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A simple, effective and clinically applicable method to compute abdominal aortic aneurysm wall stress

Grand Roman Joldes, Karol Miller*, Adam Wittek and Barry Doyle

Vascular Engineering, Intelligent Systems for Medicine Laboratory,

The University of Western Australia, 35 Stirling Highway, Perth WA 6009, Australia.

Abstract:

Abdominal aortic aneurysm (AAA) is a permanent and irreversible dilation of the lower region of the aorta. It is a symptomless condition that if left untreated can expand to the point of rupture. Mechanically-speaking, rupture of an artery occurs when the local wall stress exceeds the local wall strength. It is therefore desirable to be able to non-invasively estimate the AAA wall stress for a given patient, quickly and reliably.

In this paper we present an entirely new approach to computing the wall tension (i.e. the stress resultant equal to the integral of the stresses tangent to the wall over the wall thickness) within an AAA that relies on trivial linear elastic finite element computations, which can be performed instantaneously in the clinical environment on the simplest computing hardware. As an input to our calculations we only use information readily available in the clinic: the shape of the aneurysm in-vivo, as seen on a computed tomography (CT) scan, and blood pressure. We demonstrate that tension fields computed with the proposed approach agree well with those obtained using very sophisticated, state-of-the-art non-linear inverse procedures. Using magnetic resonance (MR) images of the same patient, we can approximately measure the local wall thickness and calculate the local wall stress. What is truly exciting about this simple approach is that one does not need any information on material parameters; this supports the development and use of patient-specific modelling (PSM), where uncertainty in material data is recognized as a key limitation.

The methods demonstrated in this paper are applicable to other areas of biomechanics where the loads and loaded geometry of the system are known.

Keywords: Abdominal Aortic Aneurysm, Patient Specific Modelling, Finite Element Method, Inverse problems

*Corresponding author, e-mail: karol.miller@uwa.edu.au , phone: + 61 8 6488 8545. The first and second author contributed equally to this work.