Center for Biomedical Computing

Non-Newtonian Effects in Cerebral Aneurysms

A Computational Study on 12 Patient Specific Aneurysms

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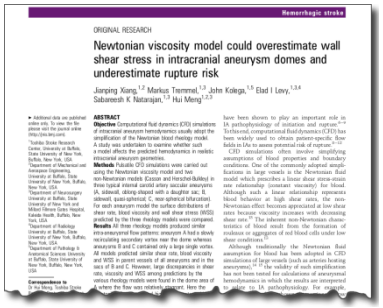
The effects of assuming Newtonian fluid not extensively studied

In most computational fluid dynamics (CFD) studies, it is assumed that blood behaves as a Newtonian fluid.

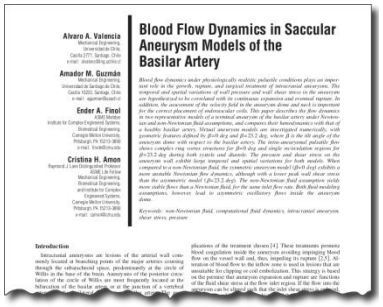
All studies of non-Newtonian effects to date involve either a few anatomically realistic geometries or idealized geometries.

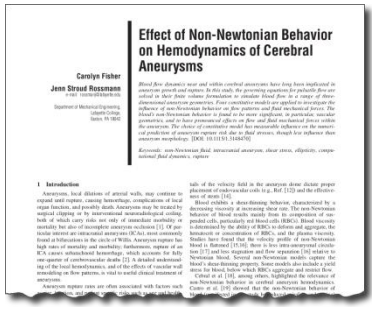

Hemorrhagic stroke

ORIGINAL RESEARCH

Newtonian viscosity model could overestimate wall shear stress in intracranial aneurysm domes and underestimate rupture risk


SENSITIVITY OF HEMODYNAMICS IN A PATIENT SPECIFIC CEREBRAL ANEURYSM TO VASCULAR GEOMETRY AND BLOOD RHEOLOGY


Blood Flow Dynamics in Saccular Aneurysm Models of the Basilar Artery

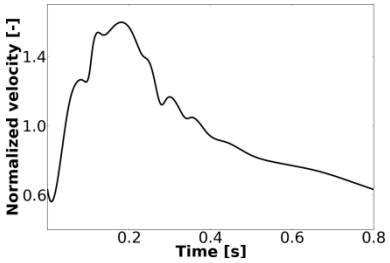

Effect of Non-Newtonian Behavior on Hemodynamics of Cerebral Aneurysms

Most comprehensive CFD study of non-Newtonian effects in intracranial aneurysms to date

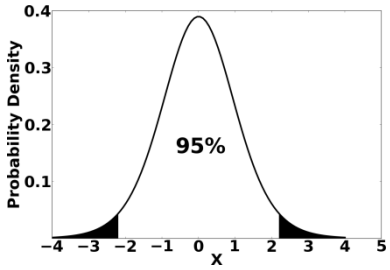
12 CT-based MCA geometries

$$\mu = \mu(\dot{\gamma}, \mathrm{Hct})$$

4 viscosity models



Pulsatile flow



Statistical analysis
(Paired difference t-test)

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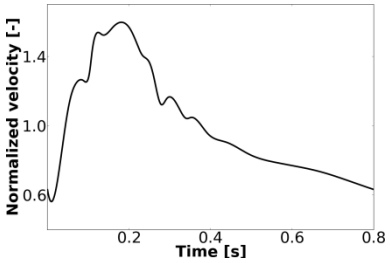

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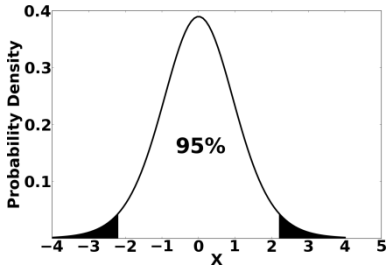

