A MECHANICAL APPROACH TO THE CHARACTERIZATION OF MATERIAL FAILURE OF ATHEROSCLEROTIC LESIONS

Lindsey Davis

ABSTRACT

Failure of atherosclerotic plaques can lead to potentially life threatening clinical events such as myocardial infarction (MI), stroke, or transient ischemic attack (TIA). The most frequently described plaque failure mechanism is tensile rupture of the fibrous cap; however, often during angioplasty another plaque failure mechanism occurs in which the atherosclerotic plaque separates from the internal elastic lamina (IEL). This study aims to apply mechanical concepts for measuring strength of materials to assess the mechanical strength of atherosclerotic lesions.

To assess likelihood of plaque dissection at the vessel wall, adhesion strength was assessed in both mouse and human specimens using plaque delamination experiments. Plaque adhesion strength is one to two orders of magnitude greater in human samples as compared to mouse samples.

To further understand adhesive failure at the plaque-IEL interface, the contributions of adhesive proteins to the mechanical strength of the plaque-IEL interface were investigated. The results from a novel semi-quantitative plaque immunoblotting technique and measurements of adhesive strength of thin protein films combine to provide an estimate of the adhesive strength of several relevant matrix proteins at approximate ex vivo concentrations. The adhesion strength in thin protein films is much lower than that determined from in situ plaque adhesion
experiments and suggests that bridging fibers, rather than adhesive proteins, are likely to be responsible for the adhesive strength of the plaque-IEL interface.

In addition to plaque adhesion strength, plaque stability was also assessed by investigating the resistance to tensile rupture of the fibrous caps in human carotid endarterectomy specimens. Crack tip opening displacement (CTOD) and stress in the uncracked segment (UCS) were both measured during failure in miniature single edge notched tensile (MSENT) experiments on strips of fibrous cap. The results show that fibrous caps with greater collagen content fail at a higher stress and a smaller CTOD than those with a lower collagen content. CTOD and stress in the UCS present conflicting rankings for the fracture resistance of fibrous caps, and the relevant fracture parameter depends on the collagen content in the fibrous cap.