Impact of Stent mis-Sizing and mis-positioning on Coronary Fluid Wall Shear and Intramural Stress

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Introduction

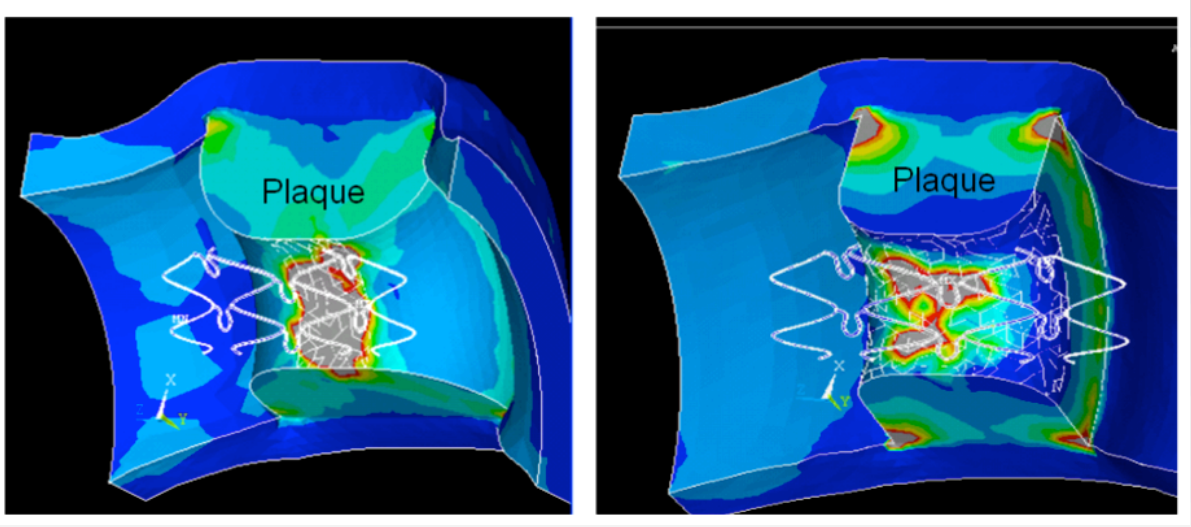
Stent deployments with geographical miss (GM) are associated with increased risk of target-vessel revascularization. The aim of the current study was to investigate the underlying biomechanical mechanisms for adverse events with GM.

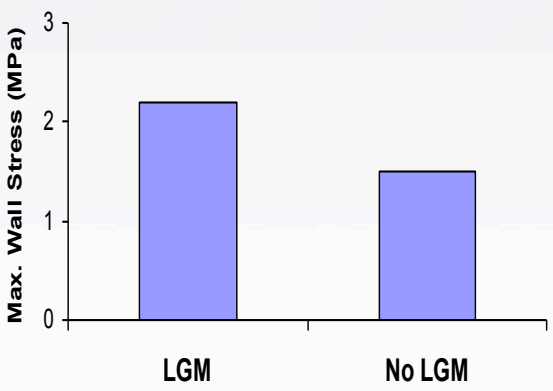
We hypothesized that stent deployment with GM (LGM, longitudinal; or radial, RGM) result in unfavorable fluid fluid wall shear stress (WSS) and gradients (e.g., WSSG, OSI) and intramural circumferential wall stress (CWS)

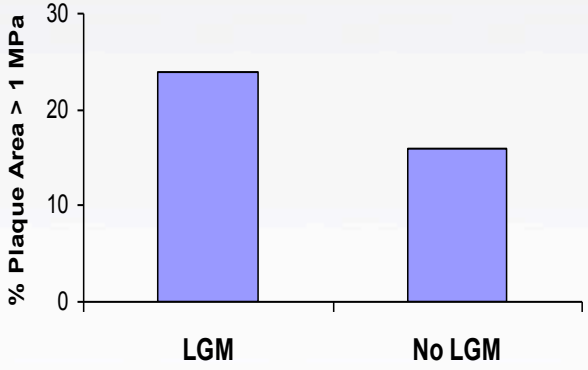
Methods

- To test this hypothesis, we developed computational models of stents and non-Newtonian blood simulations.
- The plaque was modeled as calcified tissue with material properties based on literature.
- The models were then interfaced, meshed and solved in a validated finite element package.
- The blood was modeled with flow waveform based on human left coronary artery pulsatile velocity measurements applied at the inlet of vessel.

