CFD Contributions to Device Evaluation and Understanding

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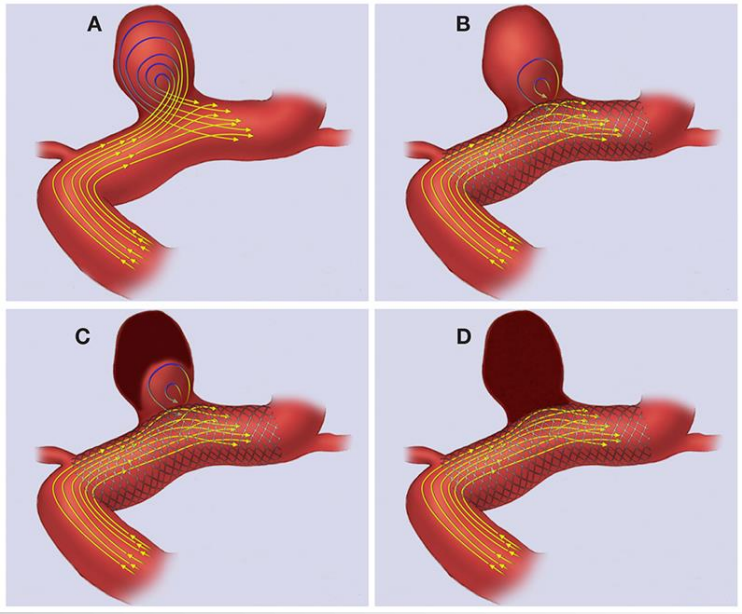
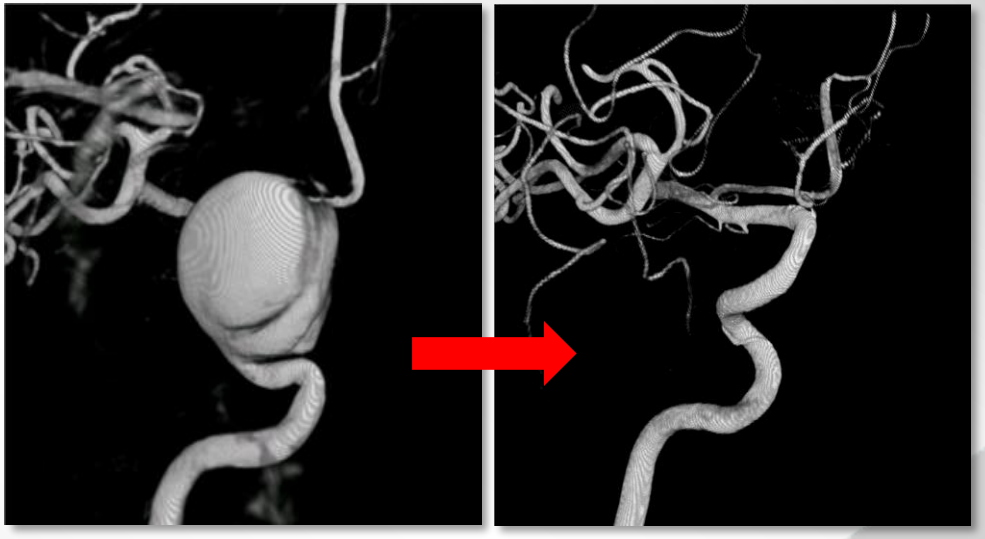
Flow Diversion Treatment

- Feasible option for difficult aneurysms that were previously considered untreatable

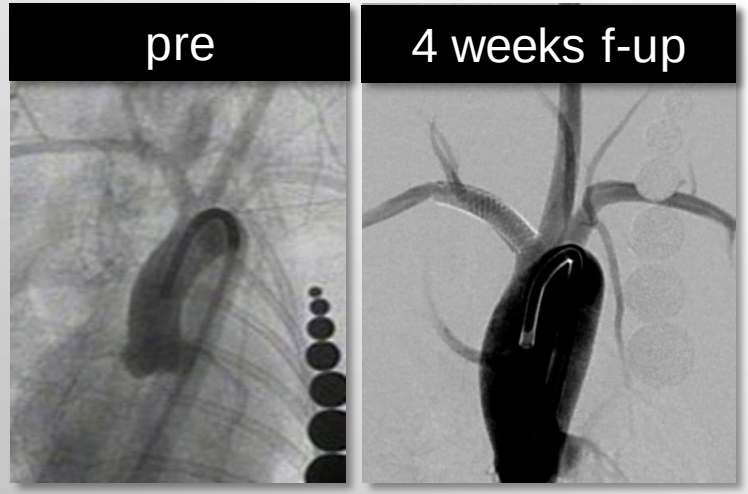




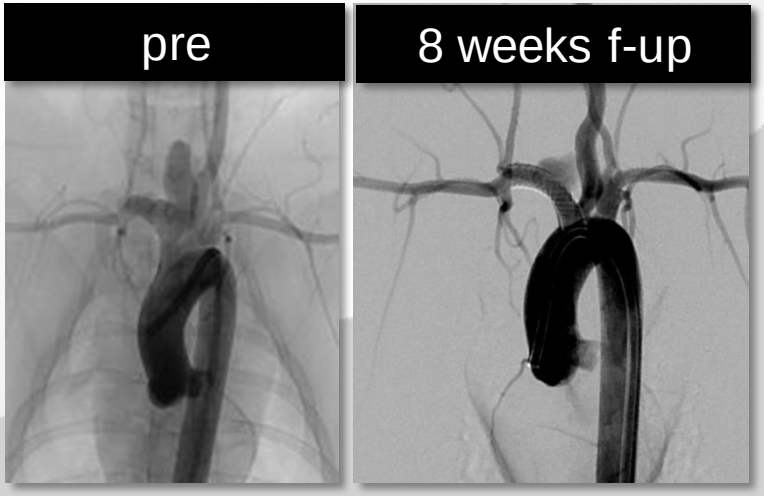
- Because the aneurysms are not immediately excluded from the circulation it is important to understand the effects of flow diverters and to predict the long term outcomes of these procedures

Flow Diversion Animal Study

- 36 aneurysms created in rabbits and treated with FD alone (PED, no coils)
- 3D rotational angiography and Doppler ultrasound imaging prior to treatment
- Fast occlusion group: complete or near complete occlusion at 4 weeks (or less) after treatment
- Slow occlusion group: incomplete occlusion at 8 weeks

