The importance of inelasticity when simulating balloon deployment in diseased arteries

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Abstract:
Introduction
Elastic recoil following drug-eluting stent (DES) or drug-coated balloon (DCB) deployment is widely used to assess procedural success. Despite its name, elastic recoil is not a purely elastic displacement, as arteries only partially restore their original shape. This phenomenon is particularly significant in DCB applications. While inelastic arterial models exist, most focus on stents, and simplified plaque models fail to capture the complexity of atherosclerotic plaques. To the best of our knowledge, no existing literature has employed a realistic inelastic plaque model for lesion preparation modelling and drug elution simulations. This computational analysis aims to accurately predict the state of the diseased artery after device deployment, therefore taking into account inelasticity in patient specific plaque geometries and lesion preparation techniques.
Methods
Finite element analysis was used to simulate arterial mechanics. Patient-specific plaque geometries were obtained from literature, and various plasticity models were tested with different plaque compositions. Internal pressure and semi-compliant balloons were deployed, and procedural efficacy was assessed using Elastic Recoil Ratio (ERR) and Lumen Gain Ratio (LGR), along with stress-strain distributions.
Results
Plastic strain and stress distributions were analysed across patient-specific geometries. Geometry 1 was tested with lipidic and calcified plaques, while Geometry 2 was analysed with uniform and mixed plaque compositions. The study compared perfect plasticity and linear hardening models, selecting the latter for further simulations due to its clinical relevance.
Discussion
Plaque composition influenced plastic strain distribution and residual stresses after balloon expansion. These effects contribute to plaque damage and potential morphological changes post-lesion preparation, which may impact drug transport following DCB use. Understanding lesion preparationâ€™s role in plaque morphology is crucial for improving DCB efficacy. This study enhances post-procedure predictions by incorporating realistic inelastic plaque modelling, supporting better lesion preparation strategies and therapeutic outcomes.