CARDIOVASCULAR IMAGES

High-Risk Plaque Regression and Stabilization

Hybrid Noninvasive Morphological and Hemodynamic Assessment

Coronary computed tomography angiography (CCTA) holds a prime role in noninvasive assessment of atherosclerosis by enabling plaque characterization and serial imaging. The napkin-ring sign has been described in plaques that are characterized at CCTA by a low attenuation center, covered by a higher attenuation ring-like periphery. Such atherosclerotic plaques are closely linked with future acute coronary syndromes, independent of other high-risk CCTA plaque features, such as low attenuation plaque and positive remodeling.[1] Medical treatment, primarily with the use of statins, that promote plaque stabilization, has been associated with resolution of inflammation and favorable histological changes in coronary plaques, leading to plaque regression.[2]

We present a 62-year-old male patient with history of hypertension and dyslipidemia who was assessed with CCTA because of atypical chest pain (Figure 1). A high-risk coronary plaque was identified at the mid left anterior descending artery (LAD) resulting in moderate luminal stenosis (≈50%; Figure 1, left). The upstream/proximal (Figure 1i, left) and downstream/distal (Figure 1iii, left) plaque shoulders exhibited partially calcified and noncalcified atherosclerotic plaque components, whereas the plaque neck (Figure 1ii, left) exhibited the napkin-ring sign (ie, a central area of low CT attenuation [HU 4], surrounded by a ring-like tissue of higher attenuation), and positive remodeling (remodeling index 1.13). The patient was advised to adhere to a healthy lifestyle and was prescribed a high-potent statin (rosuvastatin 20 mg). Follow-up CCTA at 3 years because of recurrent atypical chest pain revealed plaque regression (reduction of luminal stenosis to <25%) and stabilization without evidence of napkin-ring sign and no positive remodeling (Figure 1i through 1iii, right).

The hemodynamic significance of the lesion, by means of CCTA-derived fractional flow reserve (CT-FFR) was retrospectively estimated at baseline and follow-up, using a validated computational algorithm and by noninvasively simulating hyperemic conditions (Figure 2).[3] At baseline (Figure 2, left) the mid LAD plaque with the napkin-ring sign (insert) exhibited no hemodynamic significance (CT-FFR: 0.88). A drop of CT-FFR at the distal LAD (0.79) was within the borderline or grey zone (0.75–0.80). At follow-up (Figure 2, right), plaque regression (insert) resulted in local and overall global increase in hyperemic coronary flow and respectively improvement of the physiological index. Specifically, CT-FFR right distal to the lesion increased from 0.88 to 0.95 and at the distal LAD from 0.79 to 0.87.

In the same fashion, resting coronary blood flow was simulated in the entire coronary tree at baseline and at follow-up using a standard coronary CCTA-based vascular profiling approach[4] and the endothelial shear stress (ESS) was calculated (ESS$_{CT}$; Figure 3). For the LAD, the ESS values were reshaped into a 2-dimensional map of the LAD with the longitudinal arterial location in the y axis and the angle about the arterial centerline on the x axis. At baseline (Figure 3, left), the upstream-proximal

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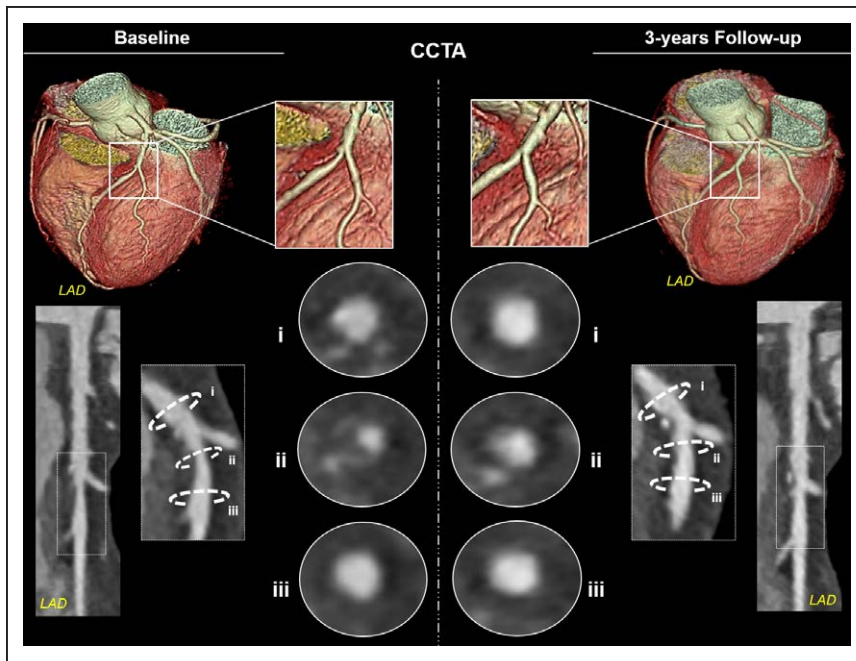
Figure 1. Serial morphological plaque imaging with coronary computed tomography angiography (CCTA).
LAD indicates left anterior descending.

