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Wide Bifurcation Angle Induces Flow Recirculation and a High Rotational Wall Shear Component at the Bifurcation Apex Promoting Aneurysmal Degenerative Change.

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Introduction

Cerebral arterial bifurcations represent preferred sites for aneurysm formation. We have previously demonstrated a correlation between wider bifurcation angles are aneurysm presence, potentially due to increased hemodynamic insult acting outside the protection of the medial apical pad. We hypothesized that higher bifurcation angles may result in flow recirculation in the bifurcation region.

Methods

3D rotational angiography of 13 MCA bifurcations (7 aneurysms, 6 controls) underwent computational fluid dynamic (CFD) simulations after digital removal of the aneurysm as were parametric idealized models of symmetric and asymmetric MCA bifurcations with increasing bifurcation angles (45°, 60°, 120°, 180°, and 240°). Wall shear stress (WSS) vectors along cross-sectional planes distal to be bifurcation apex were decomposed as orthogonal projections on the cut plane (rotational WSS, tangent on the cross-sectional plane) and in the direction of the plane normal. Rotational WSS (RotWSS) and its spatial gradient (RotWSSG) were sampled at and around the apex.

Table 1. Statistical analysis of rotational WSS (RWSS) in patient derived models. Shown are means with standard deviation.* indicates statistical significance assumed for a p-value smaller than 0.05.

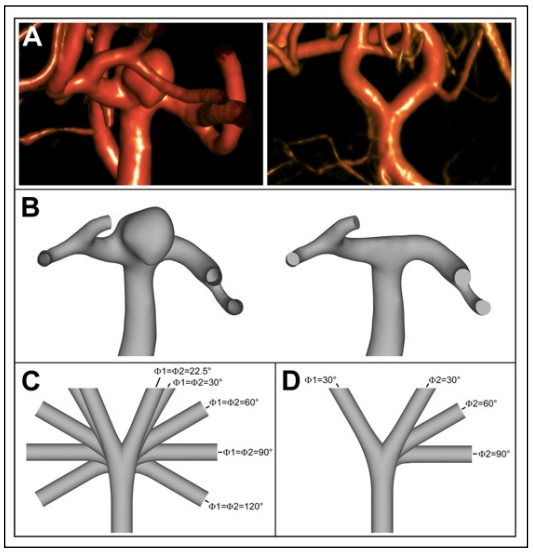
Rotational Plane Parameters	Aneurysm	Non Aneurysm	P Value
Branch Φ_1			
Max RWSS (Pa)	1.37 ± 0.67	0.48 ± 0.23	**0.01***
Max RWSSG (Pa/mm)	1.78 ± 0.92	0.76 ± 0.50	**0.03***
Branch Φ_2			
Max RWSS (Pa)	0.85 ± 0.78	0.49 ± 0.20	0.30
Max RWSSG (Pa/mm)	1.24 ± 0.82	1.16 ± 0.54	0.86

Results

In parametric models, increasing bifurcation angle was associated with higher time averaged RotWSS and high positive RotWSS gradients, fading more slowly in wider bifurcations. In asymmetric bifurcations, RotWSS was higher on the daughter vessel corresponding to the larger angle. In patient-derived models, aneurysmal MCA bifurcations were significantly wider compared to controls (149.33±12.56° vs. 98.17±8.67°, p<.001). Bifurcations harboring aneurysms had significantly higher maximum RotWSS (1.37±0.67 vs. 0.48 ± 0.23Pa, p=.01) and maximum RotWSSG (1.78±0.92 vs. 0.76 ± 0.50 Pa/mm, p=.03) compared to control non-aneurysmal control bifurcations.

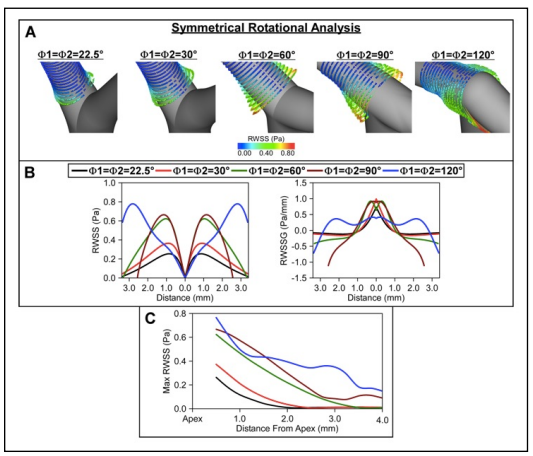
Conclusions

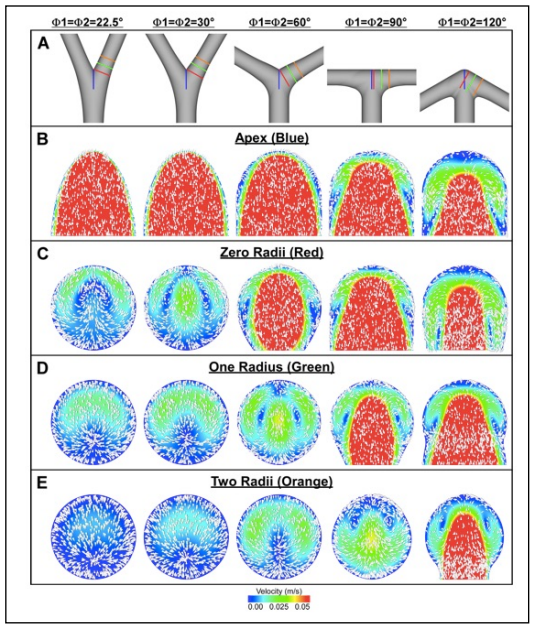
We have identified RotWSS and its spatial RotWSSG as a new component to the hemodynamic insult at the apical area in wide angle bifurcations that could serve as the trigger for the destructive remodeling seen with increased WSS and high positive WSSG; these forces occurring distal to the protective medial apical pad could serve as the initiators for aneurysm formation.



Learning Objectives

Objective is to expose the audience to the link between wide bifucation angles and aneurysm development. This work identifies a novel hemodynamic component which exists in wide bifurcations, that leads to a rotational shear stress away from the protection of the collagen strong apical pad and could explain the aneurysm genesis process.





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