In Vivo 3D Distribution of Lipid-Core Plaque in Human Coronary Artery as Assessed by Fusion of Near Infrared Spectroscopy–Intravascular Ultrasound and Multislice Computed Tomography Scan

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There is ample evidence that the development of acute coronary syndrome is linked to the presence of lipid-core, necrotic plaque. However, there is little information on the natural history of lipid-core plaques in humans. A close link between structural changes of atherosclerotic plaques over time to the local shear stress conditions in the arterial system has been reported. Although low shear stress is recognized for its proatherogenic impact on the endothelium, its role in plaque composition, destabilization, and rupture is less clear. The current paradigm postulates that low shear stress is a necessary condition for plaque accumulation. However, once lumen narrowing occurs because of plaque, local shear stress increases. We describe an approach that allows studying the interaction of lipid-core plaque accumulation and local shear stress in a correct anatomic 3D reconstruction of coronary arteries in living patients.

A 61-year-old man with a history of myocardial infarction and stenting of the right coronary artery underwent coronary catheterization for recurrent angina. A prior 128-slice dual-source computed tomography scan (MSCT, Somaton Definition Flash, Siemens, Germany) had suggested a lumen narrowing in the anterior descending artery (Figure, A) that was subsequently proven to be physiologically significant by pressure wire studies. To identify the presence of lipid-core plaque, a pullback with a recently developed combination catheter with intravascular ultrasound (IVUS) and near infrared spectroscopy (NIR) (InfraReDx, Burlington, Mass) was performed (pullback speed, 0.5 mm/s; acquiring 16 frames per second). NIR data were displayed as color maps indicating the probability of the presence of lipid core by NIR as described previously. Although the combination catheter allows simultaneous display of the IVUS-derived 2D geometry and presence of lipid-core plaque in vivo (Figure, B), it was until now not feasible to visualize that information in anatomically correct 3D space, which is crucial to understand the relationship with other pathophysiologic parameters, such as shear stress. Recently, we developed a technique to produce 3D coronary reconstructions by fusion of MSCT and IVUS information. We adapted this approach for the combined NIR-IVUS data to reconstruct the lipid-core plaque distribution in 3 dimensions. Moreover, in the lumen of this 3D reconstruction, the local shear stress was assessed by computational fluid dynamics.

In our patient, a complex plaque and shear stress distribution pattern is visible (Figure, C and D). Confluent lipid-core plaques are exclusively located on the inner curvature of the artery toward the myocardium (Figure, C), which is generally considered a low shear-stress region. In the region of maximum lipid-core plaque accumulation, lipid-core plaque extends over roughly 75% of the artery’s circumference (Figure, asterisk). At this site and at some other locations, the local shear stress as computed is relatively high (Figure, D). This can be explained by the fact that there is advanced disease with marked thickening of the vessel wall, which resulted in lumen narrowing.

Our observation illustrates that the combination of NIR, IVUS, and MSCT data can be used to study the relationship between shear stress and lipid-core distribution in the arteries of patients undergoing catheterization, which is of high potential for longitudinal studies on plaque modulation. Moreover, hypotheses on plaque progression and destabilization can be tested in patients in vivo.

Disclosures
Dr van der Steen is a consultant for InfraReDx, Burlington, Mass.

References


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Figure. Three-dimensional reconstruction of the spatial, in vivo distribution of lipid-core plaque and local shear stresses in the left anterior descending artery obtained by fusion of MSCT and cross-sectional images as derived from a combination catheter visualizing NIR and IVUS information simultaneously. A, Three-dimensional rendering of the MSCT, with a magnified image of the proximal part of the left anterior descending artery. Overlaid on this magnified image (lower panel) are the contours of the lumen (pink) and media (blue) as derived by NIR-IVUS. B, Cross-sectional coronary images obtained by the NIR-IVUS catheter. The NIR data for each cross section are displayed in a circle (color map) around the IVUS image, representing the probability for lipid-core plaque in the vessel wall (yellow indicates high probability). C, Three-dimensional reconstruction of the coronary artery, on which the NIR lipid map is superimposed. Left panel shows the epicardial vessel surface; right panel shows the endoluminal surface of the half of the artery closest to the myocardium in a cut-away view. Note that the vessel wall (brown) is markedly thickened. D, Corresponding shear stress distribution on the endoluminal vessel wall surface. The panel shows a cut-away view of the half of the artery closest to the myocardium. Dark blue indicates low shear stress; light blue indicates high shear stress; corresponding cross-sectional cut planes and images are indicated in black lines. Asterisk indicates the region of maximum lipid-core accumulation.
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