Flow diveters (FDs) aim to treat intracranial aneurysms by altering intra-aneurysmal hemodynamics. Reports have suggested aneurysm and parent artery shape may affect flow reduction in FD-treatment [1]. The purpose of this study is to gain insight into the way in which aneurysm shape and parent artery curvature influence the ability of FDs to reduce flow.

Hypothesis: Aneurysm dome size and parent artery curvature affect FD-induced flow reduction within an aneurysm.

Methods: FD models constructed based on the Pipeline Embolization Device (ev3) with 35% area coverage, 10, 20, and 30mm nominal diameter were implemented for hemodynamic simulation analysis. Aneurysm blood flow was analyzed before and after FD stenting in regions of the aneurysm neck, body, and dome. Results: We found that aneurysms with higher parent artery curvature had increased systole flow entering aneurysms before and after stenting. Regardless of aneurysm size, with pre-FD volume flow rates for curvatures of 20 and 30 degrees, respectively, 1.54 and 2.40 times those for 10 degree curvature. Furthermore, FD reduced flow less in aneurysms with higher curvature. For parent artery angles of 10, 20, and 30 degrees, overall reductions of flow entering the aneurysm were 91.1±0.56%, 88.2±1.2%, and 85.5±0.28%, respectively. 97.2% of models had more flow reduction at the aneurysm dome than neck. 1.54 and 2.40 times those for 10 degree curvature. Furthermore, FD reduced flow less in aneurysms with higher curvature. For parent artery angles of 10, 20, and 30 degrees, overall reductions of flow entering the aneurysm were 91.1±0.56%, 88.2±1.2%, and 85.5±0.28%, respectively. 97.2% of models had more flow reduction at the aneurysm dome than neck. Figure 6 shows representative, post-FD flow in 10- and 30-degree parent arteries, with a greater volume flow rate in (b) depicted by denser streamlines. Aneurysm dome size and parent artery curvature affected flow reduction across all angles for each aspect ratio. Conclusion: We found that parent artery curvature may have a large influence on FD flow reduction, indicating that FD may be effective at reducing blood flow entering aneurysms located within higher curvature arteries.

Figure 1. Three of the six models tested, unstented and stented. Shown are 1.2 AR at 10°, 1.2 AR at 20°, and 1.4 AR at 30°. Both AR 1.2 and 1.4 were each tested at 10°, 20°, and 30°.

Figure 2. Two stented models for AR 1.2 shown at systole and diastole. The vessel angles shown are (a) 10° and (b) 30°. Color indicates average flow velocity, with denser streamlines indicating higher volume flow rates.


Figure 4. PLOT of average flow velocity reduction at peak systole in the neck region of the aneurysm for AR 1.2 and 1.4, with vessel angles 10° through 30°. Overall, there is a decreasing trend for average flow velocity reduction with increasing vessel angle. Additionally, AR may have a small effect on flow reduction at higher ARs.

Figure 5. Bar graph showing the average flow reduction across all angles for each aspect ratio at systole. The results indicate that aspect ratio may have only small role in FD effectiveness. However, based on the two aspect ratios examined, this difference only appears at higher vessel angles.

Figure 6. The two representative models shown are AR 1.2 models with parent vessel angles of 10° and 30°. The flow patterns are shown at (a) systole and (b) diastole. Relative to the unstented flow streamlines, the stented 30° model showed greater average flow velocity reduction than the stented 30° model at the aneurysm neck at peak systole, as indicated by the streamline density. The same is true at diastole, though at diastole, the post-stented flow patterns are markedly different compared to the flow pattern changes at systole.

References: