JACC: CARDIOVASCULAR INTERVENTIONS
VOL. 6, NO. 7, 2013

ISSN 1936-8798/$36.00
PUBLISHED BY ELSEVIER INC.
http://dx.doi.org/10.1016/j.jcin.2013.04.008

Biomechanical Assessment of Fully Bioresorbable Devices

Bill D. Gogas, MD,* Spencer B. King III, MD,*† Lucas H. Timmins, PhD,‡ Tiziano Passerini, PhD,§ Marina Piccinelli, PhD,|| Alessandro Veneziani, PhD,§ Sungho Kim, PhD,‡ David S. Molony, PhD,‡ Don P. Giddens, PhD,‡ Patrick W. Serruys, MD, PhD,¶ Habib Samady, MD*

Atlanta, Georgia; and Rotterdam, the Netherlands

The use of bioresorbable technologies for the treatment of coronary artery disease is a novel approach with potential advantages over the use of metal stents (1). Several devices have undergone First-In-Man studies; however, the Absorb bioresorbable vascular scaffold (BVS) (Abbott Vascular, Santa

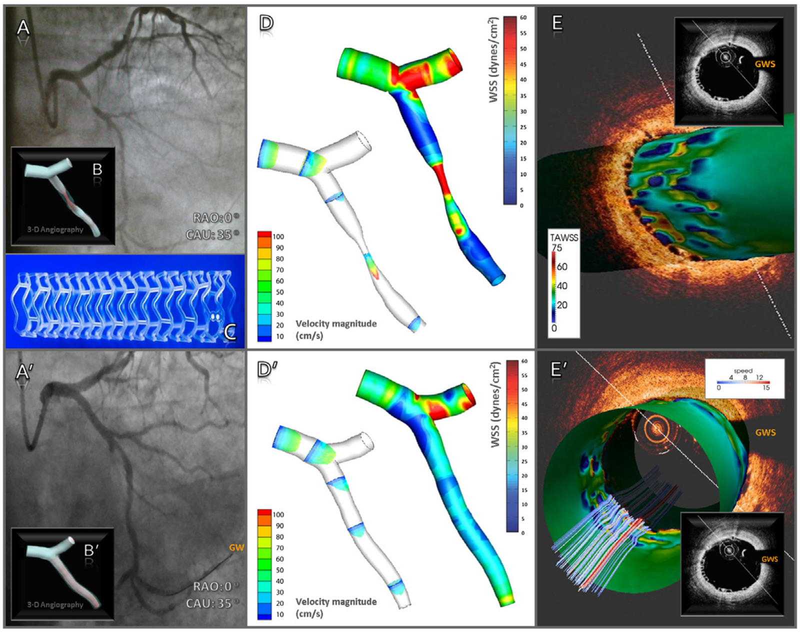

Figure 1. Presentation of WSS Derived From Angiographic and OCT Imaging Data Projections Using CFD Modeling Techniques After Implantation of the Absorb Bioresorbable Vascular Scaffold

(A, A′) Two-dimensional (2-D) angiographic views of the significant proximal left circumflex artery lesion **(A)** and the scaffolded segment after implantation of the 3.0 × 18-mm Absorb bioresorbable vascular scaffold (BVS) **(A′)**. **(B, B′)** Three-dimensional (3-D) angiographic views before **(B)** and after **(B′)** scaffold implantation. **(C)** The Absorb BVS. **(D, D′)** Time-averaged wall shear stress (TAWSS) magnitude distribution from angiographically derived 3-D geometries before **(D)** and after **(D′)** scaffold deployment. Velocity profiles pre- and post-implantation of the Absorb BVS are superimposed. **(E)** 2-D OCT cross section with embedded polymeric struts demonstrating in a 3-D pattern the distribution of TAWSS between the polymeric struts. The quantified color coding demonstrates low WSS regions **(blue color)**. The matched OCT cross section is superimposed. **(E′)** Reconstructed streamlines of the velocity field at the systolic peak demonstrating altered flow patterns in the proximity of the arterial wall induced by the polymeric struts. CFD = computational fluid dynamics; GWS = guidewire shadow.