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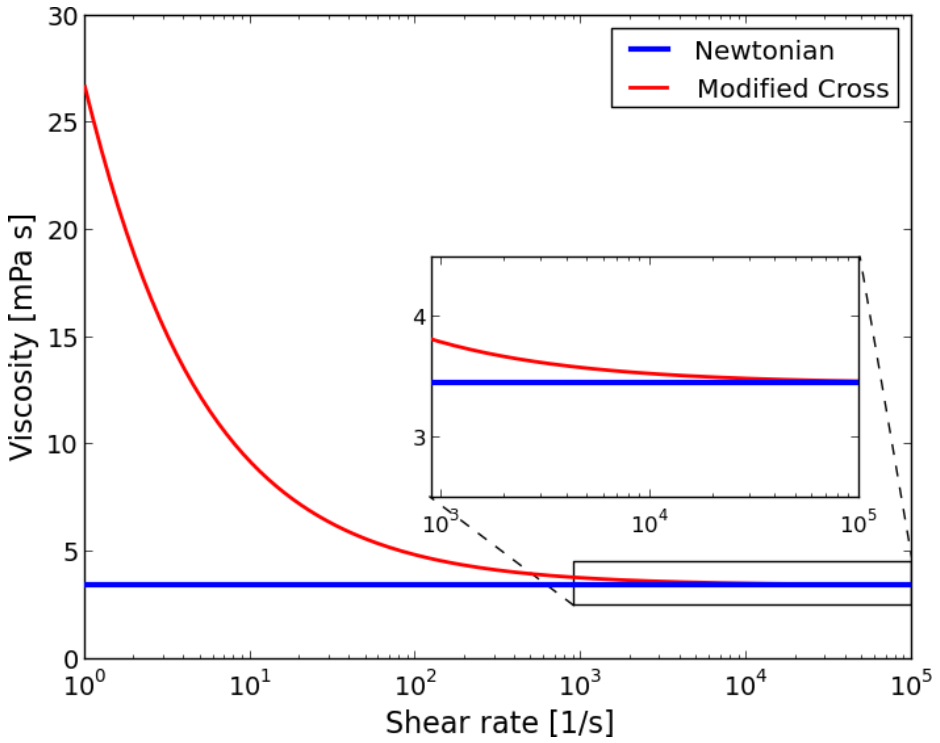
To determine the effects of viscosity changes, we have studied three measures of wall shear stress (WSS):

