JACC: CARDIOVASCULAR IMAGING VOL. 4, NO. 11, 2011

ISSN 1936-878X/$36.00
PUBLISHED BY ELSEVIER INC.

LETTERS TO THE EDITOR

# Sunflower Artifact in OCT

The sunflower effect is an intravascular optical coherence tomography (IV-OCT) artifact observed when imaging metal coronary stents deployed in patients during cardiac catheterization and appears as a bending of stent struts toward the imaging catheter—analogous to a sunflower bending toward the sun (1). The sunflower effect occurs when the catheter is at eccentric positions in the vessel lumen and is most pronounced when the catheter is adjacent to the luminal wall. As the imaging light beam from the IV-OCT catheter rotates over a stent strut, only a portion of the metal strut reflects light back to the optical fiber. The metal strut thus can artifactually appear as a straight line, perpendicular to the imaging light beam, and may be obliquely oriented to the luminal wall (Figs. 1A and 1B). Therefore, the sunflower effect can artifactually make stent struts that are well opposed to the luminal wall appear poorly opposed.

A phantom vessel was made out of polydimethylsiloxane (PDMS) with elastic properties comparable to that of arteries. Titanium dioxide was added to PDMS to simulate the light-scattering properties of the arterial wall. A 3-mm Xience V everolimus-eluting coronary stent (Abbott Vascular, Santa Clara, California) was deployed in the phantom vessel (3-mm lumen diameter) at 16 atm. For reference, microfocus computed tomography (micro-CT) images of the stent in the phantom were recorded and confirmed that struts were well opposed to the vessel wall. IV-OCT images of the stent deployed in the phantom vessel were recorded with the catheter at centered and eccentric positions. When the catheter is centered, stent struts appear properly deployed in IV-OCT images (Fig. 1C). In IV-OCT images recorded when the catheter is adjacent to the luminal wall, struts appear as a straight line perpendicular to the light beam, and obliquely oriented to the luminal wall (Fig. 1D).

To demonstrate the mechanism of the sunflower artifact, a software simulator was constructed with a graphical user interface that allows the user to modify the vessel lumen size and catheter position. The simulator utilizes angular position and thickness of the stent struts derived from a micro-CT image (Fig. 2A) to construct a simulated OCT image of a vessel with deployed stent (Fig. 2B). When the catheter is centered in the vessel lumen, position and orientation of metallic stent struts in OCT and micro-CT images match and are consistent (Figs. 2A and 2B). By shifting the catheter to an eccentric position, some struts demonstrate the sunflower effect by appearing as a straight line that is perpendicular to the light beam and obliquely oriented to the luminal wall (Figs. 2C and 2D). As in phantom images, the sunflower effect is more pronounced when the catheter is adjacent to the luminal wall.

