Prediction of impaired myocardial blood flow (MBF) with the use of machine learning techniques on CTCA based parameters

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Background: Computed Tomography Coronary Angiography (CTCA) is a non-invasive imaging modality, used effectively for anatomo-functional assessment of coronary artery disease (CAD). Machine learning (ML) processes can effectively allow the extraction of useful information from multidimensional feature spaces for evaluation of coronary lesions.

Purpose: To investigate the ability of ML for predicting impaired myocardial blood flow (MBF) by combining computational fluid dynamics (CFD) derived parameters with quantitative plaque burden, plaque morphology and anatomical characteristics obtained from CTCA.

Methods: 53 patients (31 male, mean age 64.7 ± 7.1 years) with intermediate pre-test likelihood of CAD who underwent CTCA and PET-MPI were included. PET was considered positive when > 1 contiguous segment demonstrated MBF ≤ 2.3 mL/g/min for 15O-water or ≤ 1.79 for 13N-ammonia respectively. CFD derived parameters such as a previously validated, virtual functional assessment index (vFAI), segmental endothelial shear stress (ESS), as well as anatomical and plaque characteristics were assessed. Seven classifiers were implemented and internally validated using 5-fold cross validation, repeated 1000 times. Using sequential forward selection (SFS), the highest rank features combination, based on appearances in the highest mean area under curve (AUC) classification scheme, was selected and features performance was evaluated following exhaustive search (ES).

Results: 92 coronary segments were analyzed and 34 features derived from CTCA were extracted. Classifiers performance are depicted in Figure A. k-NN was the best classifier with AUCmean = 0.791 (SENSmean= 0.622, SPECmean = 0.840, $p < 0.05$). Clusters of features and number of appearances are presented in Figure B. The combination of vFAI, stenosis severity and lumen area demonstrated the highest AUC (1473 times). ES results are depicted in Figure C. The combination of vFAI and lumen area was the best predictor among all the combinations (AUCmean = 0.830, SENSmean =0.61, SPECmean =0.83, $p < 0.05$) followed by vFAI and stenosis severity (AUCmean = 0.81, SENSmean =0.72, SPECmean = 0.87, $p < 0.05$) and vFAI alone (AUCmean = 0.806, SENSmean =0.61, SPECmean =0.87, $p < 0.05$).

Conclusion: ML analysis is feasible for predicting with reasonable specificity abnormal MBF by PET, using a combination of CFD derived parameters and anatomical features. vFAI as a single characteristic was a specific predictor of impaired MBF, whilst in combination with stenosis severity, maintained almost the same AUC and specificity values and resulted in improved sensitivity. On the other hand, addition of lumen area to vFAI, increases the AUC and provides a relatively good specificity but low sensitivity.

Abstract Figure 1