plaque shoulders exhibited moderate (normal) ESS values (Figure 3i, left), the plaque neck high (pathological) ESS values (Figure 3ii, left) and the downstream-distal plaque shoulders low (pathological) ESS values (Figure 3iii, left).

Following statin therapy and plaque regression (Figure 3, right), the ESS values at the neck of the plaque were normalized (Figure 3ii, right), whereas at the downstream part of the plaque they were slightly increased (Figure 3iii,
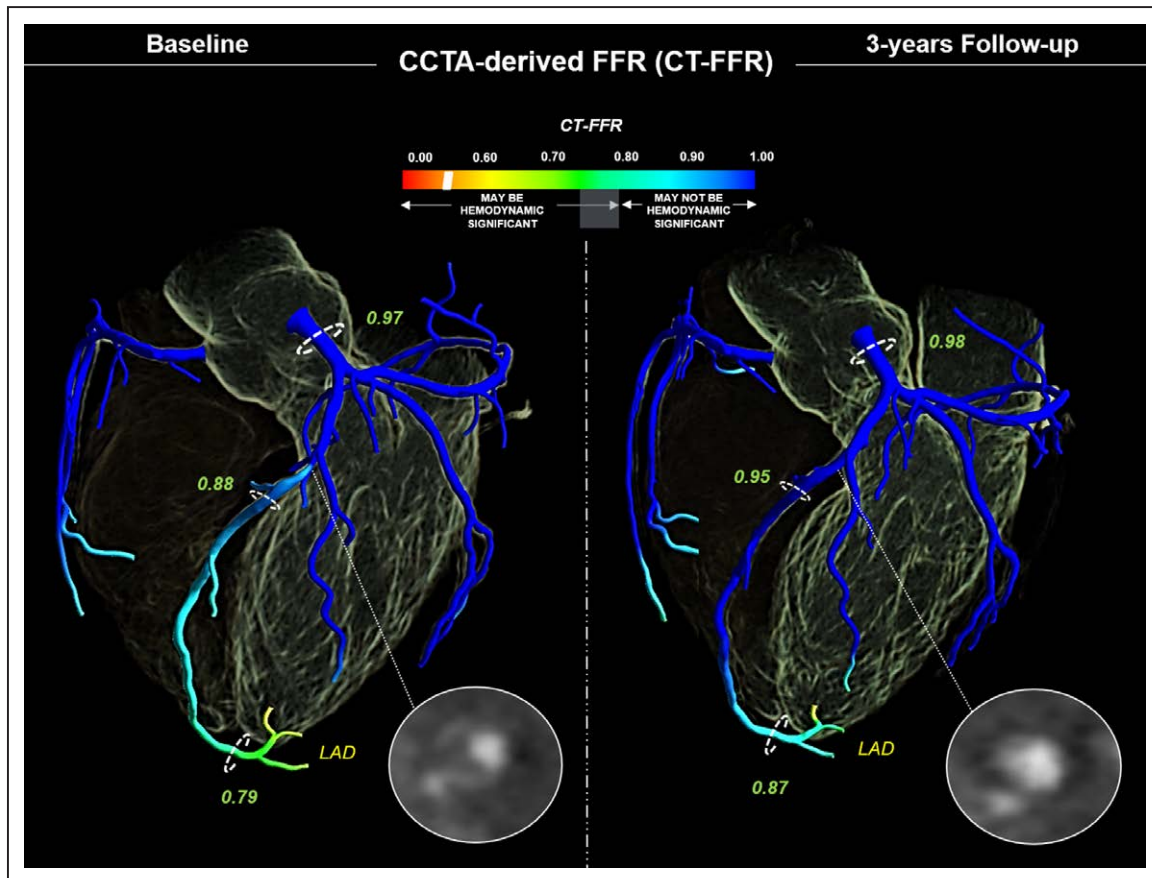
Figure 2. Serial noninvasive functional significance of the lesion with coronary computed tomography angiography (CCTA)-derived fractional flow reserve (CT-FFR).
LAD indicates left anterior descending.
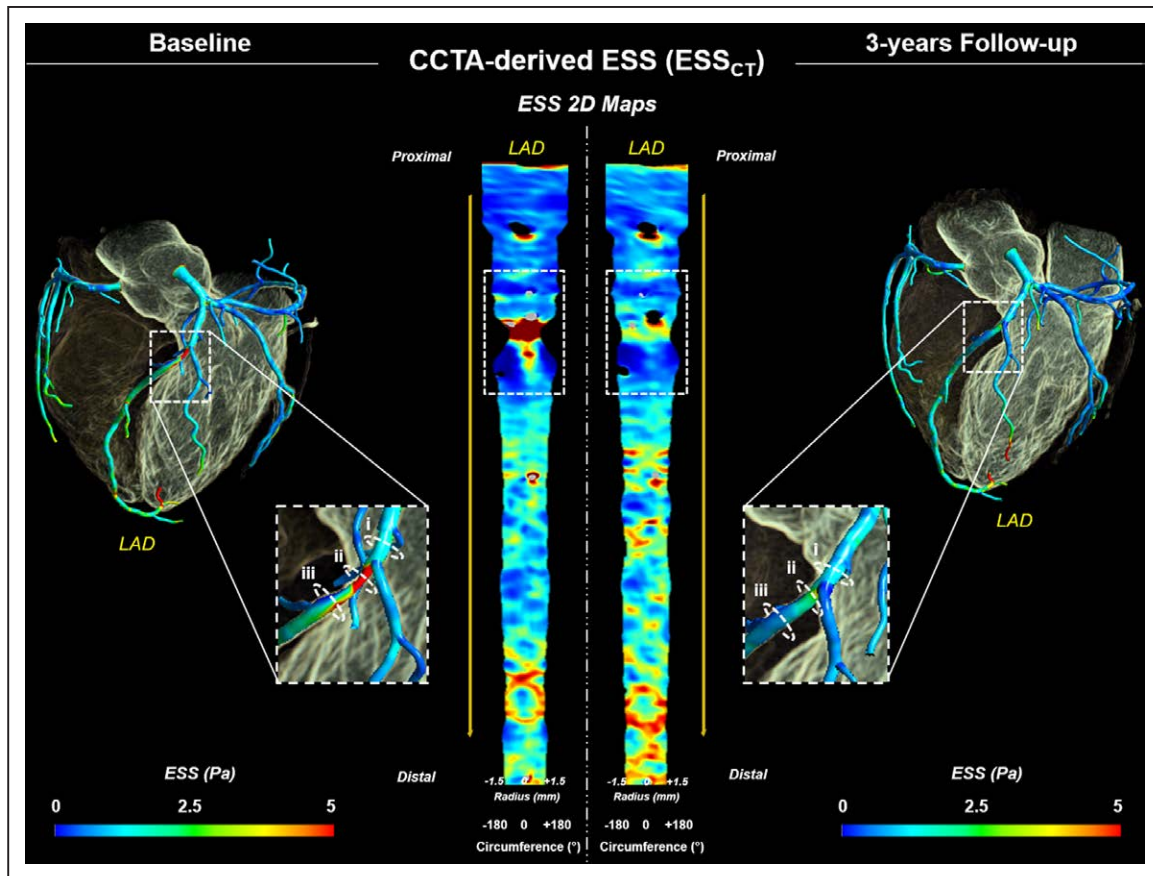
Figure 3. Serial local hemodynamic-environment assessment with computed tomography (CT)-derived endothelial shear stress (ESS$_{CT}$).
Boxed area represents the location of the plaque; side branches are depicted as voids; and the y-extent of the maps is further shaped by the vessel radius at each longitudinal location; Pa: Pascal. CCTA indicates coronary computed tomography angiography; and LAD, left anterior descending.

right). The upstream shoulder plaques remained in a local hemodynamic environment of normal ESS. Low ESS is associated with inflammation, lipid accumulation, and promotes progression of atherosclerosis to a high-risk phenotype. Similarly, high ESS and expansive remodeling with concomitant erosion of fibrous tissue, contribute to plaque susceptibility to rupture or erosion.

Serial, hybrid, noninvasive imaging combining anatomic plaque characteristics, CT-derived FFR, and ESS demonstrated plaque regression and stabilization over time associated with normalization of the local hemodynamic milieu after moderate-intensity statin therapy. This descriptive case highlights the vicious cycle between plaque geometry, vascular biology, and local hemodynamics, and the importance of antiatherosclerotic therapies in the modification of adverse local morphological plaque characteristics as well as in the improvement of local and global coronary hemorheological features.

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Disclosures

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