcific, fibronecrotic, or fibrocellular plaque.

Results Late absolute and percent recoil of the BVS was 0.65 ± 1.71 mm^2 (95% confidence interval [CI]: 0.49 to 0.80 mm^2) and 7.60 ± 23.3% (95% CI: 5.52% to 9.68%). Calcified plaques resulted in significantly less late recoil (0.20 ± 1.54 mm^2 and 1.97 ± 22.2%) than fibronecrotic plaques (1.03 ± 2.12 mm^2 and 12.4 ± 28.0%, p = 0.001 and p = 0.001, respectively) or fibrocellular plaque (0.74 ± 1.48 mm^2 and 8.90 ± 19.8%, p = 0.001 and p = 0.001, respectively).

Conclusions The BVS shrank in size during the follow-up period. The lesion morphology of stented segments might affect the degree of late recoil of the BVS. (ABSORB Everolimus Eluting Coronary Stent System First in Man Clinical Investigation; NCT00300131) (J Am Coll Cardiol 2008;52:1616–20) © 2008 by the American College of Cardiology Foundation

Compared with metallic stents, bioabsorbable polymer stents could have a lower radial strength, resulting in more stent recoil after implantation, because polymers are more flexible than metals. The bioabsorbable everolimus-eluting coronary stent (BVS) (Abbott Vascular, Santa Clara, California) is composed of a high-molecular-weight poly-L-lactic acid (PLLA) backbone, coated with a matrix of bioabsorbable polymer and everolimus. All components of the BVS, except for 2 radio-opaque platinum markers on both ends of its surface, are expected to be fully metabolized and absorbed in the human body between 2 and 3 years (1,2). Although acute recoil of the BVS as assessed by quantitative coronary angiography (QCA) was slightly but not significantly higher than that of the everolimus-eluting metallic stent (2), little is known about late mechanical behavior of the BVS. In the present study, we evaluated late recoil of the BVS and assessed its relationship with lesion morphology of the stented segments.

Methods

Study population. Of the 30 patients included in the ABSORB (ABSORB Everolimus Eluting Coronary Stent System First in Man Clinical Investigation) trial, 16 were enrolled at the Thoraxcenter, Erasmus Medical Center, Rotterdam, the Netherlands. The trial has been described in detail previously (1,2). It was approved by the local ethics committee, and all patients gave written informed consent. In brief, patients were eligible for the study if they had single de novo native coronary artery lesions that could be covered with a single BVS. Patients were ineligible if they had evolving myocardial infarction, left main coronary

From the *Thoraxcenter, Erasmus Medical Center, Rotterdam, the Netherlands; and the †Computer Vision Center, Autonomous University of Barcelona, Bellaterra, Spain.

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artery stenosis, an ostial lesion, a bifurcation lesion, a totally occluded lesion, a lesion with moderate-to-heavy calcification, angiographically visible thrombus within the target lesion, or a left ventricular ejection fraction <30%.

Study procedure. Target lesions were electively treated with standard interventional techniques with mandatory pre-dilation and stent deployment at a pressure not exceeding the rated burst pressure (16 atm). Post-dilation with a balloon shorter than the implanted stent was allowed at operator discretion. Bailout stenting for edge dissection was permitted with metallic stents. At the end of the procedure, intravascular ultrasound (IVUS) procedures were performed with a 40-MHz IVUS catheter (Atlantis SR Pro, Boston Scientific Corporation, Natick, Massachusetts) with an automated pullback system at 0.5 mm/s. After IVUS examinations, no other stent-related procedures were added. All patients were planned to undergo both a coronary angiography and an IVUS examination 6 months after the initial procedure.

QCA and quantitative IVUS analysis. The QCA was performed with the CAAS II analysis system (Pie Medical BV, Maastricht, the Netherlands) by an independent observer blinded to the clinical and IVUS findings. The following QCA parameters were computed: minimal lumen diameter, reference vessel diameter, percent diameter stenosis, and lesion length. The accuracy of this method has been reported in detail previously (3).