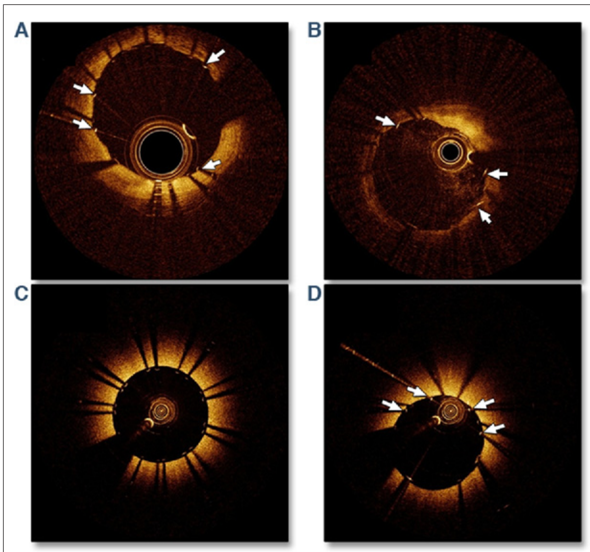


**Figure 1. Patient and Phantom Images**

**(A and B)** Sunflower effect in bare-metal stents deployed in a right coronary artery with the intravascular optical coherence tomography (IV-OCT) catheter at maximum eccentricity. Some struts **(arrows)** appear as a straight line, perpendicular to the imaging light beam, and are obliquely oriented to the luminal wall. It can be uncertain clinically whether these struts are truly underdeployed, or simply artifactually turned perpendicular to the light source. **(C)** IV-OCT image of a 3-mm Xience V everolimus-eluting coronary stent (Abbott Vascular) deployed in a phantom vessel with centered catheter, demonstrating properly deployed stent struts. **(D)** IV-OCT image of the phantom vessel with the catheter adjacent to the luminal wall; some struts **(arrows)** appear as a straight line perpendicular to the imaging light beam, and obliquely oriented to the luminal wall, as seen in patient images.

When an eccentric IV-OCT catheter emits light that is incident on a metal stent strut at any angle, returning light to the catheter is reflected from a small-sized region on the metal strut surface (Fig. 2E, black arrow), whereas other strut surface areas scatter light away from the catheter (Fig. 2E, gray arrows). As light is transmitted from the catheter, a finite beam width at the stent strut ensures return reflections are recorded at each angular position. Since reflections return from a small-sized region on the stent strut, echo time is nearly constant at each angular position, and the metal strut appears in IV-OCT images as a straight line bending towards the catheter (Fig. 2E, dotted blue line). This effect can be accentuated by the broadening of the beam due to light scattering when blood is present (Fig. 1B, strut at 4 o'clock).

Complete deployment of coronary stents improves long-term patient outcomes, and an early application of IV-OCT is to verify full deployment. Although IV-OCT provides high-resolution images of stent struts to make this assessment, the sunflower effect can erroneously lead to a conclusion of stent underdeployment. Ughi et al. (2) suggested using the stent strut midpoint in IV-OCT images to measure stent