1. Maximum WSS.
2. Spatial-temporal average WSS
3. Area fraction of low WSS (< 0.4 Pa)

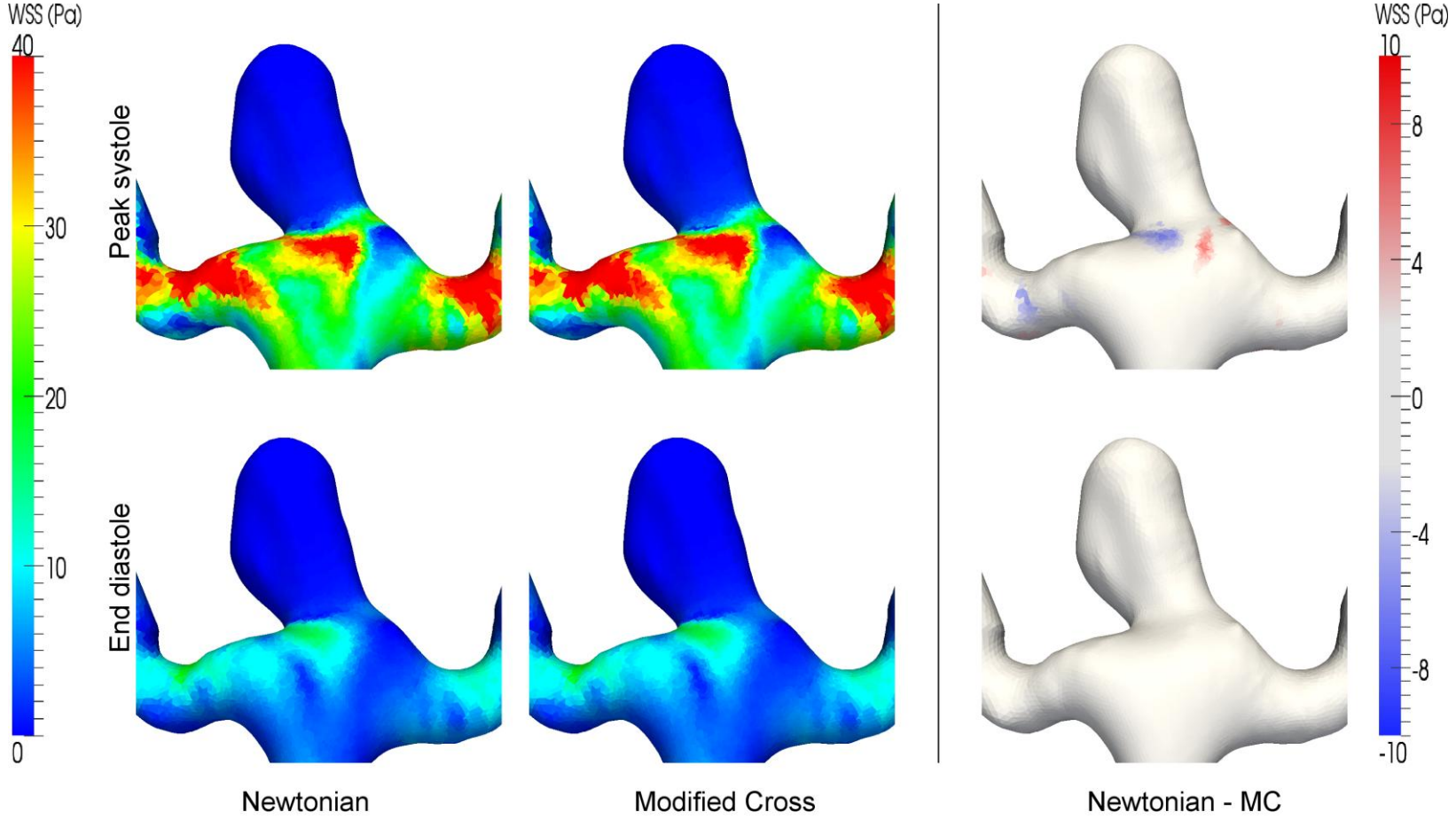
A modified Cross viscosity model was compared to a constant Newtonian model

- Modified Cross model chosen from 7 viscosity models as an extreme case.
- Newtonian viscosity model chosen to isolate the shear thinning effects.

