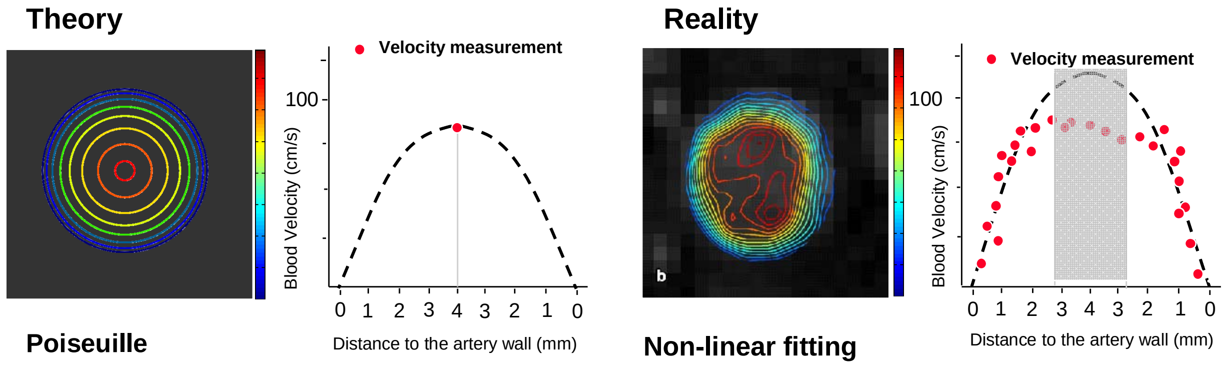
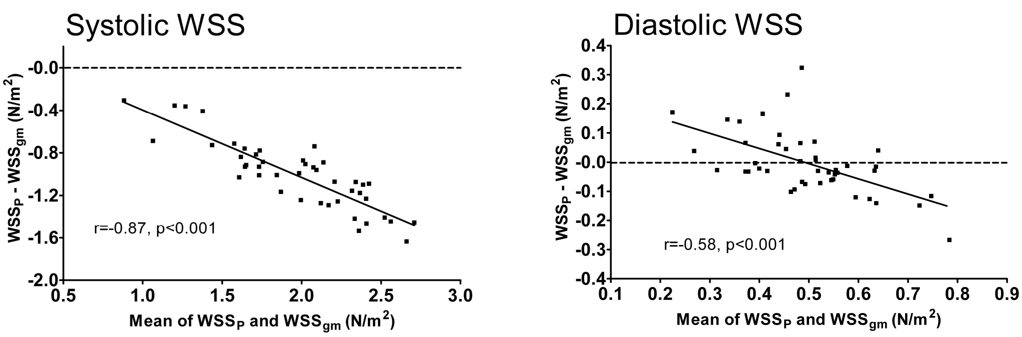
3.0 Tesla MRI Common Carotid Wall Shear Stress Quantification: Poiseuille Estimation versus non-linear fitting of Velocity Data.

R. Duivenvoorden[1], E. de Groot[2], E. van Bavel[3], R. Amri[2], E. Stroes[4], J. Lameris[5], J. Kastelein[2], and A. J. Nederveen[5]
[1]Vascular Medicine, Academic Medical Center, Amsterdam, Netherlands, [2]Vascular Medicine, Academic Medical Center, [3]Medical Physics, Academic Medical Center, [4]Academic Medical Center, [5]Radiology, Academic Medical Center

Introduction Wall Shear Stress (WSS) is an important determinant of endothelial function and phenotype. WSS determination based on MRI data is a promising method that needs further validation for use in clinical studies. The aim of this study was to compare 3.0 Tesla MRI WSS estimated based on Poiseuille flow to a new method using non-linear fitting of the velocity gradient near the wall.



Methods 3.0 Tesla MRI scans were performed on three different days in the common carotid arteries of 45 subjects (aged 49 ± 18). Axial gradient echo Phase-Contrast images were acquired over 60 phases per heartbeat (retrospective gating), using a 5 cm single-element microcoil (Philips). Sequence parameters: slice thickness 3 mm, non-interpolated pixel size 0.625 x 0.625 mm, velocity encoding 150 cm/s. WSS was assessed by Poiseuille (WSS_P) and by non-linear gradient modeling (WSS_{gm}). WSS_P was calculated using: WSS = 4 * Vmax / D. Vmax is the maximum velocity and D is the vessel diameter. Poiseuille assumes the blood flow is fully developed into a parabolic velocity profile, which occurs only in a long rigid cylinder with constant flow. In reality, a parabolic velocity profile is not present in arteries in vivo. Therefore we calculated WSS_{gm} by determining the slope of the velocities close to the artery wall using second order curve fitting of the velocity profile, excluding the center of the vessel. We compared both methodologies in a Bland Altman analysis and interscan reproducibility was compared by calculating the intraclass correlation coefficients (ICC) of the initial and repeat scans of both methods.



Bland Altman analyses for WSS_P and WSS_{gm}

Results Mean WSS values were: systolic WSS_P 1.45 (SD 0.31) N/m², diastolic WSS_P 0.49 (SD 0.10) N/m², systolic WSS_{gm} 2.47 (SD 0.58) N/m², diastolic WSS_{gm} 0.50 (SD 0.16) N/m². In a Bland Altman analysis a systematic downward bias for systolic WSS of -1.0 N/m² was observed (WSS_P minus WSS_{gm} $p<0.001$). No systematic bias for diastolic WSS was observed. For both systolic and diastolic WSS the per subject difference between both modalities negatively correlated with the per subject mean of both modalities in a Bland Altman analysis ($r=-0.87$, $p<0.001$ for systolic WSS and $r=-0.58$, $p<0.001$ for diastolic WSS). This indicates that the Poiseuille method underestimates WSS at increasing WSS levels. The ICC's for intersession reproducibility were: systolic WSS_P 0.75 (95% CI 0.60 to 0.86), diastolic WSS_P 0.71 (95% CI 0.55 to 0.84), systolic WSS_{gm} 0.73 (95% CI 0.60 to 0.83), diastolic WSS_{gm} 0.78 (95% CI 0.66 to 0.87).

Conclusion The use of non-linear modeling provides a more accurate estimation of both systolic and diastolic WSS in the common carotid artery. Moreover, the Poiseuille method underestimates systolic WSS. Reproducibility of both methods is similar.