**Results**

Idealized aneurysms of 3 representative shape index values (ASI = 2, 4, 6) were generated for 5 diameters (z-score = 6, 8, 10, 12, 14) at three positions along the right coronary artery (RCA) and one position in the left anterior descending (LAD) for a total of 40 cases. Hemodynamic simulation results were isolated over aneurysmal regions to identify the effects of shape, diameter, and position on local hemodynamic conditions.

**Hemodynamic Variations with Shape and Size**

Hemodynamic parameter distributions at the vessel wall have been hypothesized to be an effective way to assess aneurysm hemodynamics. Broadly, we expect similarly shaped aneurysms to give rise to similar hemodynamic behaviors; further, we expect that increases in Z-score correspond to decreases in fluid velocity and the potential for turbulence or recirculation. Indeed, these expectations are reflected qualitatively in distributions of TAWSS over the vessel surface (Figure \_\_\_). We observe that surface hemodynamic patterns vary consistently with respect to increasing Z-score, with overall decrease in TAWSS as the diameter increases. Additionally, for each value of ASI, aneurysms appear to bear similar spatial distributions of TAWSS.

To understand hemodynamic variations with geometric parameters, distributions of hemodynamic parameters are quantified in an aggregate manner, revealing that multiple combinations of aneurysm shape and size can produce similar hemodynamics. First, the average TAWSS over each aneurysm surface is computed and plotted with respect to ASI, stratified by aneurysm Z-score (Figure \_\_\_\_). We observe that as shape index increases (i.e. more elongated aneurysms), and as Z-score increases, the average TAWSS seems to decline. While in the LAD, the lowest values are observed in the longest aneurysms of largest diameter, with relatively steep negative trend overall, average values in the RCA remain relatively similar; the lowest values are observed in aneurysms with ASI = 4.

The fractional aneurysm surface area exposed to TAWSS values less than a critical threshold is another aggregate measure that has been proposed for evaluating CAA hemodynamics and stratifying patient risk [CITATION]. A plot of fractional area exposed to low TAWSS as a function of ASI, again stratified by aneurysm Z-score is given in Figure \_\_\_. We observe that for aneurysms in both the RCA and LAD, the fractional area under 1 dyne/cm2 increases as either of Z-score or ASI increase. Notably, the longest aneurysms of moderate Z-score (ASI = 6, Z-score = 8) produce similar values to shorter aneurysms of largest Z-score (ASI = 2, Z=score = 14). Together with trends in average TAWSS over the aneurysm surface, we find that multiple combinations of aneurysm shape and size can produce similar hemodynamics.

**Aneurysm Position and Hemodynamics**

Aneurysms generated in proximal, medial, and distal positions along the RCA enable comparison of hemodynamics as a function of position. Computing time-dependent flow rate into each aneurysm indicates that for each position, flow into the aneurysm is independent of size, but decreases with position along the centerline (Supplemental Figure \_\_\_\_) due to the presence of additional branches diverting blood flow. Despite variation in flow rate, Figure \_\_\_\_ depicts similar levels of TAWSS in aneurysms of the same shape aneurysms of the same shape (ASI = 2). Aneurysms in the proximal RCA exhibit comparatively little variation with increasing Z-score, relative to medial and distal locations. Although average TAWSS is higher in medial aneurysms than in proximal and distal ones, fractional surface area exposed to low TAWSS exhibits low variation with respect to both position and diameter.

To further investigate hemodynamic mechanisms underlying the non-linear relationship between average TAWSS and aneurysm position, we investigated average WSS over the cardiac cycle. We observe that in proximal and medial aneurysms of ASI=2 in the RCA, values of average WSS are ranked in decreasing order by Z-score over the cardiac cycle (Fig \_\_\_). However, in aneurysms in the distal RCA, intermediate values of Z-score (8, 10, 12) correspond to consistently increased values of average WSS compared to both low and high values (Z-score = 6, 14) throughout much of the cardiac cycle.

Hemodynamics within each aneurysm are determined through joint effects of aneurysm size and curvature. In fact, velocity streamlines through aneurysm cross sections reveal that inflow jet through the aneurysm expansion produces different impingement behaviors against the vessel wall (Figure \_\_\_). Aneurysms of the same position feature similar inflow jet patterns, producing the similar surface distributions of TAWSS as seen in Figure \_\_\_. In proximal and medial cases, increases in Z-score did not significantly alter inflow jet impingement area; however, in the distal cases, increases in Z-score alter the angle of the inflow jet, resulting in differing patterns of recirculation and the WSS trends observed in Figures \_\_\_, \_\_\_, \_\_\_. Similarly, these inflow jet patterns explain how average TAWSS can increase in medial aneurysms without altering the fractional surface area exposed to low TAWSS (Figures \_\_\_, \_\_\_).

Overall, inflow jet patterns seem to underlie relationship between aneurysm position and hemodynamics, suggesting that vessel curvature may be an effective low-dimensional predictor of hemodynamic behavior.

**Vessel Curvature and Hemodynamics**

[need to do curvature plot, discuss curvature plot]

**Clinical Predictive Value**

[map clinical data onto plots]

Discussion

These temporal variations in average WSS are difficult to identify through aggregate functions of TAWSS alone.

The potential for similar hemodynamics to arise under multiple combinations of ASI and aneurysm Z-score suggests that a combination of both parameters may be predictive of aneurysm hemodynamics. Plotting aggregate hemodynamic parameters with respect to volume shows a strong linear relationship.

Discussion

Averaging TAWSS over the surface of the aneurysm presents a single-dimensional summary value of internal aneurysm hemodynamics, yet the potential for multiple shape and size combinations to achieve similar average TAWSS values suggests that this aggregate measure is insufficient to represent the complexity and variability of CAA hemodynamics.

Given potential clinical significance of consistently low shear in relation to flow stagnation and thrombosis,