On the Identification of Heterogeneous Nonlinear Material Properties of the Aortic Wall from Clinical Gated CT Scans

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Abstract: It is well known that mechanical properties of the aortic wall exhibit patient-specific variations. Recent experimental findings also suggest the aortic wall properties are highly region-specific [1-2]. Thus, *in vivo* heterogeneous (non-uniform) nonlinear mechanical properties of the aortic wall of individual patients needs to be noninvasively identified for accurate prediction of clinical events (e.g. aortic rupture).

In this study, we developed an inverse approach for identification of patient-specific non-uniform material properties of the aortic wall from gated 3D CT scans. This inverse approach leverages the fact that the *in vivo* transmural mean stress (tension) of the aortic wall is independent of material properties and residual deformations under known physiological loading condition [3]. Hence, using multi-phase (e.g. diastole and systole) CT images, heterogeneous material parameters can be identified following the steps of: (1) computing diastolic and systolic stress/tension fields using the corresponding geometries and blood pressure levels, (2) building stress/tension-based objective functions for each anatomic regions with constraints on the smoothness of the material parameter fields, and (3) obtaining the identified material parameters by minimizing the objective functions. Numerical justification of the inverse approach was successfully conducted using a numerically-generated example from an ascending thoracic aortic aneurysm (ATAA) patient. For experimental validation, the inverse approach was applied to identify heterogeneous material properties from pre-operative gated CT scans of two patients, and ATAA tissues of the two patients were collected for planar biaxial testing experiments to measure tension-stretch responses. Relatively close matches were achieved for the inversely estimated and experimentally-derived tension-stretch responses. The developed inverse approach may facilitate personalized biomechanical analysis of aortic tissues in clinical applications, such as ATAA rupture risk analysis.

Keywords: *In vivo* material properties; inverse method; static determinacy; finite element analysis

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