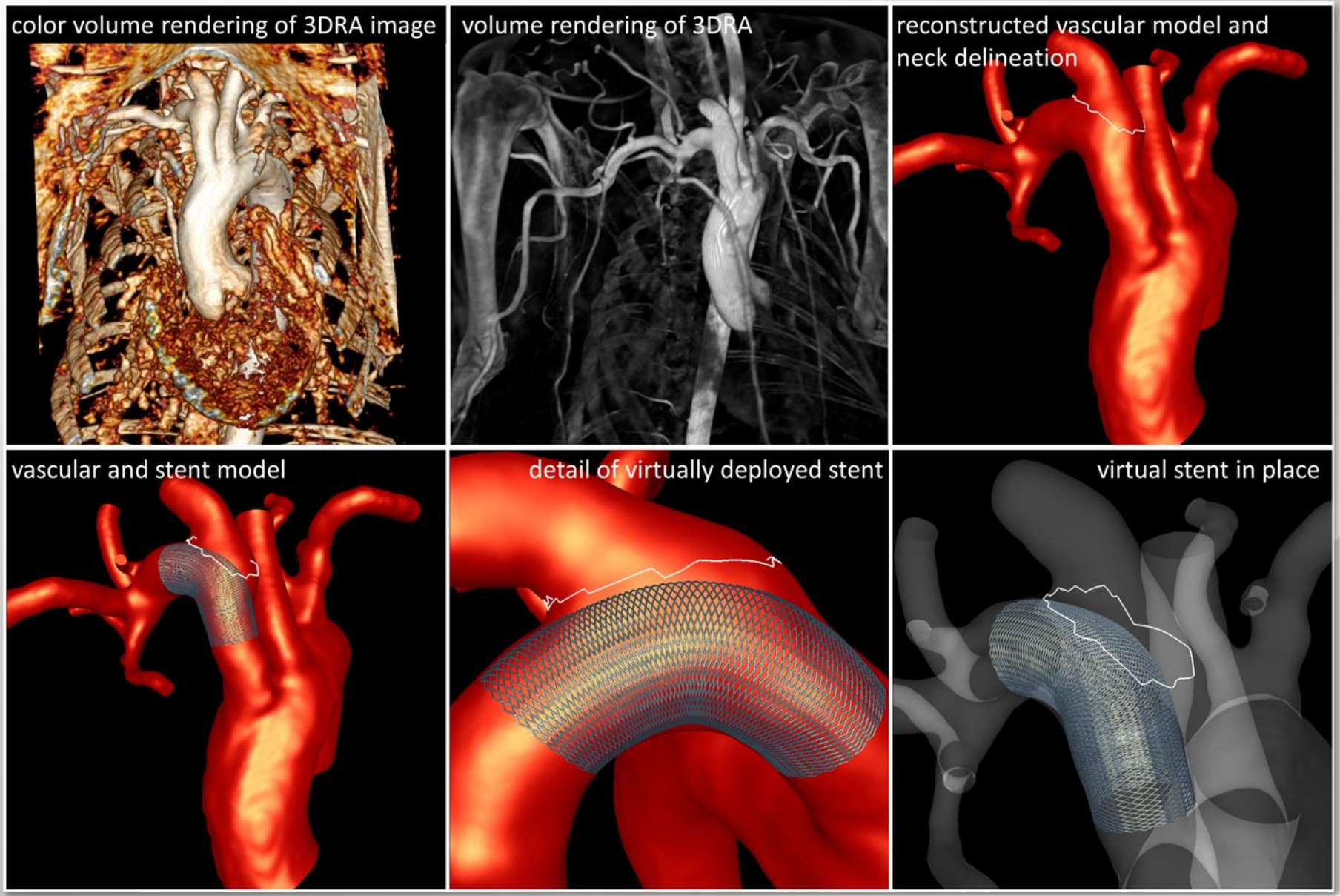


fast occlusion

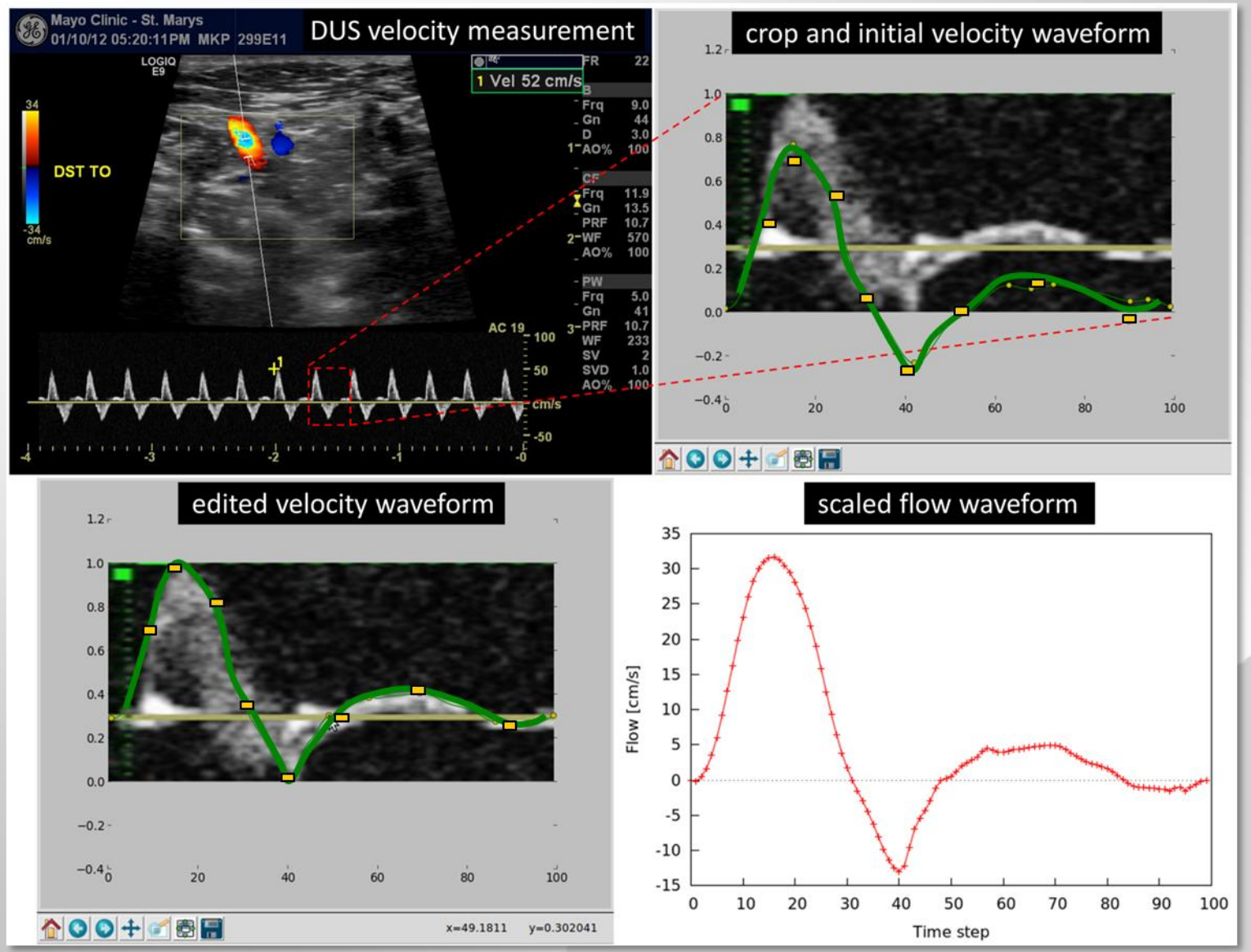


slow occlusion

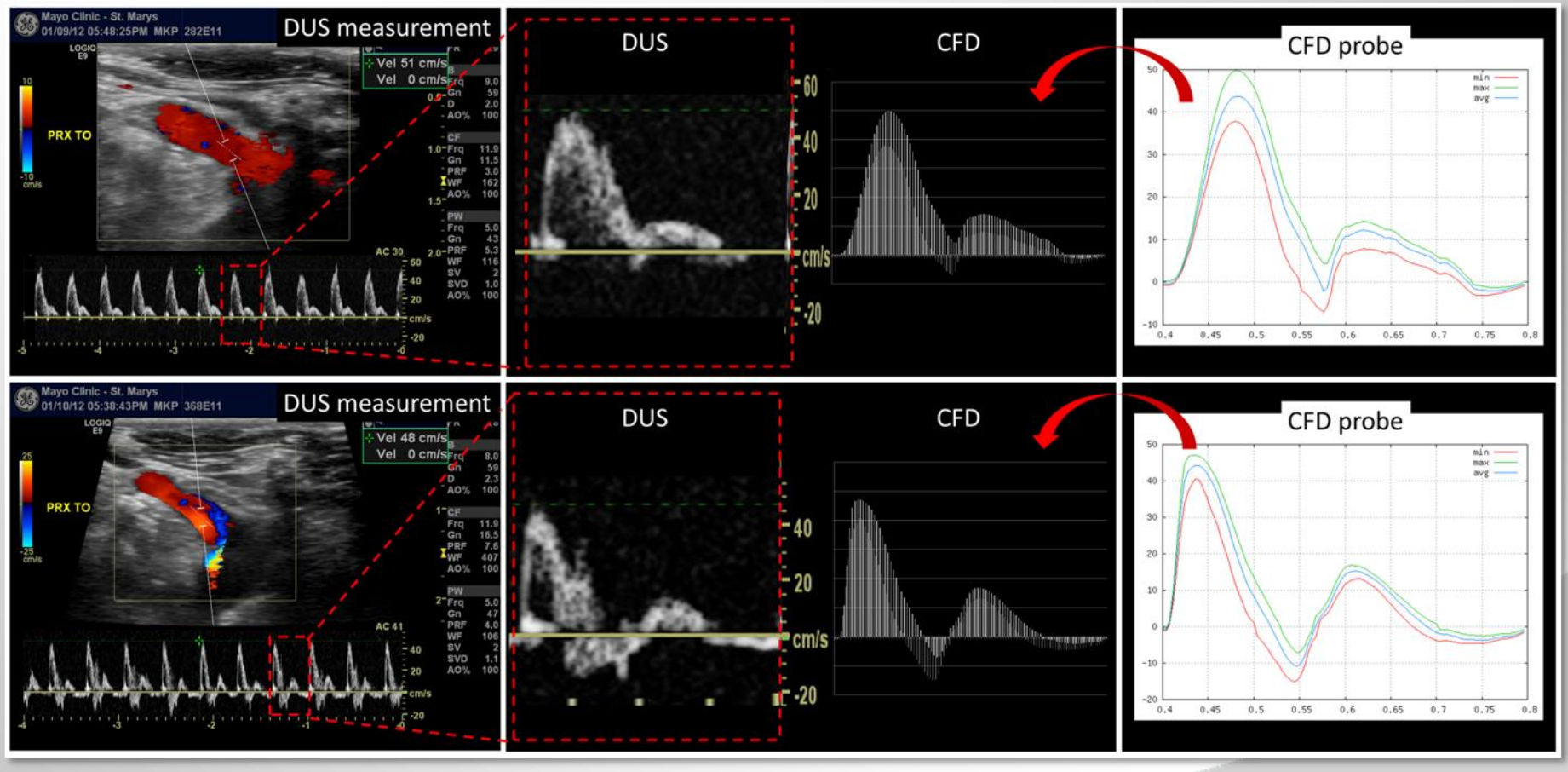
Image-Based Modeling



Flow Waveform Reconstruction

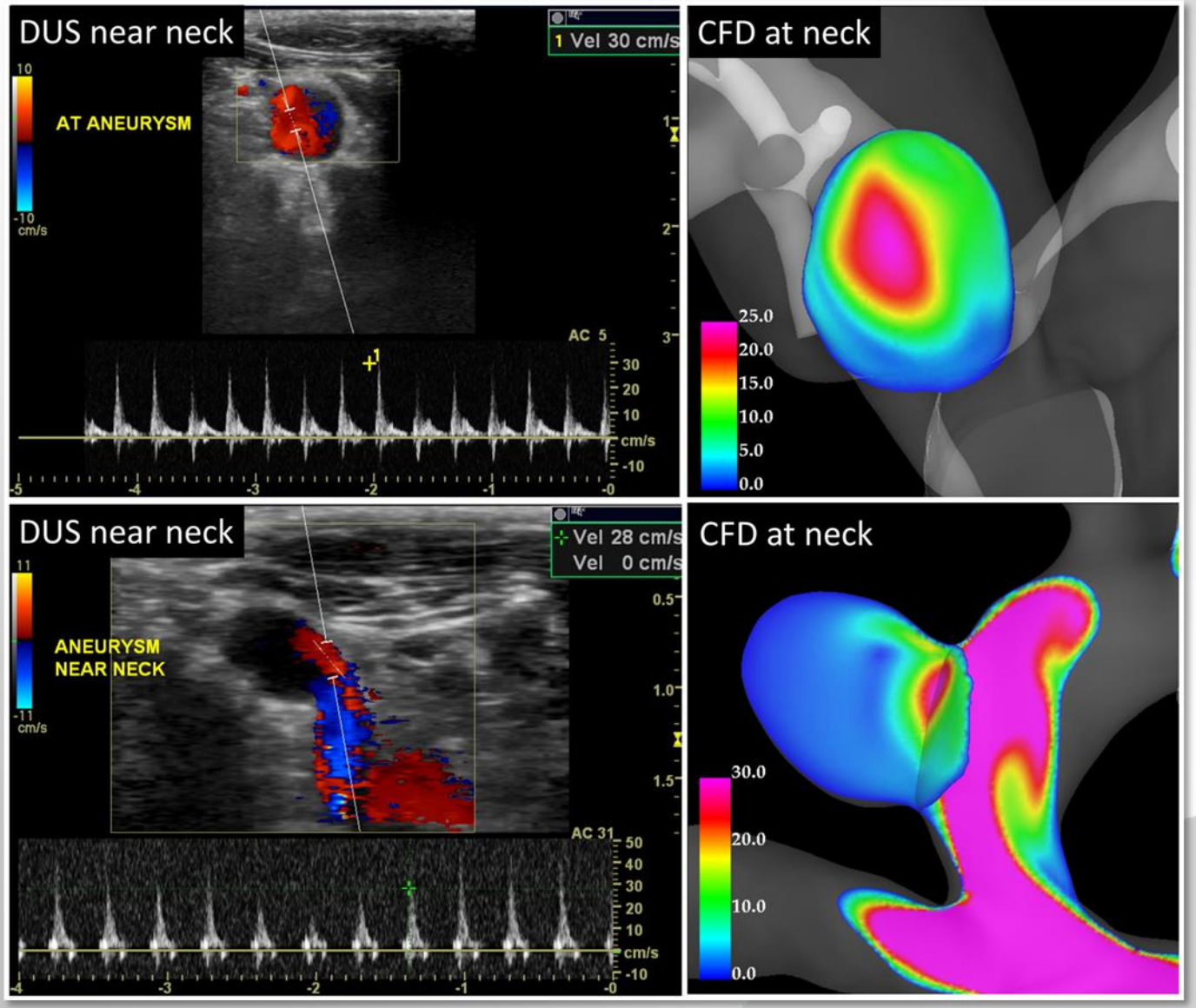


