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ASSESSMENT OF A CLINICALLY RELEVANT GEOMETRIC MEASURE FOR IDENTIFYING VULNERABLE CAROTID PLAQUES

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INTRODUCTION

One of the primary causes of stroke is the rupture of atherosclerotic plaque at the carotid artery bifurcation[1]. More than half of these types of strokes occur in patients displaying no symptoms[2]. Clinical decisions on asymptomatic cases are currently based on the percentage of vessel stenosis, despite evidence that this not a good indicator of plaque rupture risk[3]. Therefore there is a clinical need for improved quantitative measures to assess the risk of plaque rupture.

Structural analysis of carotid bifurcations using the finite element (FE) method can identify regions of high stress where there is a risk of rupture[4]. The accuracy of these analyses is limited, however, by the heterogeneity and unknown material properties of the plaque. Furthermore these analyses require significant investment in time and expertise. It has previously been shown that vessel lumen curvature and thickness, taken individually, do not correlate with regions of high stress in 2D FE simulations of idealized vessels[5].

This study presents a new metric for the assessment of plaque rupture risk using lumen and plaque curvature as well as vessel thickness. It is shown that this new metric gives good predictions of regions of high stress which may be at risk of plaque rupture.

MATERIALS AND METHODS

<u>2-D Models</u> Idealized 2-D geometries of a stenosed vessel cross-section were constructed considering a circular plaque and vessel wall, and an elliptical lumen offset from the circular centre. Ellipse major-to-minor axis ratios of 1.2:1, 1.4:1, and 1.6:1 were examined (Fig. 1A). FE analyses of the geometries were performed using separate material properties for the plaque and artery wall and a lumen pressure of 120 mmHg[4]. The von Mises stress, σ, in the vessel wall was computed (Abaqus, v6.14). Next the curvature of the lumen, κ_l, and plaque, κ_p, boundaries were calculated (Matlab, 2015b). A new metric, the weighted curvature difference (WCD) was defined and calculated as,

$$\text{WCD} = \frac{\Delta\kappa}{t}, \qquad (1)$$

where $\Delta\kappa = \kappa_l - \kappa_p$ is the curvature difference between the lumen and plaque curvatures with respect to radial lines from the lumen centroid, and t is the plaque thickness along these radial lines.

<u>3-D Models</u> Idealized 3-D geometries of stenosed vessels were created by lofting a series of the 2-D geometries described above (Fig. 1B). FE analysis of the 3-D geometry was performed as above. Next the principal surface curvatures of the lumen and plaque boundaries were computed. The WCD was calculated using the maximum principal curvatures, and plaque thickness was evaluated in planes normal to the lumen centreline.

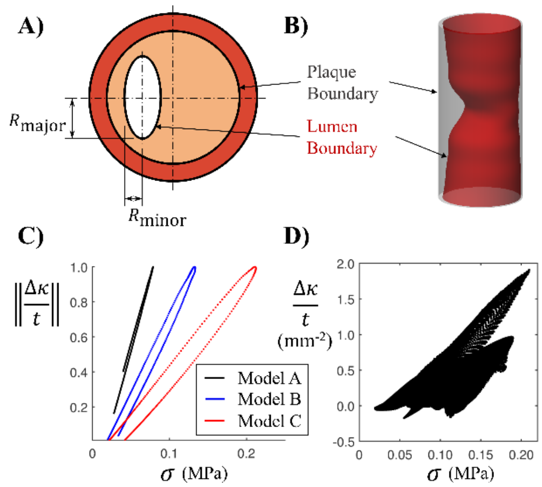

Figure 1 **A)** Idealized 2-D and **B)** 3-D geometry used for assessment of lumen stress and weighted curvature difference (WCD). **C)** Scatter plot of WCD, normalized by the max WCD, and corresponding stress for three idealized 2-D models. **D)** Scatter plot of the WCD and corresponding stress in the idealized 3-D model. Note the coincidence of max. WCD and the max. stress.

RESULTS

A plot of the WCD and corresponding stress (Fig. 1C) shows that the maximum curvature occurs at the same locations as the maximum stress for the three 2-D idealized models. This correlation is also present in the 3-D models (Fig. 1D), though the distribution of WCD and stress is significantly more complex.

DISCUSSION

Preliminary results obtained using idealized geometries demonstrate that WCD has good potential as a clinical metric to assess risk of plaque rupture. Further studies analysing large numbers of real patient datasets are ultimately required to determine its efficacy as a diagnostic tool in clinical practice.

REFERENCES

1. Baroncini *et al.* Cardiovasc Ultrasou 4:1, 2006
2. Naghavi *et al.* Circulation 108:1664, 2003
3. Golledge *et al.* Stroke 31:774, 2000
4. Creane *et al.* Comput Biol Med 40:419, 2010
5. Teng *et al.* Ann Biomed Eng 38:3096, 2010

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