Does Aneurysm Biomechanical Ratio Predict Rupture or Repair in Patients with Abdominal Aortic Aneurysm?

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Biomechanical analysis of abdominal aortic aneurysms (AAA) is an extremely active area of research, with hundreds of papers with aneurysm and biomechanics as search terms in Web of Science and PubMed databases. The main goal of this research programme is identifying quantities from biomechanical models that have value as biomarkers of disease progression and rupture risk. Indeed, finding such a quantity would be of immense importance.

Recently results of biomechanical analysis of AAA in 285 patients have been published in EJVCS [1]. In this Research Letter we attempt to reassess the main conclusion of this paper – that the value of ratio of maximum principal wall stress divided by wall strength (ABR) is a predictor of future rupture or repair – by including into consideration the uncertainty in AAA wall thickness measurement.

Doyle et al. [1] report that they used Magnetic Resonance images with resolution 0.822 mm x 1.042 mm (within slice) x 5 mm (between slices) to measure AAA wall thickness for every patient. The accuracy of this measurement is fundamentally limited by image resolution. Based on experience from our Laboratory and others [2], the accuracy of such a measurement cannot be assumed to be better than half of within slice pixel size, in this case +/- 0.5 mm. As

the average wall thickness reported in Doyle at al. [1] is 2.00 mm, the +/- 0.5 mm uncertainty is equivalent to +/- 25% of the measured value.

Our parametric studies indicated an approximately linear relationship between measured/assumed wall thickness and computed maximum principal stress [3]. This relationship implies that 1/2 of within slice pixel size inaccuracy in AAA wall thickness measurement will immediately result in +/- 25% inaccuracy in the maximum principal stress calculation.

The Aneurysm Biomechanical Ratio (ABR) presented in Fig 3(A) in Doyle et al. [1] is computed by dividing maximum principal stress by the AAA wall strength estimated using population-based statistics. Therefore ABR is subject to at least as large uncertainty as the principal wall stress, as shown in Figure 1 below. This uncertainty is larger than 16% difference between the median ABR for the patients with and without clinical events reported on page 5 in Doyle et al. [1].

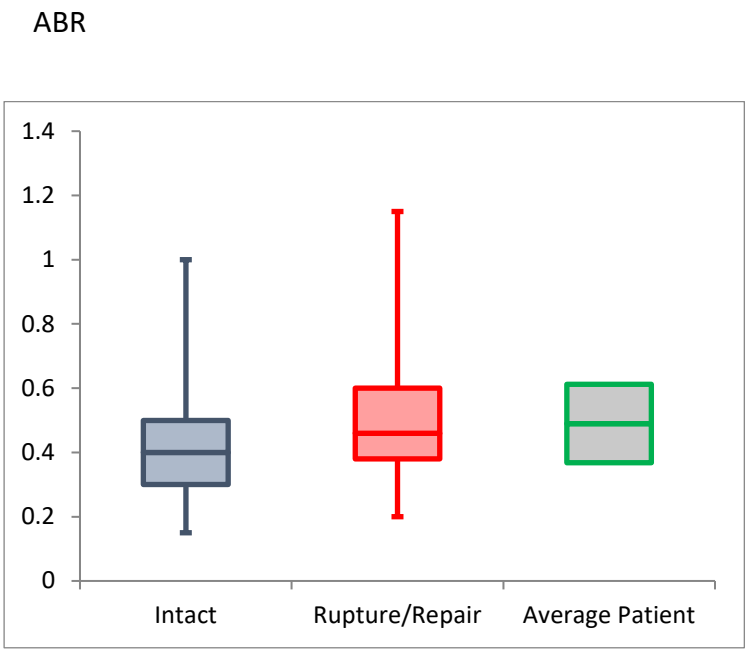

Figure 1. Aneurysm Biomechanical Ratio (ABR) for intact and ruptured/repaired cases, reproduced from Fig. 3A from Doyle at al. [1] , together with our estimate of uncertainty of ABR for the average patient. For the average patient we used ABR=0.49 (Table 2 in Doyle at al. [1]).

As indicated in Figure 1, the uncertainty in ABR for a single patient overlaps with the results computed for intact and repaired/ruptured cases. Moreover, there are (at least) three other sources of uncertainty in patient-specific ABR computation: i) variability of AAA reconstruction from CTA (in our experience this variability is not large and perhaps can be omitted from consideration); ii) inaccuracy of patient-specific AAA wall strength estimation based on population-based statistics (the magnitude of this uncertainty is unknown but potentially very large due to e.g. localised weakening of tissue); and iii) impact of residual stress on computed maximum principal stress [4].

Even if the uncertainties discussed above are disregarded, a very large proportion of patients would be misclassified (Fig. 1): all intact cases in quartile 4, all ruptured/repaired cases in

quartile 1 plus a large proportion of intact quartile 3 cases and ruptured/repaired quartile 2 cases. Therefore, no conclusions about ABR's capability of predicting future events for a particular AAA patient can be drawn.

The result presented in this Research Letter is consistent with findings of Miller at al. [5] where, together with colleagues from University Hospital Leuven, we showed that the AAA wall stress computed with current version of BioPARR (i.e. including residual stress) does not appear to be a reliable predictor of the severity of the disease as the stress distributions and magnitudes do not correlate with clinically observed symptoms. Image data, segmentations and finite element meshes used in Miller at al. [5] are freely available on line.

References:

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