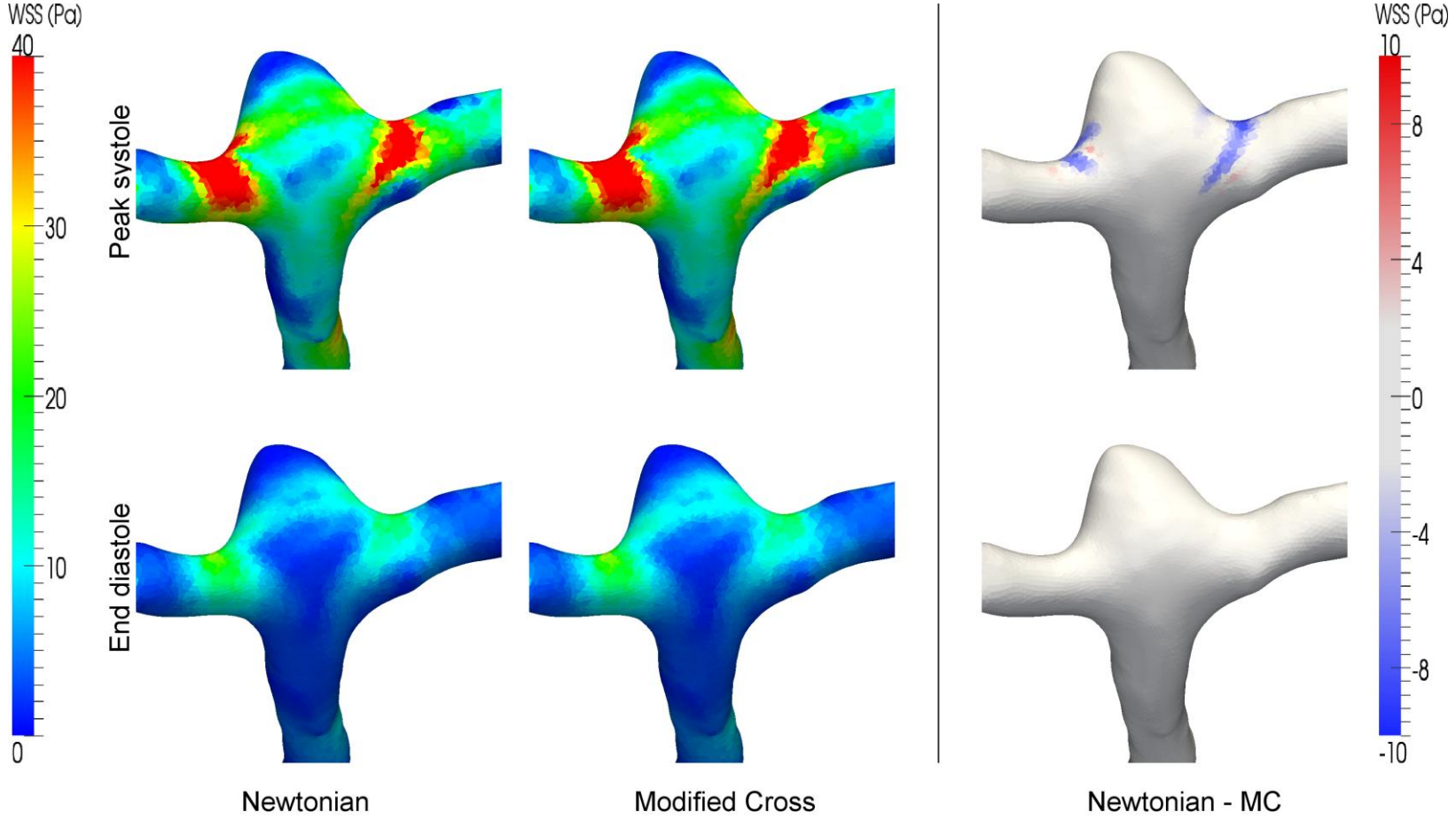


Same viscosity at high shear rate!