To analyze and compare the IVUS data consistently, all IVUS examinations were retrospectively electrocardiogram (ECG)-gated with the validated Intelligate method, which automatically selects near end-diastolic frames from prerecorded non–ECG-gated IVUS data (4). The IVUS images of both post-procedure and follow-up studies were analyzed by side-by-side viewing, comparing for matched segments. Only the stented segments were analyzed and were identified by the first and the last cross section containing visible stent struts. The lumen, stent, and external elastic membrane contours were detected with the validated software (CURAD QCU Analysis Software, Curad B.V., Wijk bij Duurstede, the Netherlands), which allows semi-automated detection of the lumen–intima interface and the external elastic membrane in longitudinal reconstructed views of coronary vessels (5,6).

Late stent recoil assessment. Stent recoil was computed from measurements of IVUS cross-sectional areas (CSAs), obtained every 0.5 mm. Late absolute stent recoil was defined as stent area at post-procedure (X) − stent area at follow-up (Y). Late percent stent recoil was defined as $(X - Y)/X \times 100$.

Image-based plaque characterization. The IVUS appearance of the BVS struts is unique and differs from that of metallic stents. The polymer struts are visible as 2 parallel lines of echoes without acoustic shadowing (AS), due to the fact that the ultrasound is mainly backscattered at the interfaces (blood/polymer interface and polymer/tissue interface) of the struts with the surrounding environment. Therefore, plaque characterization of BVS implanted segments can be assessed without the image artifacts as seen in IVUS of metallic stents.

To investigate the possible relationship between the degree of late stent recoil and plaque morphology in stented segments, plaque characterization of BVS implanted segments was qualitatively assessed by IVUS appearance. All acquired CSAs were classified into 3 different plaque types: calcific, fibronecrotic, or fibrocellular plaque. Each plaque type was defined as follows (7–11): calcific plaque: highly echogenic areas having a density greater than that of the adventitia and causing AS, possibly combined with reverberations; fibronecrotic plaque: plaque components causing echolucent areas within the plaque combined with AS or plaque having AS without reverberations; and fibrocellular plaque: plaque components other than calcific and fibronecrotic plaques. In case several plaque types were identified in 1 CSA, the predominant plaque type was selected.

Abbreviations and Acronyms

AS = acoustic shadowing
BVS = bioabsorbable everolimus-eluting coronary stent
CI = confidence interval
CSA = cross-sectional area
ECG = electrocardiogram
IVUS = intravascular ultrasound
PLLA = poly-L-lactic acid
QCA = quantitative coronary angiography

Statistical analysis. Statistical analysis was performed with SAS software (SAS Institute Inc., Cary, North Carolina). Categorical variables were expressed as counts and percentages. Continuous variables were presented as mean values with SDs. The Student *t* test was performed for testing differences of late BVS recoil among 3 different plaque types of stented segments. To adjust for multiple observations/patient, with possible correlations of adjacent cross sections, the *t* statistic was divided by $C = (1 + [m - 1]\rho)$, where m is the number of observations/patient and ρ is the intracluster correlations (12). The intracluster correlation ρ is defined as: variance (between patients)/(variance [between patients] + variance [within patients]). A value of $p < 0.05$ was considered statistically significant.

Results

All patients were successfully treated and underwent follow-up coronary angiography and IVUS procedures at 6.0 ± 1.2 months. Only 1 patient received bailout stenting. A total of 484 paired (post-procedure and follow-up) CSAs were acquired. Baseline and follow-up results are shown in Table 1. According to the protocol, lesion complexity was relatively simple: no type C lesion, short lesion length (9.83 ± 4.02 mm), large reference vessel diameter (2.96 ± 0.48 mm), and mild degree of diameter stenosis (62 ± 13%). Late absolute stent recoil was 0.65 ± 1.71 mm^2 (95% confidence interval [CI]: 0.49 to 0.80 mm^2), and late percent stent recoil was 7.60 ± 23.3% (95% CI: 5.52% to 9.68%). All acquired CSAs were qualitatively assessable in terms of lesion morphology of stented segments. The fibrocellular,