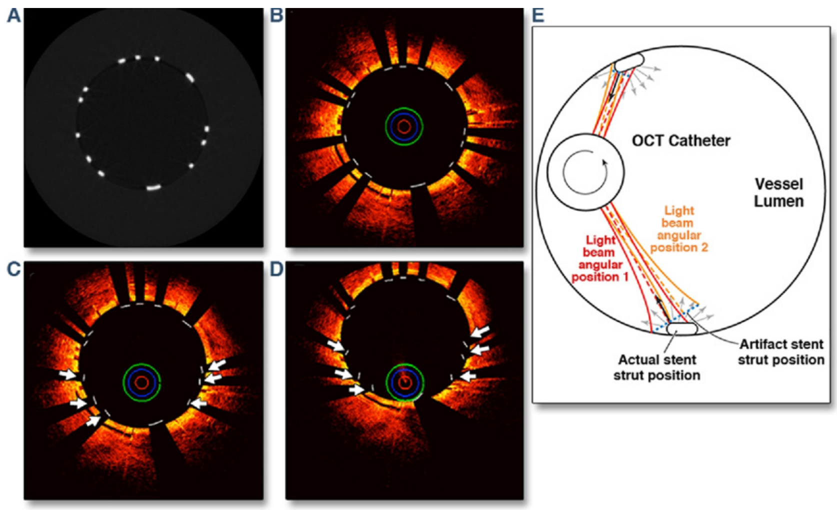


**Figure 2. Simulated Images and Mechanism of Sunflower Effect in Metallic Stents**

**(A)** Microfocus computed tomography (micro-CT) image of a 3-mm diameter everolimus-eluting coronary stent deployed in a phantom vessel, demonstrating that the stent is properly deployed. **(B)** Simulated intravascular optical coherence tomography (IV-OCT) image of vessel with centered catheter, where the position and orientation of metallic stent struts are consistent with the micro-CT. **(C)** Simulated IV-OCT image of vessel with eccentric catheter ($x = 0.05$ mm and $y = -0.55$ mm), some struts **(arrows)** appear as a straight line, and are perpendicular to the imaging light beam and obliquely oriented to the luminal wall. **(D)** Simulated IV-OCT image of vessel when catheter is adjacent to the wall ($x = 0.1$ mm and $y = -1.1$ mm), orientation of some struts **(arrows)** are more oblique to the luminal wall than in **(C)**. **(E)** An eccentric IV-OCT catheter emits light that is incident on metal stent struts at 2 angular positions. At both angular positions, returning light to the catheter is reflected from a small-sized region on the metal strut surfaces **(black arrows)**, whereas other strut surfaces scatter light away from the catheter **(gray arrows)**. As light is transmitted from the catheter, a finite beam width at the stent strut ensures return reflections are recorded at all intervening angular positions. Since reflections return from a small-sized region, echo time is nearly constant for all intervening angular positions, and the metal struts appear in IV-OCT images as straight lines bending towards the catheter **(dotted blue lines)**.

apposition; results reported here, however, suggest that in this case, the correct apposition distance is obtained only when the location on the strut that reflects light into the catheter is the physical midpoint of the strut. Unfortunately, since one does not know, a priori, from where on the strut light is reflecting back into the catheter, a fundamental uncertainty is recognized when selecting the point on the apparent strut to measure distance to the vessel wall. Further studies, possibly utilizing well-characterized stents deployed in phantom vessels, can provide a better estimate of the location on the stent strut from where light is reflecting into the catheter and provide a better estimate of stent apposition. Interestingly, IV-OCT images of deployed bioresorbable stents are not expected to be as susceptible to the sunflower artifact since strut surfaces are not as highly reflective or smooth compared with metal struts.

**Sahar Elahi, MS, J. Jacob Mancuso, MD, Thomas E. Milner, PhD, Marc D. Feldman, MD***

*Room 5.642, 7703 Floyd Curl Drive, University of Texas Health Science Center, San Antonio, Texas 78248. *E-mail: feldmanm@uthscsa.edu*

doi:10.1016/j.jcmg.2011.04.022

Dr. Feldman has received research support from Volcano Corporation. The authors thank Jouke Dijkstra at Leiden University Medical Center for many helpful discussions. Nate Kemp and Badr Elmaanaoui at Volcano Corporation provided assistance recording IV-OCT images of phantom vessels. Donation of stents by Abbott Vascular is gratefully acknowledged.

## REFERENCES

1. Bezerra HG, Costa MA, Guagliumi G, Rollin AM, Simon DI. Clinical and research applications intracoronary optical coherence tomography: a comprehensive review. J Am Coll Cardiol Intv 2009;2:1035–46.
2. Ughi GJ, Adriaenssens T, Onsea K, et al. Automatic segmentation of in-vivo intra-coronary optical coherence tomography images to assess stent strut apposition and coverage. Int J Cardiovasc Imaging 2011 Feb 24 [E-pub ahead of print], doi: 10.1007/s10554-011-9824-3.

# Evolution and Clinical Importance of Fibrosis in HCM

The histopathologic features of hypertrophic cardiomyopathy (HCM) are left ventricular hypertrophy, myocyte disarray, and interstitial fibrosis (1).

Cardiac magnetic resonance (CMR) is the gold standard for in vivo assessment of focal myocardial fibrosis using the late gadolinium enhancement (LGE) technique (2). This correlates with clinical risk factors for sudden death and arrhythmias, and is predictive of adverse outcomes including heart failure (3). It remains unclear how fibrosis evolves and how evolution correlates with ventricular remodeling. Our aim was to track long-term changes in CMR LGE in HCM over a 7-year follow-up period.

From 2001 to 2003, 59 patients with HCM (5 gene-positive for sarcomeric gene mutations with electrocardiogram changes fulfilling familial criteria) (1) underwent CMR LGE. Follow-up scans were performed in 12 patients on average 7.4 ± 0.4 years after the initial