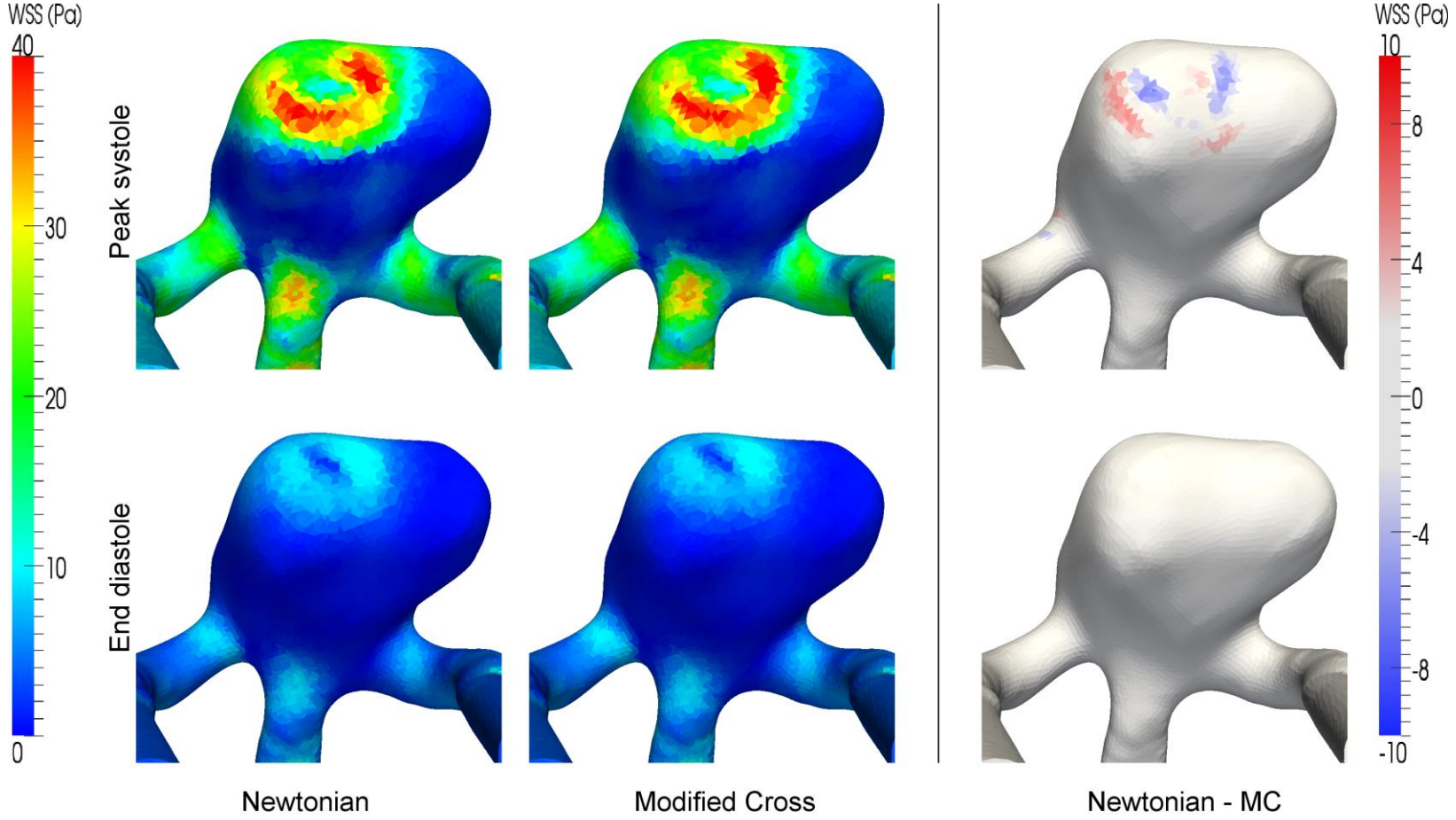
Example #1: Largest difference in maximum WSS



