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The Effect of Three-Dimensional Morphology on Vulnerability Assessment of Atherosclerotic Plaque

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Abstract : Atherosclerotic plaque rupture is the main trigger of heart attack and brain stroke which are the leading cause of death in developed countries. Better understanding of rupture-prone plaque can help clinicians detect vulnerable plaques-rupture prone or instable plaques- and apply immediate medical treatment to prevent these life-threatening cardiovascular events. Therefore, there are plenty of studies addressing disclosure of vulnerable plaques properties. Necrotic core and fibrous tissue are two major tissues constituting atherosclerotic plaque; using histopathological and numerical approaches, many studies have demonstrated that plaque rupture is strongly associated with a large necrotic core and a thin fibrous cap, two morphological characteristic which can be acquired by two-dimensional imaging of atherosclerotic plaque present in coronary and carotid arteries. Plaque rupture is widely considered as a mechanical failure inside plaque tissue; this failure occurs when the stress within plaque excesses the strength of tissue material; hence, finite element method, a strong numerical approach, has been extensively applied to estimate stress distribution within plaques with different compositions which is then used for assessment of various vulnerability characteristics including plaque morphology, material properties and blood pressure. This study aims to evaluate significance of three-dimensional morphology on vulnerability degree of atherosclerotic plaque. To reach this end, different two-dimensional geometrical models of atherosclerotic plaques are considered based on available data and named Main 2D Models (M2M). Then, for each of these M2Ms, two three-dimensional idealistic models are created. These two 3D models represent two possible three-dimensional morphologies which might exist for a plaque with similar 2D morphology to one of M2Ms. Finite element method is employed to estimate stress, von-Mises stress, within each 3D models. Results indicate that for each M2Ms stress can significantly varies due to possible 3D morphological changes in that plaque. Also, our results show that an atherosclerotic plaque with thick cap may experience rupture if it has a critical 3D morphology. This study highlights the effect of 3D geometry of plaque on its instability degree and suggests that 3D morphology of plaque might be necessary to more effectively and accurately assess atherosclerotic plaque vulnerability.

Keywords : atherosclerotic plaque, plaque rupture, finite element method, 3D model
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