CFD vs DUS in Parent Artery



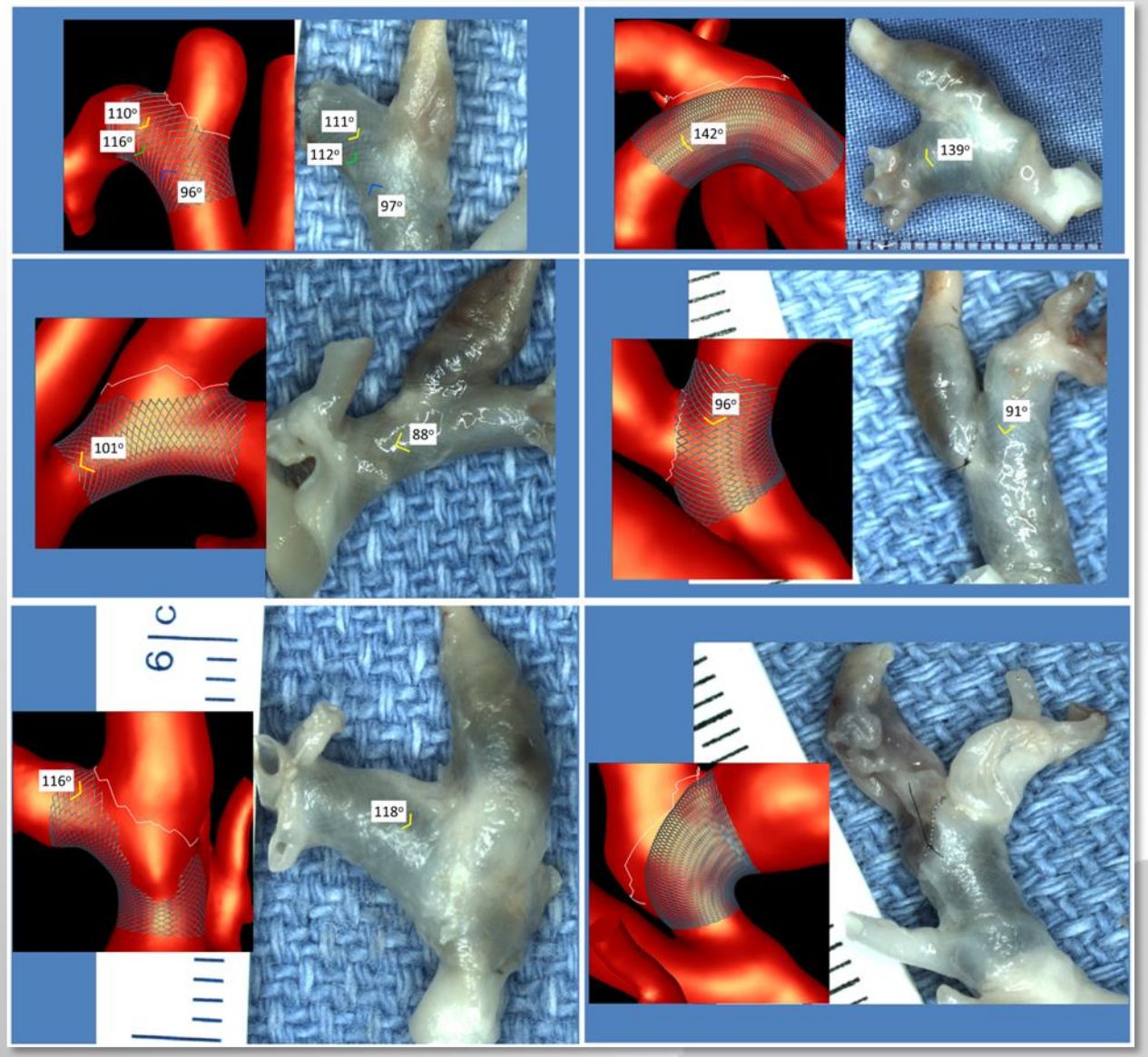
→ Consistent flow waveforms and peak velocities

CFD vs DUS Near Aneurysm Orifice



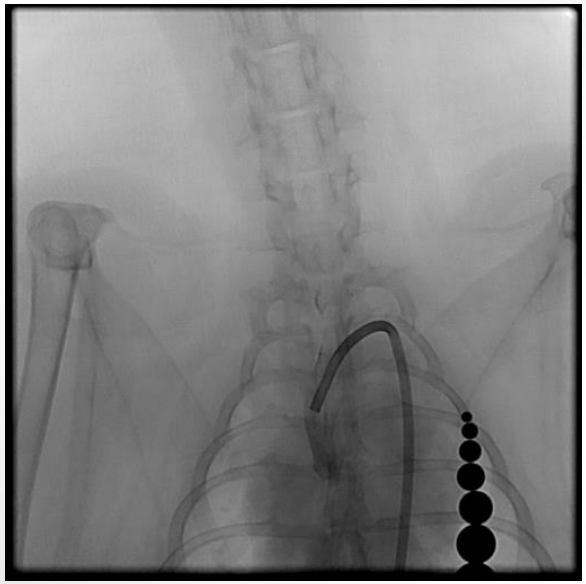
→ Consistent peak velocity & inflow location

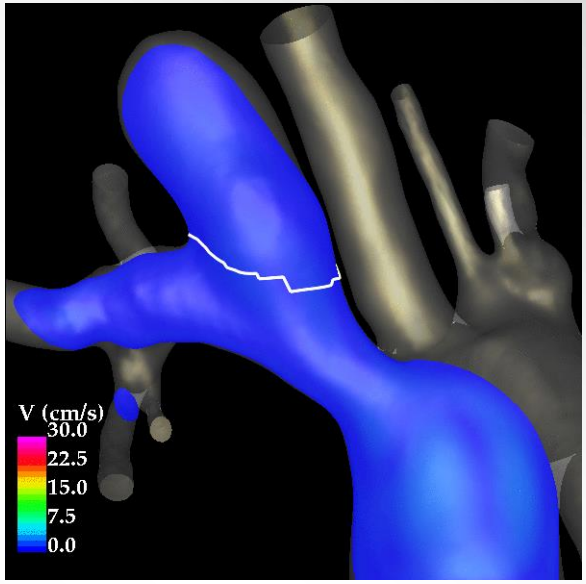
Stent Model vs Ex-vivo Samples

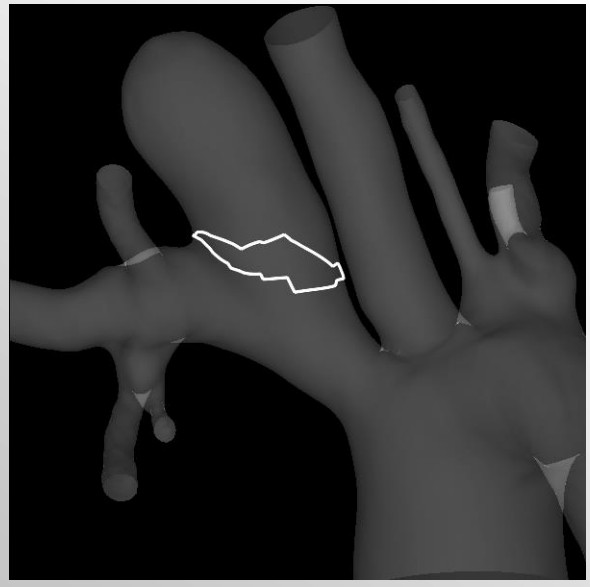


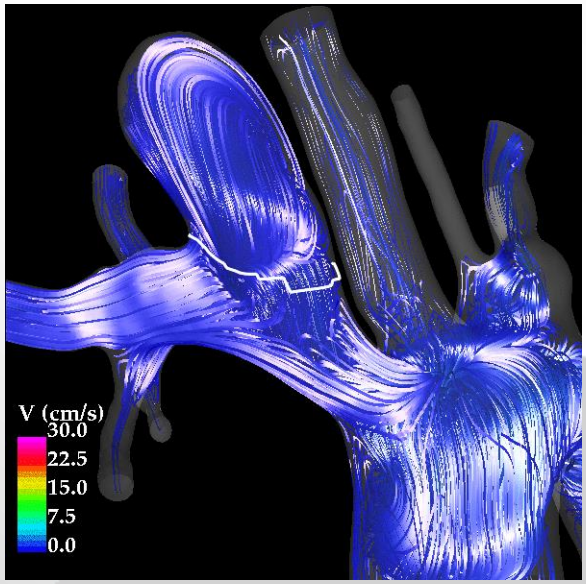
→ Consistent
FD geometries

CFD vs DSA Before Treatment



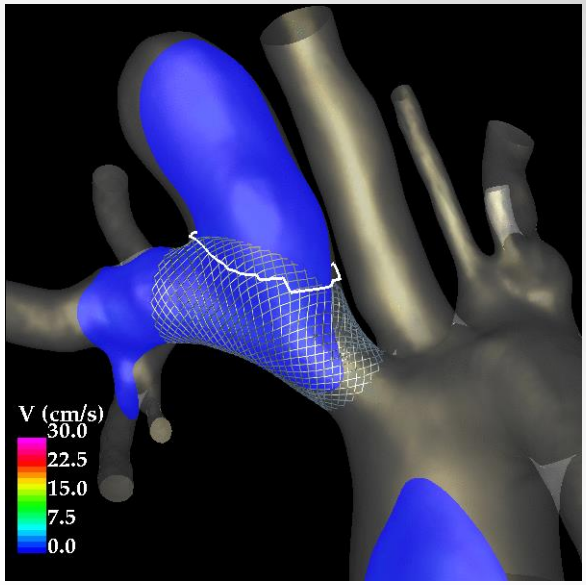


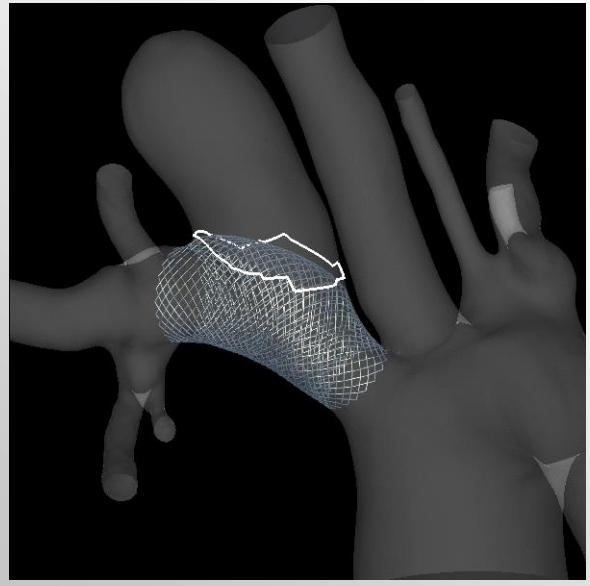


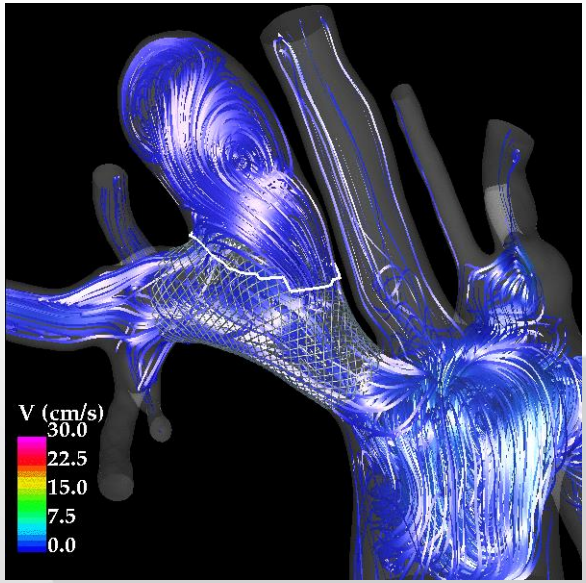


→ Consistent flow structures

CFD vs DSA After Treatment

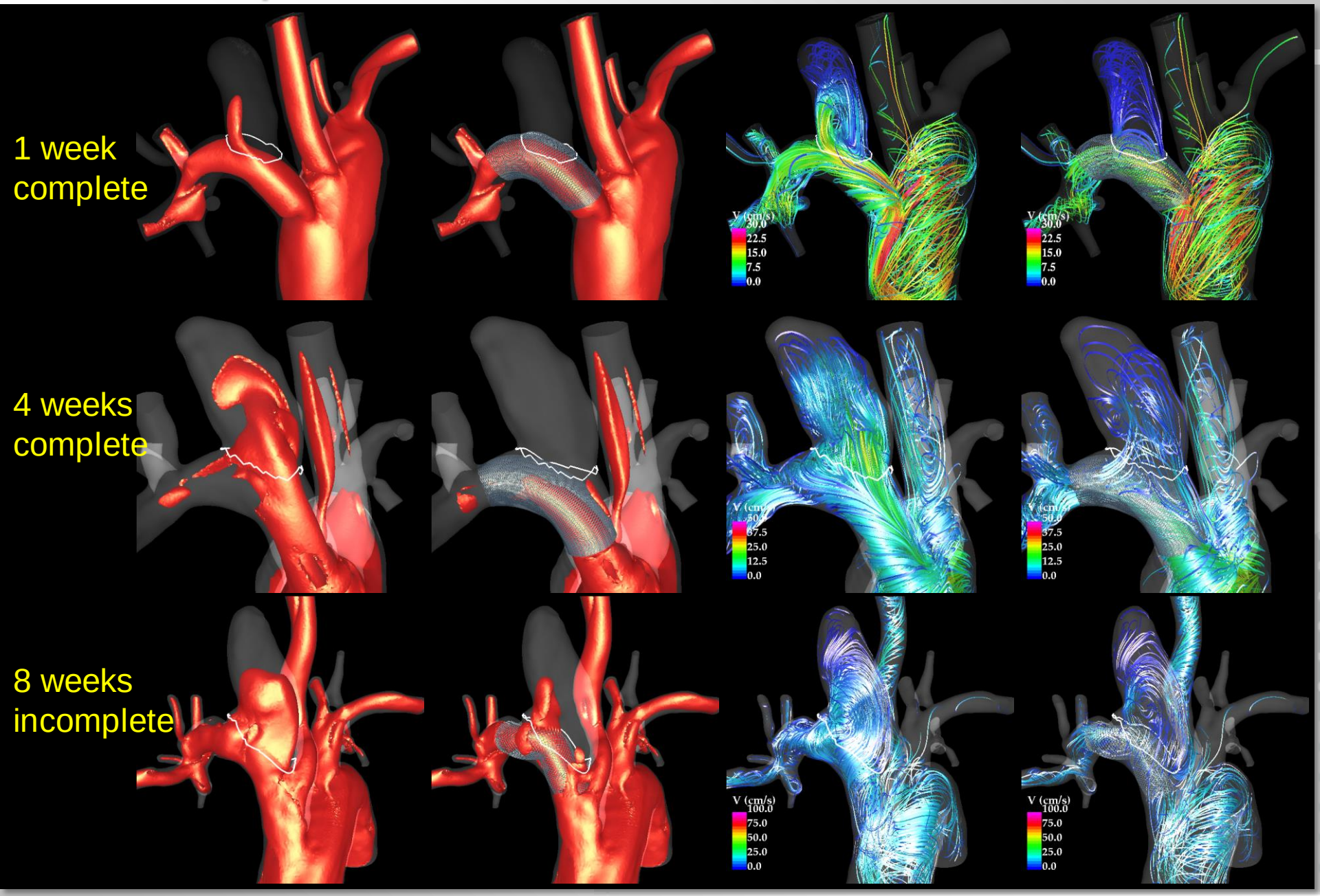






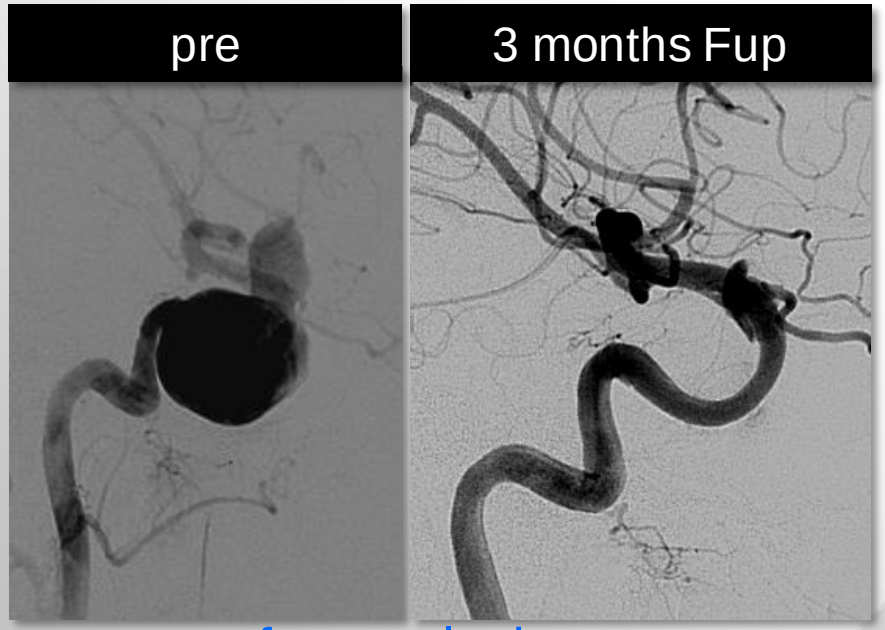
→ Consistent flow structures

Examples

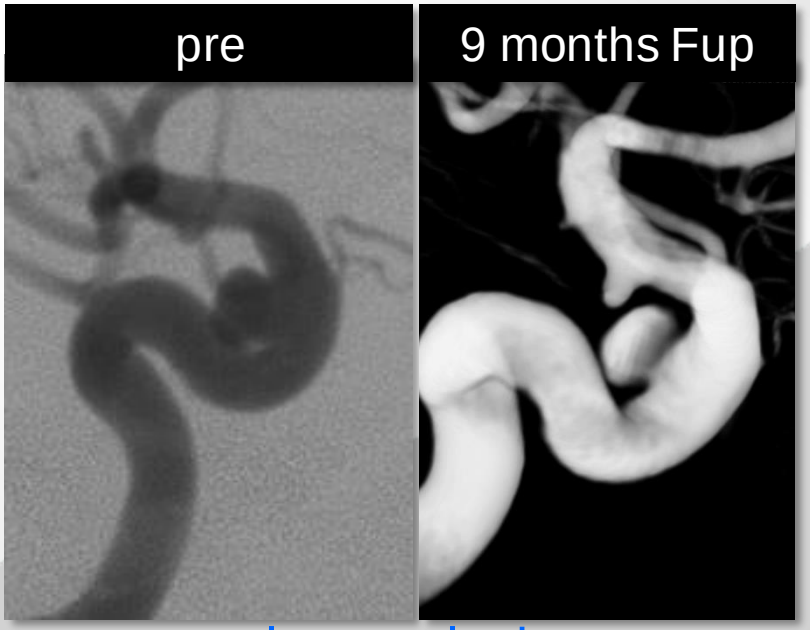

1 week complete
4 weeks complete
8 weeks incomplete
V (cm/s)
30.0
22.5
15.0
7.5
0.0
V (cm/s)
30.0
22.5
15.0
7.5
0.0
V (cm/s)
50.0
37.5
25.0
12.5
0.0
V (cm/s)
50.0
37.5
25.0
12.5
0.0
V (cm/s)
100.0
75.0
50.0
25.0
0.0
V (cm/s)
100.0
75.0
50.0
25.0
0.0

Flow Diversion Clinical Study

- 26 Aneurysms treated with FD alone (PED, no coils)
- 3D rotational angiography imaging prior to treatment
- Aneurysm followed with angiography for at least 1 year
- Aneurysm either completely occluded at 3 months (fast) or still partially permeable at 6 months (slow)



fast occlusion

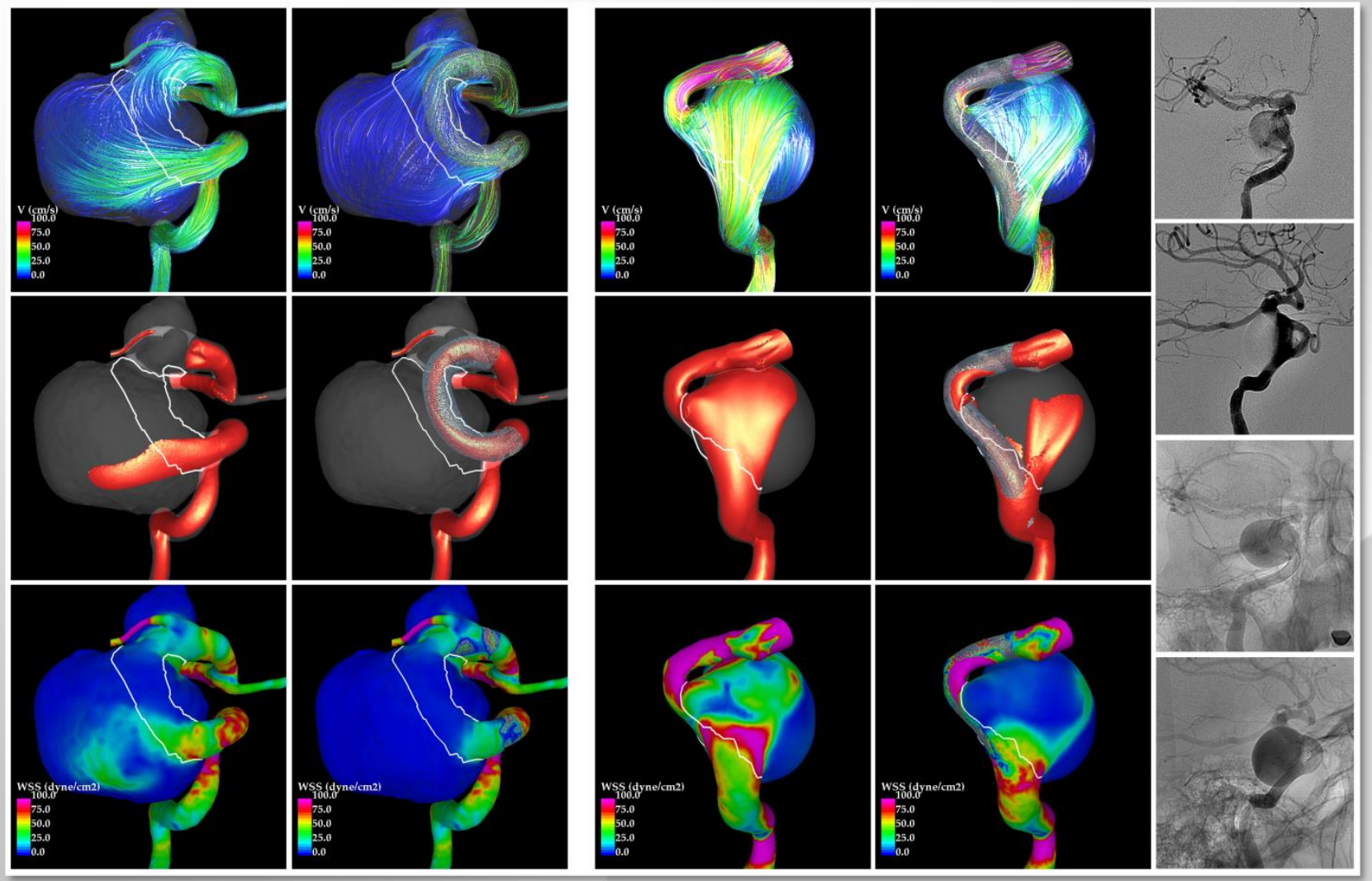


slow occlusion

Examples

Fast occlusion

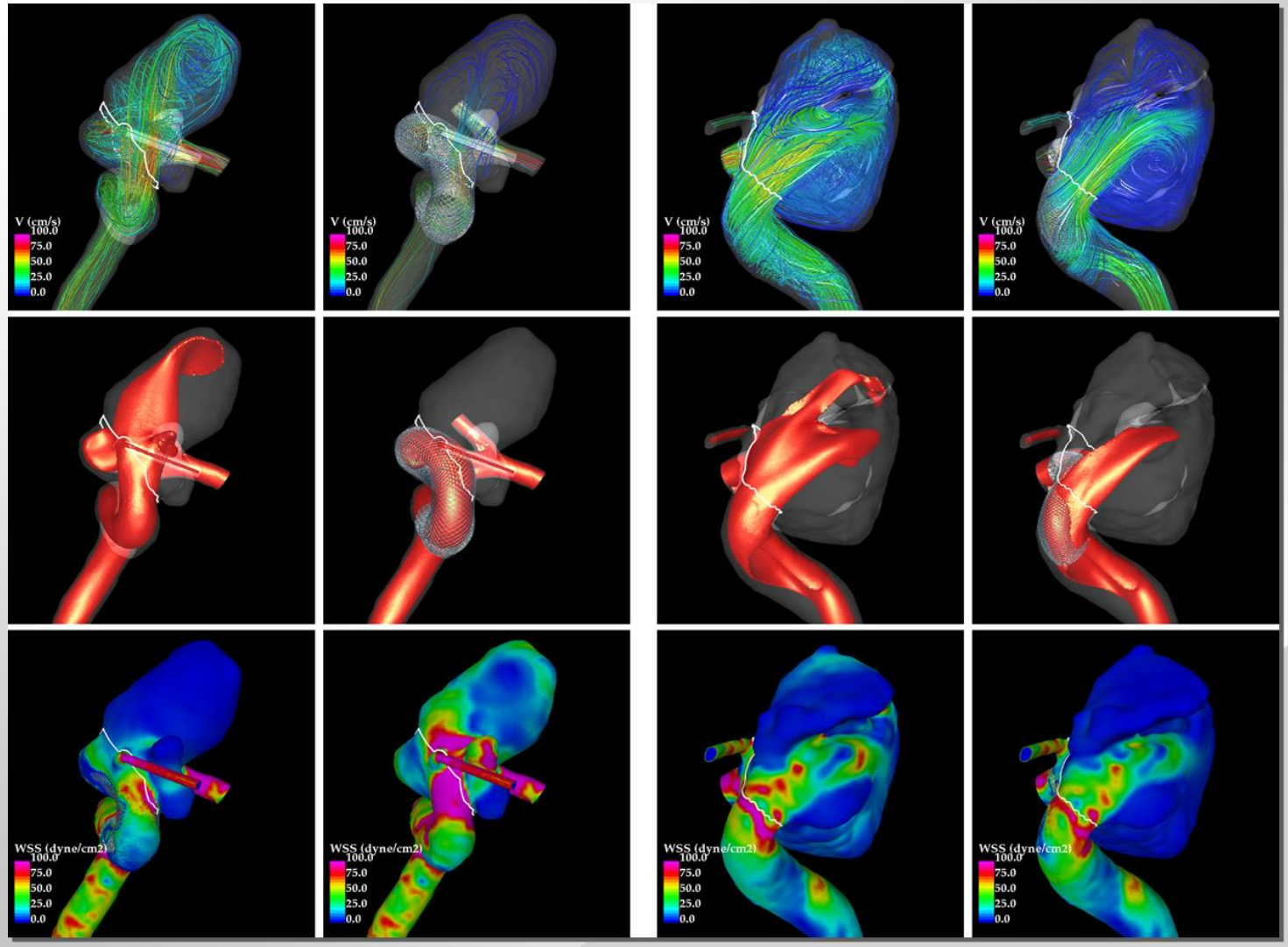
Slow occlusion



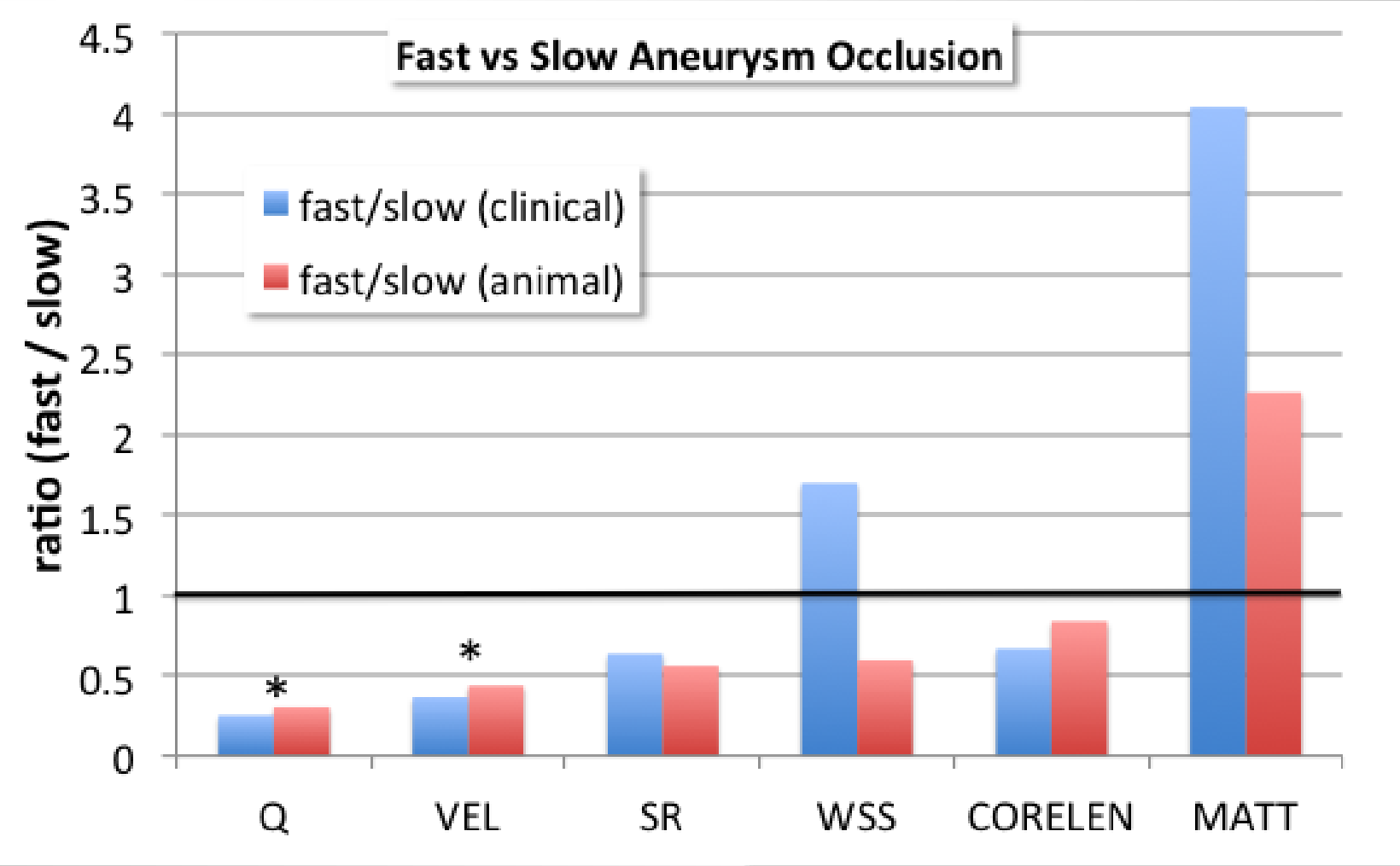
Examples

Fast occlusion

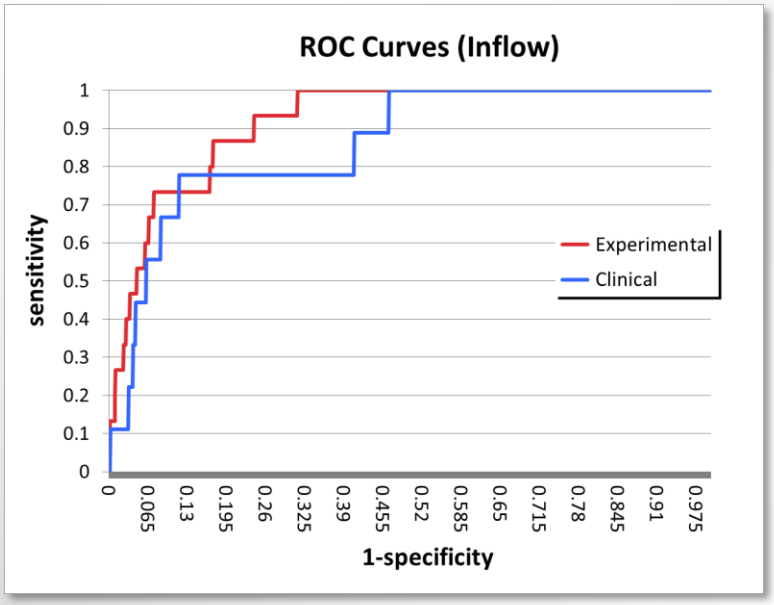
Slow occlusion



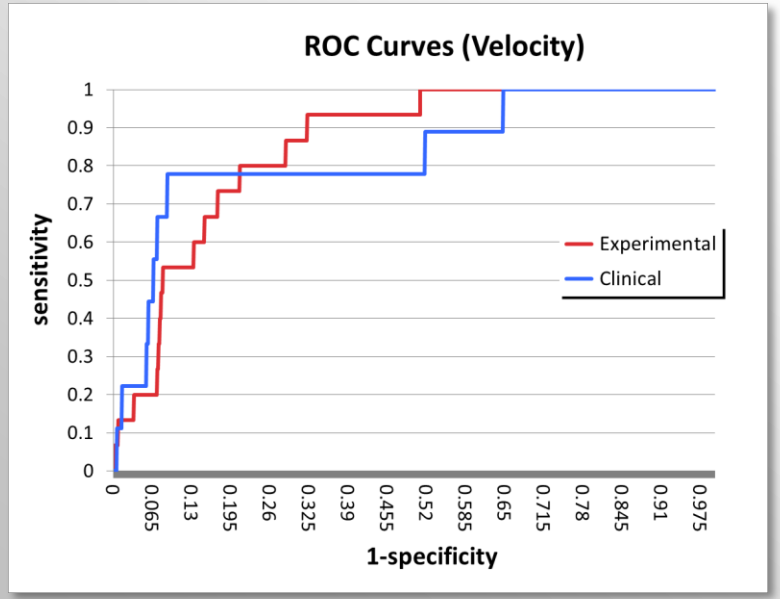
Hemodynamics and Aneurysm Occlusion

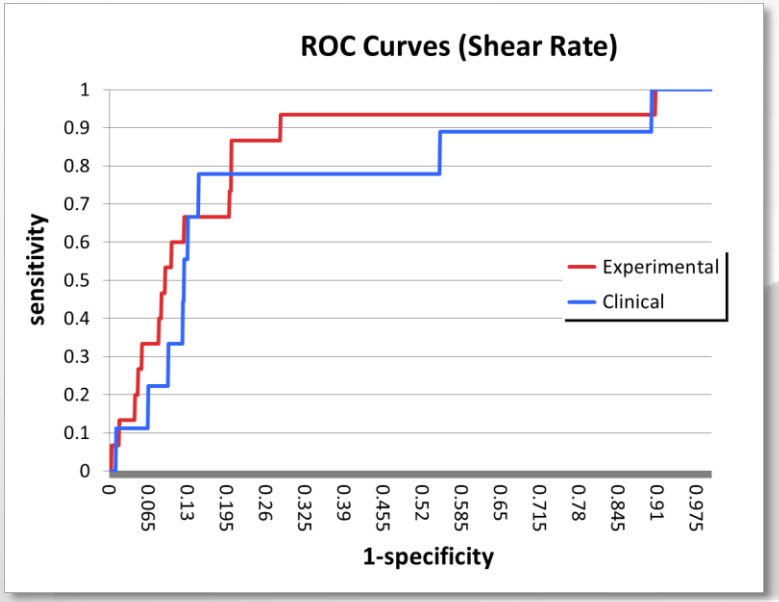


Predicting Aneurysm Occlusion

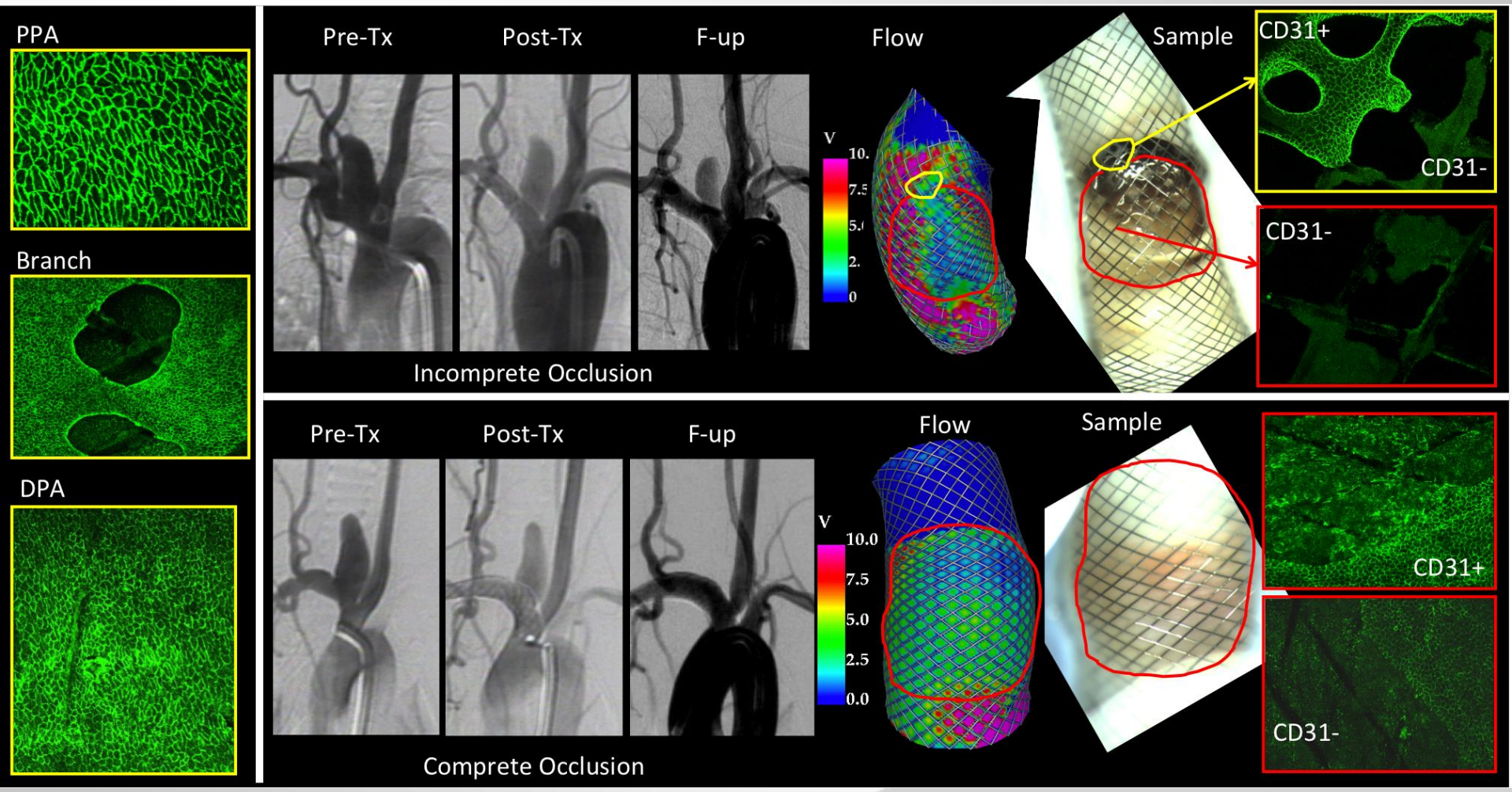


Data	Variable	Ratio (slow/fast)	P-value	AUC
Experimental	Q	3.29	0.0239	0.90
	VEL	2.29	0.0582	0.83
	SHR	1.78	0.0722	0.76
Clinical	Q	4.02	0.0210	0.77
	VEL	2.75	0.0044	0.84
	SHR	1.57	0.0210	0.76