Example #2: Largest difference in average WSS

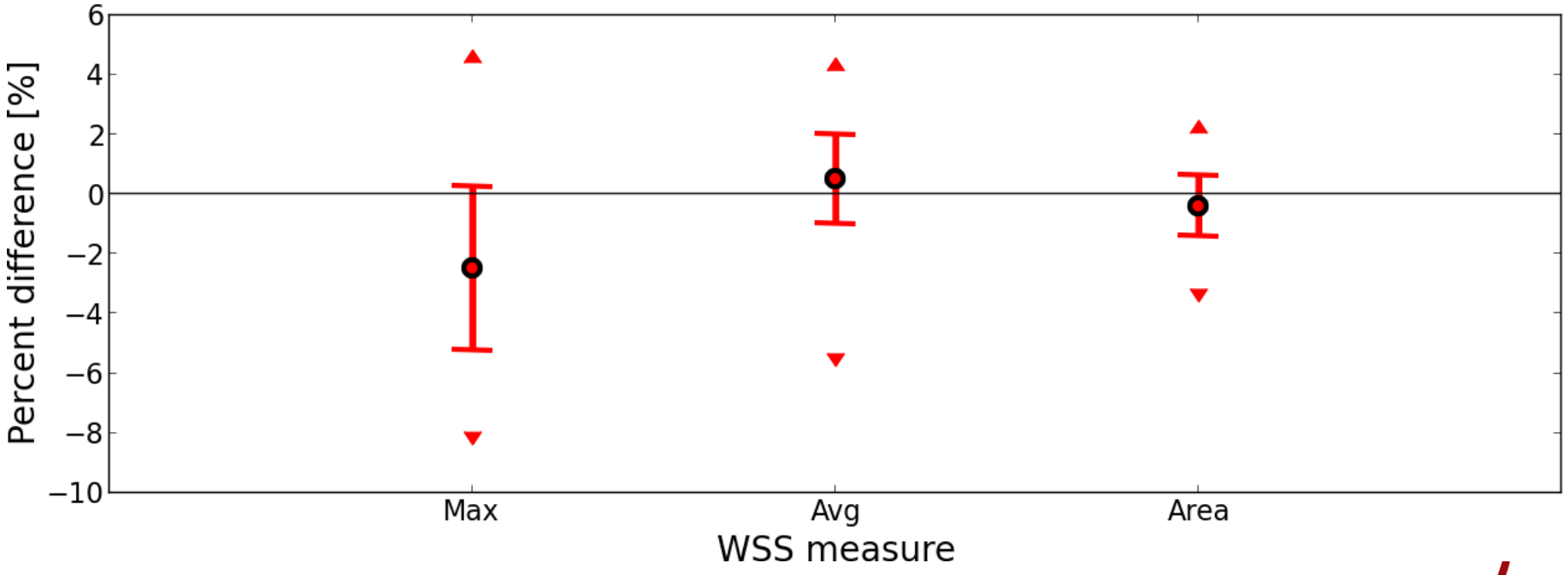


Example #3: Largest difference in area of low WSS



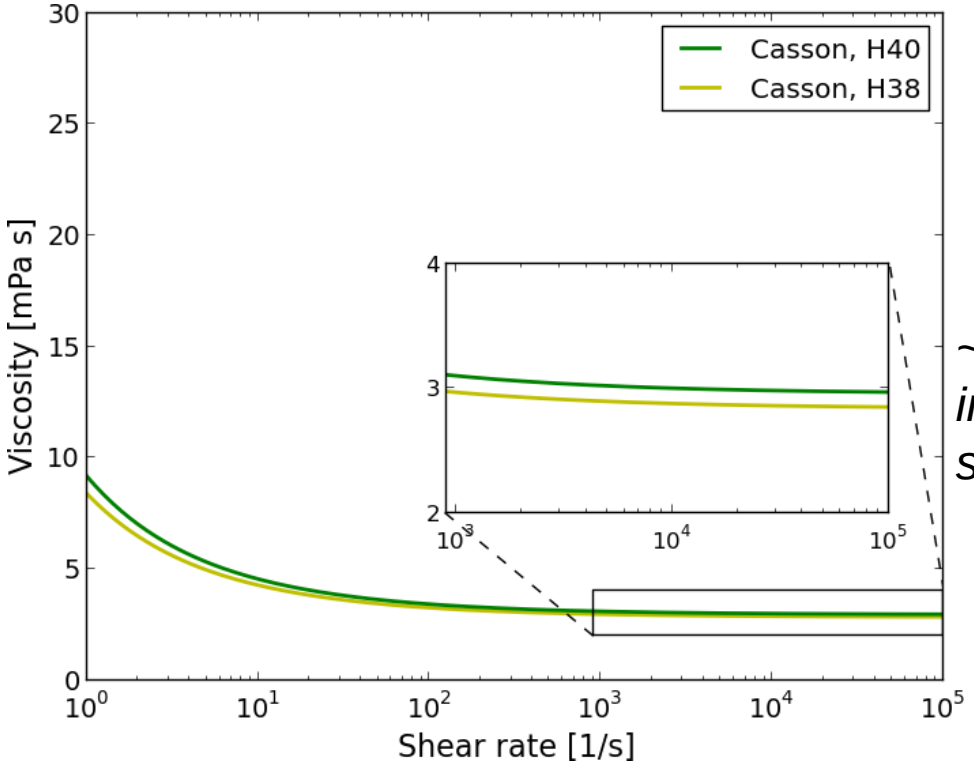
Analysis revealed no statistically significant differences

- All differences caused by the modified Cross model were within 9% of the Newtonian reference values.
- All average differences were within 3%.



