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ESAO abstract

Title
Numerical Comparison of Shear and Elongational Stresses in Rotary Ventricular Assist Devices

Background
Despite the evolution of Ventricular Assist Devices (VADs), VAD patients still suffer from complications, often due to damage to the blood by fluid dynamic stress. To date, most numerical models for blood damage are functions of the scalar shear stress (SSS), the second invariant of the strain rate. Since rotary VADs are assumed to exert mainly shear stress, the measurements of blood damage for these models are obtained from shear flow experiments. However, measurements of cell deformation show elongational and shear stress deform cells differently, and then potentially damage cells differently.

Aim
The aim of this work was to use computational fluid dynamics (CFD) to assess the significance of elongational stress, in comparison with shear stress, in rotary VADs.

Methods
CFD was used to calculate flow fields in a centrifugal and an axial VAD. The velocity of the blood defined the reference frame, with both stresses computed from the transformed strain rate. Firstly, volumes of the VADs experiencing shear or elongational stress above threshold values were found. And secondly, the cell deformation index (DI= (L-W)/ (L+W); given the cell's length, L, and width, W) was set to 0.5, and the regions of the VADs producing DI > 0.5 due to shear or elongation stress were compared.

Results
Compared with elongation stress, blood in the VADs experiences higher shear stress over a larger volume. However, when comparing the stress using a threshold value for cell deformation, elongational stress occurs in a smaller but significant volume of both VADs (significant elongational stress volumes: centrifugal 0.2 cm3, axial 0.15 cm3, compared with significant shear stress volumes: centrifugal 0.3 cm3, axial 0.5 cm3).

Conclusion
Although shear stress volumes are larger than elongational volumes for both VADs, the latter are still significant in size. Crucially, given that the axial design reduces the significant elongational stress volume, but increases that for shear stress, more experimental data is needed on elongational stress-induced damage, with which to inform the design of new VADs.