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CORRESPONDENCE

Rupture of Abdominal Aortic Aneurysms. What Matters Most: Geometry or Blood Pressure?

We read with great interest the article by Truijers *et al.*[1] concerning the use of wall stress analysis in order to detect patients at high risk for small diameter abdominal aortic aneurysm (AAA) rupture. By using finite element analysis of reconstructed three-dimensional models the authors found that wall stress at maximal systolic blood pressure is significantly higher for ruptured compared to asymptomatic AAAs. At the same time, stress analysis at uniform blood pressure of 120 mmHg resulted in insignificant differences in wall stress between asymptomatic and ruptured small aneurysms.

Although this is an interesting finding, there are some points that need be addressed. First, computational studies of the normal aorta have already shown that increased systolic blood pressure causes an elevation of peak wall stress.[2] Second, we believe that the role of AAA geometry should not be underestimated even in AAAs with diameters of 5–5.5 cm. Raghavan *et al.*[3] found that AAA volume appeared to have a stronger correlation with peak wall stress than systolic blood pressure. Other computational studies have well correlated the curvature and torsion of the AAA model with the peak wall stress and the resulting rupture risk.[4] Third, as the authors correctly state AAA rupture could result in the formation of hematoma, thus distorting the original geometry. Therefore, we believe that stress analysis in ruptured AAAs should not be performed post-rupture because the geometry, loading conditions and outer-wall material properties are altered in these conditions. Finally, the authors could have emphasized that a dynamic fluid-structure interaction analysis incorporating the circadian fluctuations of blood pressure could be more realistic with regard to prediction of rupture risk.

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Letter to the Editor re: Rupture of Abdominal Aortic Aneurysms. What Matters Most; Geometry or Blood Pressure?

We thank Drs Giannakoulas, Giannoglou, Soulis, louradis and Parharidis for their valuable comments concerning our study and for their attribution to the discussion on aneurysm wall stress analysis and rupture risk prediction in general.

Computed wall stress depends upon the input of both blood pressure data and aneurysm geometry into a material model designed for finite element analysis. Both determinants therefore seem equally

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important and synergetic. In order to investigate the true influence of both variables on computed wall stress, additional analysis should be performed after normalization of both blood pressure and AAA geometry. Unfortunately, as normalization of AAA geometry is not possible, we performed additional analysis at normalized blood pressure only. Although we still observed differences in wall stress between asymptomatic and ruptured aneurysms these differences no longer reached significance. Although this could obviously be a Type II error owing to the relatively small number of patients, we concluded that AAA geometry in our series had to be relatively similar between asymptomatic and ruptured aneurysms.

Giannakoulas *et al*. may be correct in stating that AAA wall properties change at the time of rupture, and we acknowledge that the development of a patient specific material model will further improve rupture risk prediction. However in spite of the use of a population-derived material model, and the fact that subtle geometrical differences between ruptured and asymptomatic AAA could have been obscured in the rupture group, wall stress was still elevated for ruptured aneurysms.

As both blood pressure and aneurysm geometry vary during the cardiac cycle (systolic vs. diastolic) wall stress will vary accordingly. However, since aneurysm rupture occurs at peak wall stress all our calculations have been based upon maximal systolic blood pressure. Although the incorporation of fluid-structure interaction analysis could provide valuable information on variation in wall stress during the cardiac cycle, aneurysm wall tensile stress is orders of magnitude greater than wall shear stress, and the addition of FSI appears unlikely to add to rupture risk prediction at this point.[1]

Lastly, we did not intend to convey in our paper that aneurysm geometry should be overlooked in larger aneurysms. As papers by one of our co-authors indicate, geometry is important in all aneurysms, but aneurysm wall stress appears to be superior.[2,3]

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