Effects were compared to those caused by a 2pp hematocrit increase

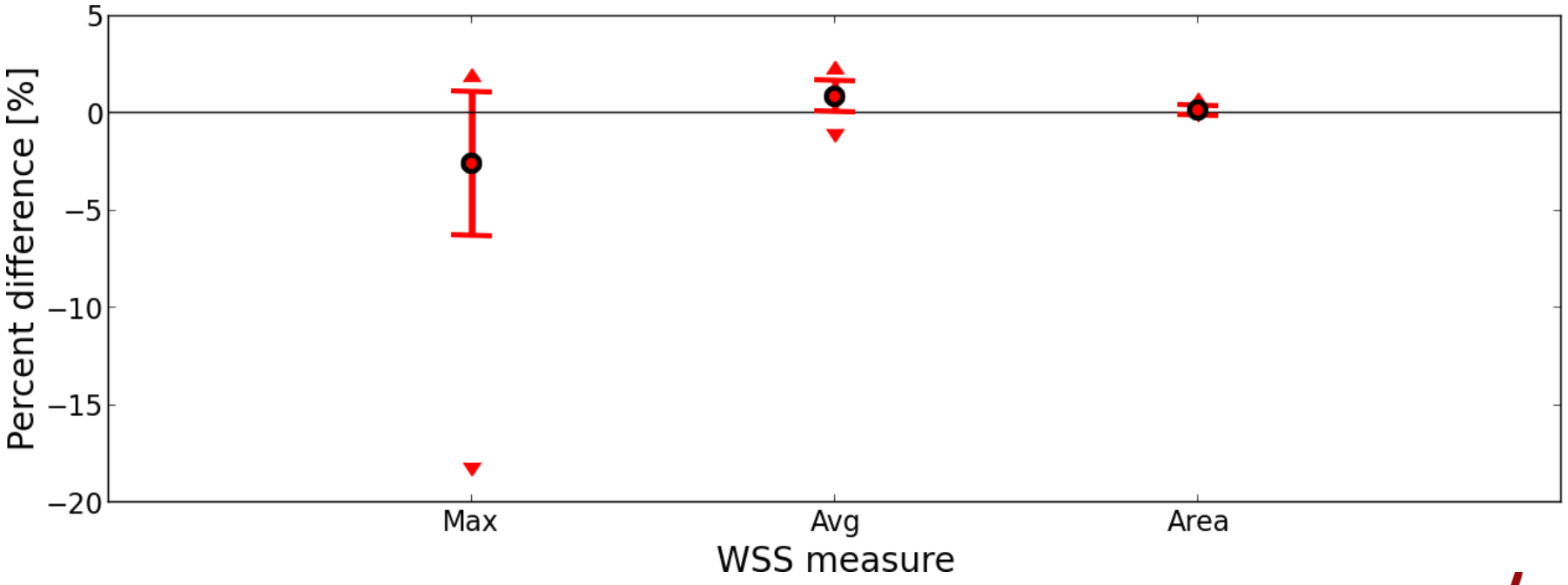
- Casson model implemented with hematocrit levels of 38% and 40%.
- Similar responses to shear rate, with only a slight shift in viscosity.



~0.12 mPa s difference in viscosity at high shear rates!

Increased levels of hematocrit resulted in comparable differences in WSS

- Statistically significant slight increase in average WSS.
- One outlier at 18%, all other changes within 8%.



Conclusions

- The non-Newtonian effects are comparable to the effects of an hematocrit increase from 38% to 40%.
- No statistically significant effects are found from shear thinning alone.
- Given the uncertainty of other modelling assumptions (image quality, segmentation, boundary conditions etc.), changes in WSS of 0-10% can not be considered dramatic.

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The assumption of Newtonian behaviour of blood is reasonable in cerebral aneurysms.