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SHORT REPORT

Peak Wall Stress Does Not Necessarily Predict the Location of Rupture in Abdominal Aortic Aneurysms

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Abstract Using finite element analysis, we evaluated if the site of an aortic bleb, known to be prone to rupture, coincides with the location of peak wall stress (PWS) in a patient-specific abdominal aortic aneurysm (AAA) model.
Report: PWS was not located at the bleb site, even when stress values were estimated for different bleb wall thicknesses (0.5–2.0 mm) while the rest of the AAA wall was considered constant (2 mm).
Discussion: The sites of PWS in AAAs should not always be considered as the sites most prone to rupture since other factors, such as wall strength, may play a role in rupture-risk prediction, depicting the need for further investigation of these parameters.

Aortic blebs are focal saccular outpouchings of the wall surface, detected in 10–20% of the aneurysms and related with increased risk of rupture.[1] From a mechanical point of view, these blebs present lower tensile strength compared with the rest of the aneurysm.[2] We applied the finite element analysis (FEA) in a case of a symptomatic abdominal aortic aneurysm (AAA) with a bleb on its anterior surface to study whether this wall surface anomaly, which is the area most prone to rupture, actually coincided with the location of the peak wall stress (PWS).

Materials and method

A 65-year-old male patient complaining of severe abdominal pain, attributed to an infrarenal AAA (7.5 cm), was investigated. During open surgery, an easily compressible 'bleb' (4 × 4 cm) on the anterior surface of the sac was

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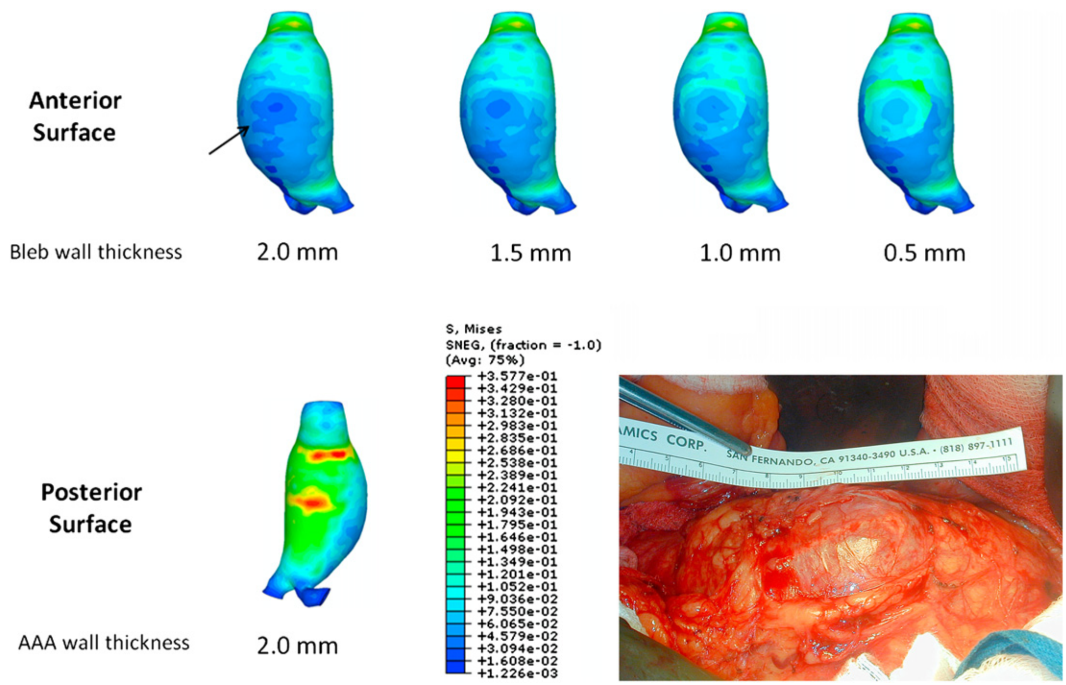

Figure 1 Comparison of PWS distribution for each model of different ''bleb'' wall thickness (BWT). PWS is always located in the same sites (posterior wall), despite the elevated stress values in anterior surface, when BWT declined. The colour scale is the same for all measurements. (Arrow denotes the ''Bleb'' area). **Inlet**: The wall ''bleb''. The inferior mesenteric artery origin is on the bleb.

found (Fig. 1, **Inlet)**, with a considerably thinner wall than that of the surrounding. We estimated PWS, taking into account the presence of intraluminal thrombus (ILT), using the methodology previously described in detail.[3] Reconstructions of the given aneurysm were conducted for various wall thickness values (e.g., 2.0, 1.5, 1.0 and 0.5 mm) in the 'bleb' area, with the rest of wall thickness of the aneurysm fixed at 2 mm. The P-values <0.05 were considered significant.

Results

Wall stress distribution in each AAA model can be seen in Fig. 1. In general, the posterior wall always had higher wall stress values than the anterior wall, with the highest wall stress values located in its mid-part and close to the conjunction with the neck.

Wall stress calculations for the anterior and the posterior surfaces of the aneurysm are depicted in Table 1. The lowest stresses anteriorly were always located at the bleb apex, reaching its highest value at 6.0 N/cm^2 when the thickness of the bleb wall was modelled (or considered) to be 0.5 cm, which was 4 times smaller than that of the posterior wall thickness. Estimation of wall stress values at the bleb site, after decreasing its wall thickness in our model, revealed increasing wall stress values but still much lower than wall stresses of the posterior wall ($P < 0.01$) (Table 1, Fig. 1).

The maximum value of wall stress anteriorly was always located at the rim of the bleb. The same held true when bleb wall thickness was reduced, reaching 19.4 N/cm^2 when the wall thickness there was assumed to be 0.5 mm (Table 1). The difference between PWS at the apex compared with the rim of the bleb was significant ($P = 0.01$).

Discussion

AAA blebs have been associated with increased risk of rupture and have an estimated sevenfold lower strength than that of the rest of the aneurysm.[1,2] We conducted this study to investigate if the clinically postulated site of imminent rupture coincided with the site of PWS. Contrary to our expectations, the bleb showed very low wall stress values, even when its wall thickness was considered 4 times thinner than the rest of the aneurysm wall.

We have previously reported that the presence of ILT reduces PWS in AAA patients.[3] However, ILT acts as a source of proteolytic enzymes affecting AAA wall structure and thus its mechanical strength.[4] Furthermore, blebs are characterised by gradual decrease of the amount of elastic tissue in the media, in contrast to the rest of the aneurysm wall.[1] Therefore, the mechanical consideration of ILT in computational models as a mean that just reduces the wall stress may be inadequate for the determination of the possible rupture site.

Table 1 Comparison of wall stress values between the bleb located on the anterior wall and the posterior wall.

Bleb wall thickness (mm)	Wall Stress (N/cm^2)		
	Anterior wall (Bleb area)		Posterior wall (wall thickness 2 mm)
	Apex	Rim	
2.0	2.4	9.1	35.8
1.5	3.4	11.1	35.8
1.0	4.3	13.6	35.8
0.5	6.0	19.4	35.8
	$P = 0.01$		$P < 0.01$

The bleb showed lower wall stress value than the rest of the AAA. The sites of PWS should not always be considered as the sites most prone to rupture since other factors, such as wall strength, may play a role in wall stability. Future AAA predictive models of rupture should take into account the interaction between these two counteracting factors.

Conflict of Interest

None.

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