Radiomics-based Analysis of Biomechanical Maps for Cardiovascular Risk Stratification

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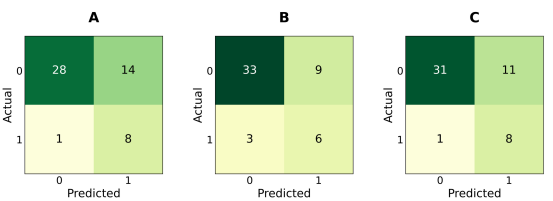
Aims: Predicting major adverse cardiovascular events (MACE) remains a critical clinical challenge, given the high global burden of coronary artery disease. Despite several proposed vulnerability biomarkers, accurate patient stratification remains elusive, and comprehensive approaches integrating multiple complementary markers have shown to be promising. This study proposes a multi-domain machine learning framework for the prediction of MACE, integrating conventional biomechanical markers from finite element analysis (FEA) and radiomic features extracted from 2D maps of von Mises stress and strain.

Methods: The study included 168 patients with 577 plaques who underwent coronary computed tomography angiography, of whom 28 experienced a MACE. Three independent models were developed: (A) a biomechanical model using scalar FEA-derived markers, (B) a radiomics-on-biomechanics model using radiomic textural features extracted from 2D stress/strain maps, and (C) a combined model integrating the features of A and B. Model selection and hyperparameter tuning were performed via 3-fold cross validation, while final evaluation was performed on a held-out test set.

Results: The biomechanical model achieved an AUC of 0.80 and a balanced accuracy (BA) of 0.78, with high sensitivity (0.89) but limited specificity (0.67). The radiomics-on-biomechanics model showed slightly lower overall performance (AUC = 0.78, BA = 0.73), but a complementary specificity (0.79)-sensitivity (0.67) trade-off. The combined model achieved the best performance, with AUC = 0.87 and BA = 0.81, while preserving sensitivity (0.89) and improving specificity (0.74).



Confusion matrices for the three models.

Conclusion: Integrating radiomic features from FEA-derived 2D maps with biomechanical markers yields a more balanced MACE predictor than either approach alone, demonstrating the potential of multi-domain integration for a more comprehensive assessment of cardiovascular risk.