3D axial and circumferential wall shear stress from 4D flow MRI data using a finite element method and a laplacian approach

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Abstract

Purpose

To decompose the 3D wall shear stress (WSS) vector field into its axial (WSS_A) and circumferential (WSS_C) components using a Laplacian finite element approach.

Methods

We validated our method with in silico experiments involving different geometries and a modified Poiseuille flow. We computed 3D maps of the WSS, WSS_A, and WSS_C using 4D flow MRI data obtained from 10 volunteers and 10 patients with bicuspid aortic valve (BAV). We compared our method with the centerline method. The mean value, standard deviation, root mean-squared error, and Wilcoxon signed rank test are reported.

Results

We obtained an error <0.05% processing analytical geometries. We found good agreement between our method and the modified Poiseuille flow for the WSS, WSS_A, and WSS_C. We found statistically significance differences between our method and a 3D centerline method. In BAV patients, we found a 220% significant increase in the WSS_C in the ascending aorta with respect to volunteers.

Conclusion

We developed a novel methodology to decompose the WSS vector in WSS_A and WSS_C in 3D domains, using 4D flow MRI data. Our method provides a more robust quantification of WSS_A and WSS_C in comparison with other reported methods. Magn Reson Med 79:2816–2823, 2018.