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Cyclic Bending Contributes to High Stress in Human Coronary Atherosclerotic Plaque and Rupture Risk

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Summary

Cardiovascular disease (CVD) is the No. 1 killer in the developed countries and is becoming the No. 1 killer in the world. Many acute cardiovascular syndromes such as heart attack and stroke were caused by atherosclerotic plaque rupture which happens without warning most of the time. Mechanisms causing plaque rupture are not fully understood. MRI-based 3D multi-component models with fluid-structure interactions (FSI) have been introduced to perform flow and stress/strain analysis for atherosclerotic plaques and identify possible mechanical and morphological indices for accurate plaque vulnerability assessment. In this paper, we are adding cyclic bending to 3D FSI coronary plaque models for more accurate mechanical predictions. We hypothesize that cyclic bending of coronary atherosclerotic plaques may be a major contributor to critical stress variations in the plaque leading to increased plaque rupture risk. Computational models were constructed based on ex vivo MRI human coronary plaque data to assess the effect of cyclic bending, pulsating pressure phase angle, and inhomogeneous plaque structure on plaque stress/strain distributions. In vitro experiments using hydrogel stenosis model with cyclical bending were performed to observe effect of cyclical bending on flow conditions. Our results indicated that cyclical bending may cause 100%-400% increase in maximum principal stress values at locations where the vessel was bent the most. The stress-strain distributions in the plaque were very different when bending was included. Our initial study indicates that cyclic bending affects stress variations in coronary plaques with a magnitude at least as important a role as blood pressure does. These effects may be included in coronary models for accurate mechanical analysis and stress-based plaque vulnerability assessment.

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