From the *Andreas Gruentzig Cardiovascular Center, Emory University School of Medicine, Atlanta, Georgia; †Saint Joseph's Heart and Vascular Institute, Atlanta, Georgia; ‡Wallace H. Coulter Department of Biomedical Engineering Georgia Institute of Technology and Emory University, Atlanta, Georgia; §Department of Mathematics and Computer Science, Emory University, Atlanta, Georgia; ||Department of Radiology and Imaging Sciences, Emory University, Atlanta, Georgia; and the ¶Thoraxcenter, Erasmus University Medical Center, Rotterdam, the Netherlands. Abbott Vascular was the sponsor of ABSORB Extend study. The authors have reported that they have no relationships relevant to the contents of this paper to disclose. Marco Costa, MD, has served as Guest Editor.

Manuscript received January 24, 2013; revised manuscript received March 29, 2013, accepted April 17, 2013.

Clara, California) is the only bioresorbable platform approved for clinical use in Europe (CE mark). The BVS platform is made of poly-L-lactide that is shown to completely resorb over a 2- to 3-year period. Insights from the ABSORB Cohort B trial [NCT00856856] suggest that the scaffold is more conformable than metal stents (Xience everolimus-eluting stent, Abbott Vascular), resulting in less vascular straightening and greater retention of the original angulation and curvature. Although the polymeric struts of the ABSORB BVS are thicker (150 μm) compared with those of second-generation metal stents, the hemodynamic effects change over time as the scaffold resorbs. Therefore, the overall biomechanical footprint of the bioresorbable scaffold compared with metal stents is transient with different effects on local vessel and strut level wall shear stress (WSS). We have proposed that such detailed biomechanical evaluation of the ABSORB BVS will add critical mechanistic insights into its potential beneficial effects, particularly in angulated and curved vessels (2).

Here we illustrate the assessment of biomechanical properties by 2 methods in 2 selected patients who underwent implantation of the ABSORB BVS from the ABSORB Extend study [NCT01023789]. The evaluation used 3-dimensional (3-D) angiographic reconstruction techniques and computational fluid dynamics (CFD) to calculate the WSS pre- and post- BVS deployment (Figs. 1A to 1D) for vessel-level analysis. The second used optical coherence tomography (OCT) imaging data to reconstruct the 3-D geometry and CFD to visualize flow streamlines over the polymeric struts for more detailed strut level analysis. (Figs. 1E and E′). Fusion of angiographic with OCT data has been previously shown to be a feasible approach to calculate WSS by CFD simulations (3), and biomechanical analyses by these methods may yield important insights into potential advantages of bioresorbable technologies over metal stents.

Acknowledgments
Dr. Gogas acknowledges the American College of Cardiology Foundation for the International Society of Cardiovascular Translational Research Scholarship. Dr. Timmins and Dr. Passerini acknowledge the American Heart Association for their Postdoctoral Fellowships. The authors thank Prof. Didier Carrie from the Hôpital de Rangueil, Toulouse, France, Prof. Stephen Lee, from the Queen Mary Hospital, Hong Kong, and Christos Bourantas from the Thoraxcenter, Erasmus University Medical Center, Rotterdam, for their valuable comments.

Reprint requests and correspondence: Dr. Habib Samady, Emory University School of Medicine, 1364 Clifton Road, Suite F606, Atlanta, Georgia 30322. E-mail: hsamady@emory.edu.

REFERENCES

1. Serruys PW, Garcia-Garcia HM, Onuma Y. From metallic cages to transient bioresorbable scaffolds: change in paradigm of coronary revascularization in the upcoming decade? Eur Heart J 2012;33:16–25b.
2. McDaniel MC, Samady H. The sheer stress of straightening the curves: biomechanics of bioabsorbable stents. J Am Coll Cardiol Intv 2011;4:800–2.
3. Tu S, Holm NR, Koning G, et al. Fusion of 3D QCA and IVUS/OCT. Int J Cardiovasc Imaging 2011;27:197–207.

Key Words: bioresorbable scaffolds ■ optical coherence tomography ■ 3-D wall shear stress.