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Assessment of endothelial shear stress and functional significance of coronary lesions by computed tomography coronary angiography (CTCA) and computational fluid dynamics: a comparison with PET

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Background: The feasibility of assessing endothelial shear stress (ESS) in coronary lesions by non-invasive imaging and its potential role in different clinical settings has been recently explored. However, the relationship of ESS with functional indices derived by computed tomography coronary angiography (CTCA) and its value in predicting perfusion changes by quantitative positron emission tomography (PET) downstream stenotic vessels has not been assessed.

Purpose: To investigate the feasibility of calculating local ESS, its relationship with stenosis severity as well as with virtual functional assessment index (vFAI), and the comparative performance of the two parameters for predicting impaired coronary vasodilating capability in terms both of stress myocardial blood flow (MBF) and myocardial flow reserve (MFR) in patients submitted to CTCA.

Methods: Thirty-two patients (23 male-9 female, mean age 65.6±7.2 years) with intermediate pre-test likelihood of coronary artery disease (CAD), who were enrolled in the EVINCI and SMARTool projects, and had undergone CTCA with vFAI and PET myocardial perfusion imaging with 15 O-water or 13 N-ammonia were included in the study. PET was considered positive when >1 contiguous segments showed both stress MBF ≤2.3 mL/g/min and MFR ≤2.5 for 15 O-water or ≤1.79 mL/g/min and ≤2.0, for 13 N-ammonia respectively. A vFAI threshold of 0.85 was used as predictor of impaired coronary vasodilating capability. ESS computation was based on a mean aortic pressure of 100 mmHg for the inlet and a mean blood flow at rest of 0.00105 kg/s for the outlet. ESS was calculated (Pa) in the full length of the stenosis and the mean value was obtained.

Results: Hybrid imaging analysis was performed in CTCA and PET datasets. 51 coronary segments were assessed. There were 27 lesions with stenosis 31–50% and 24 lesions with stenosis 51–70%. ESS was higher in the latter (20.4, IQ: 11.4–32.1 vs. 10.4, IQ: 5.5–15.7, p=0.04). Similarly, ESS was higher in stenoses with impaired vasodilating capacity compared to those without, although this difference did not reach statistical significance (22.8, IQ: 13.2–35.1 vs. 10.6, IQ: 5.7–22.1, p=0.10). The ROC curve analysis for prediction of both abnormal stress MBF and MFR followed the same pattern (AUC=0.668, 95% confidence interval (CI): 0.490–0.810, p=0.11). On the other hand, there was a moderate negative correlation (r=−0.41, p=0.004) between ESS and vFAI and the former was lower in stenoses with vFAI >0.85 compared to those below this threshold (7.35, IQ: 3.2–13.9 vs. 19.1, IQ: 14.1–32.8, p=0.012). vFAI was a good predictor of coronary flow capacity (AUC=0.737, CI: 0.58–0.85, p=0.02).
Conclusion: Calculation of ESS is feasible in CTCA datasets. ESS was related with stenosis severity and there was a trend to be higher in lesions with impaired coronary vasodilating capability. ESS is modestly related with vFAI and may also be an additional predictor of impaired regional myocardial flow obtained by PET imaging.