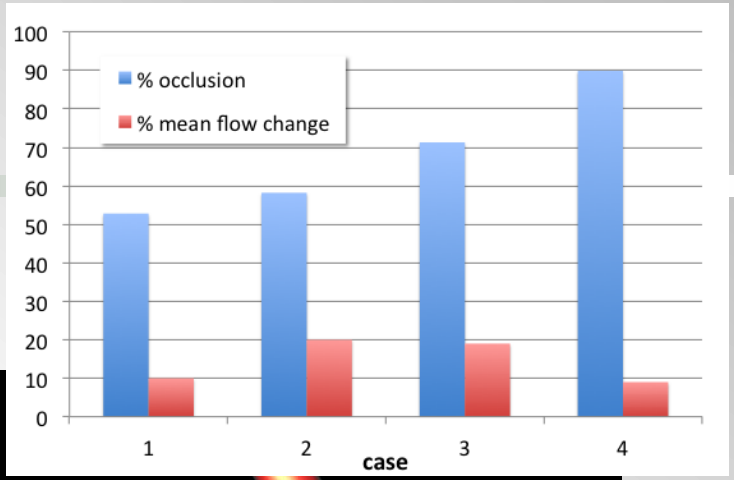


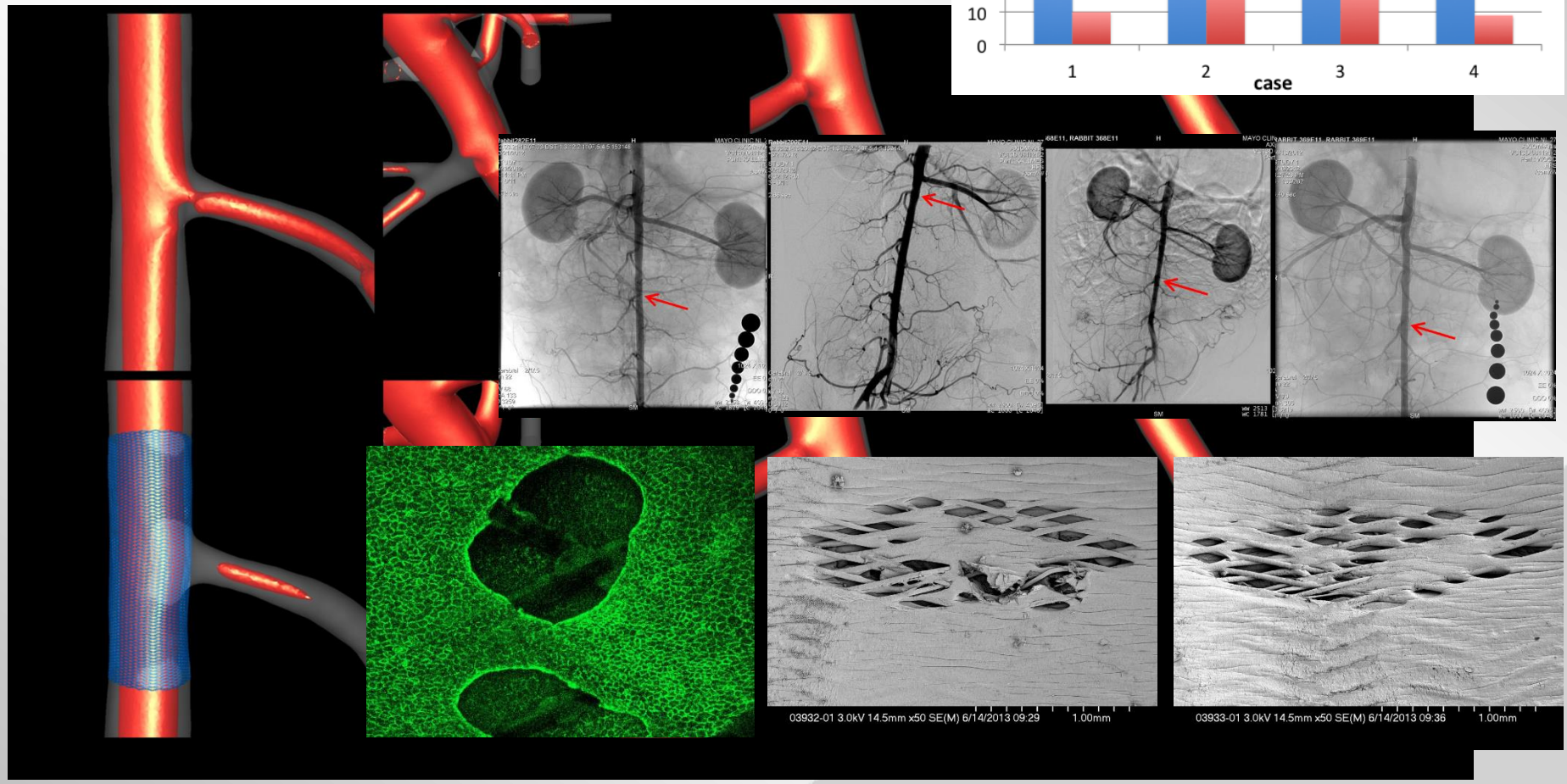
Tissue growth at the aneurysm neck



→ Need to understand relation between flow, thrombosis & tissue growth

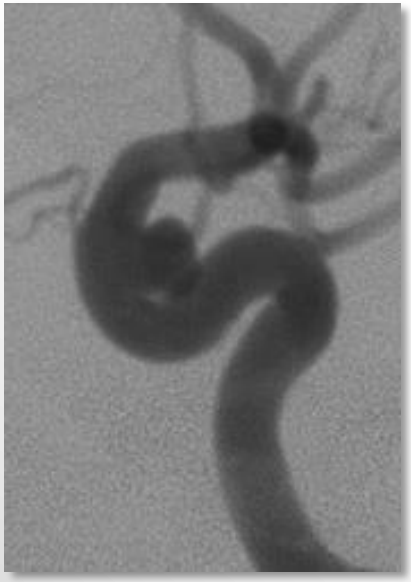
Flow in Jailed Branches



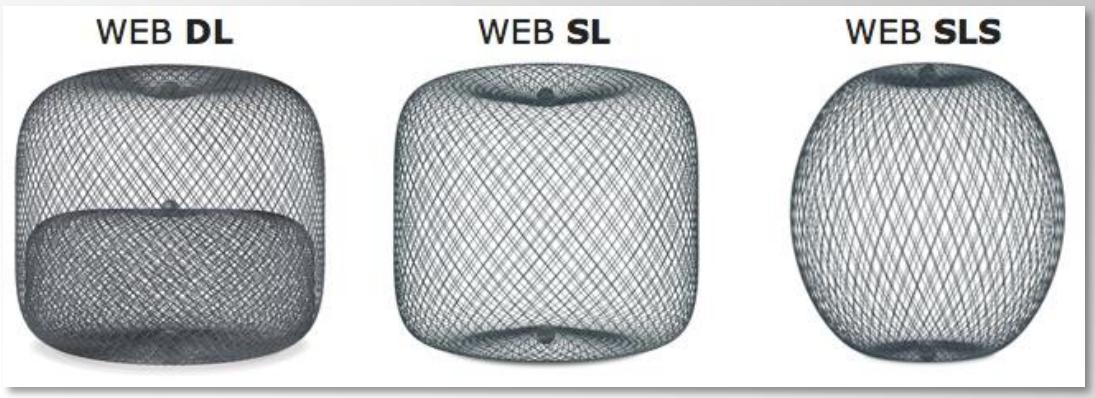


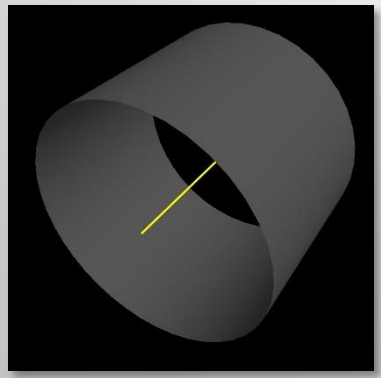
→ Little Reduction of flow velocity near side branch origin

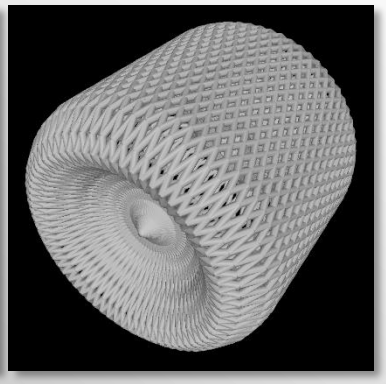
WEB Device



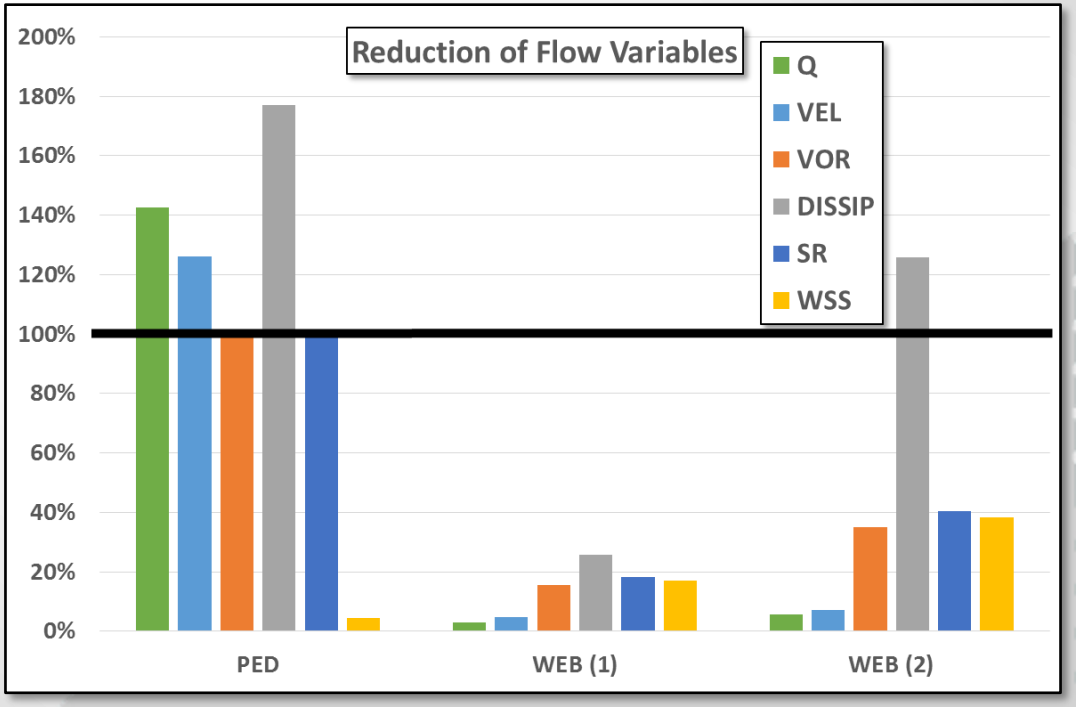
Slow occlusion with PED



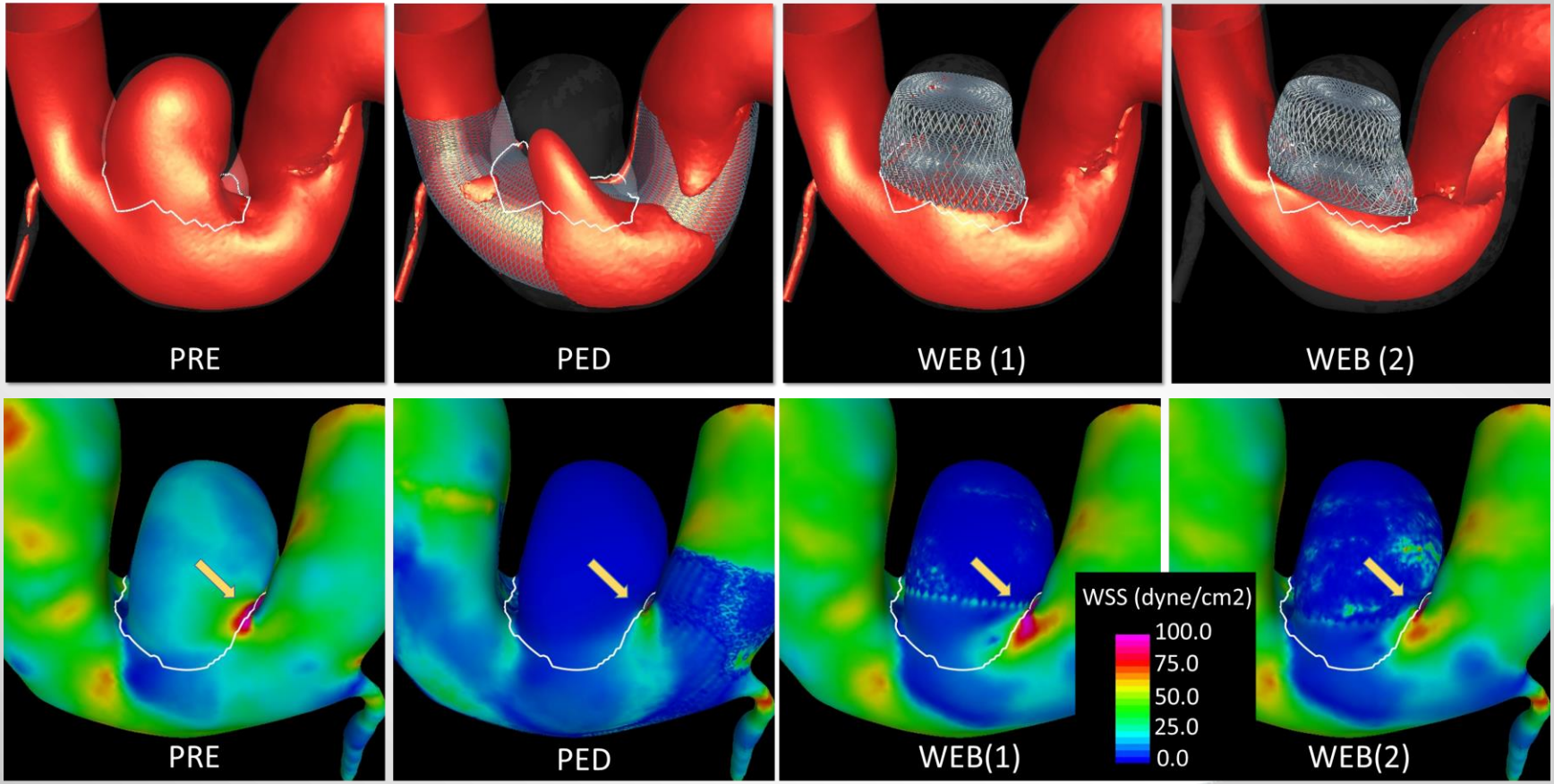




Computational model



Flow Visualization



→ Larger flow diversion, but different behavior at neck

Conclusions

- The occlusion of cerebral aneurysms treated with FDs can be predicted by post-Tx hemodynamics
- Specifically, low post-Tx flow velocity, inflow rate and shear rate are associated to fast occlusions
- Results of clinical and animal studies are consistent
- Adverse conditions can be generated by improper positioning of the stents, insufficient blockage of the ostium, …
- Need to better understand biological mechanisms of vessel reconstruction / repair

Acknowledgements

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