Geometric predictors of abdominal aortic aneurysm maximum wall stress

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Abstract

Abdominal aortic aneurysm (AAA) is a dilation of the abdominal aorta (above 50 % of its original diameter), which can cause death upon rupturing. It usually grows asymptomatically leading to late clinical intervention. The medical criteria to indicate surgery are based on measuring the diameter and growth rate, but in many cases aneurysms fail at uncharacterized critical values. In search of a more efficient technique in predicting AAA failure, there is consensus on the importance of studying its geometric characteristics and estimation of the wall stress, but no fully successful correlation has been found between the two yet. This work examines the relationship between a parameterized geometry (18 input variables and 10 dependent indices) and 1 output variable: the maximum wall stress. Design of Experiments (DOE) techniques are used to generate 183 geometric configurations, for which Finite Element Analyses are performed using ANSYSTM state-of-the-art solver with a hyperelastic, isotropic and homogeneous arterial model for the wall, considering systolic internal pressure (steady state) and the restriction of longitudinal movement at the blood vessel end-sections. Due to the large number of independent parameters to consider, a preliminary Parameters Correlation analysis was performed to determine if a correlation between all input parameters and the maximum stress existed. The correlations between input parameters and the output variable were determined using the Spearman Rank correlation. Correlations with the maximum wall stress for: maximum diameter ($p = 0.46$), wall thickness ($p =-0.35$), dc parameter ($p = 0.21$) and tortuosity ($p = 0.55$) were found. The response surface function between geometry and maximum wall stress was estimated by three models: Universal Kriging geostatistical regression (18 parameters), multiple linear regression (4 parameters) and multiple exponential regression (4 parameters). The models accounted for the stress variance by 99 %, 61 % and 66 %, respectively, with average percentage errors of 0.12 %, 16 % and 17 %, respectively. The solution spaces obtained from this study might provide physicians with a better estimation of the AAA rupture potential and thus, facilitate safer and anticipated treatments of the condition.

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