Circumferential Wall Stress

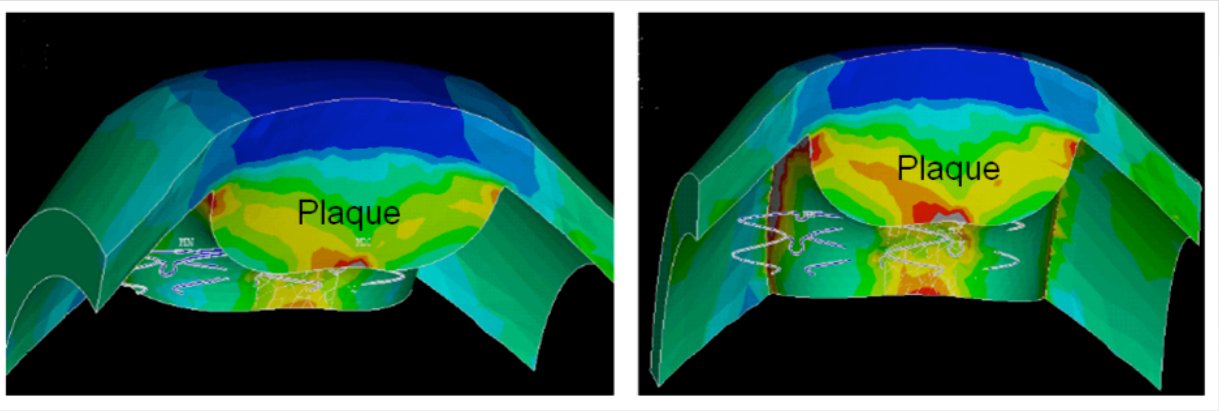


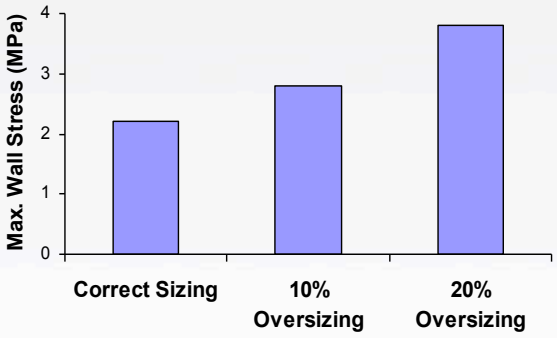


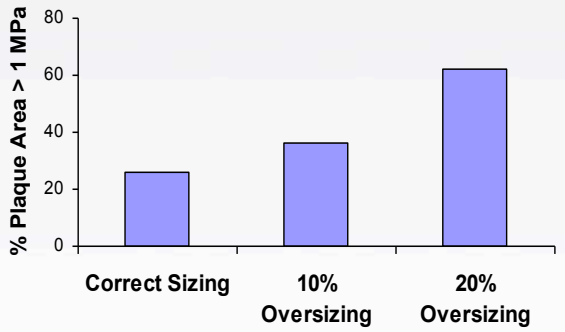


Upper left) with geographic miss, and **Upper right**) with centered stent; **Lower left**) Longitudinal GM resulted in 45% increase of wall stress (2.10 MPa vs. 1.45 MPa). The stresses were highest at the contact region between the plaque and stent; **Lower right**) % of plaque area with stress > 1 MPa (24% vs. 16%).

Effects of radial GM or stent oversizing are shown

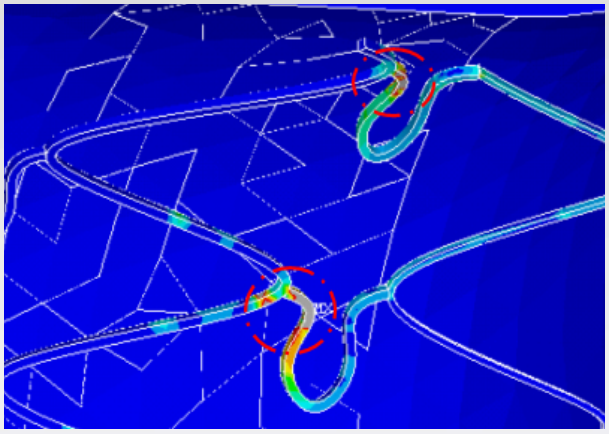


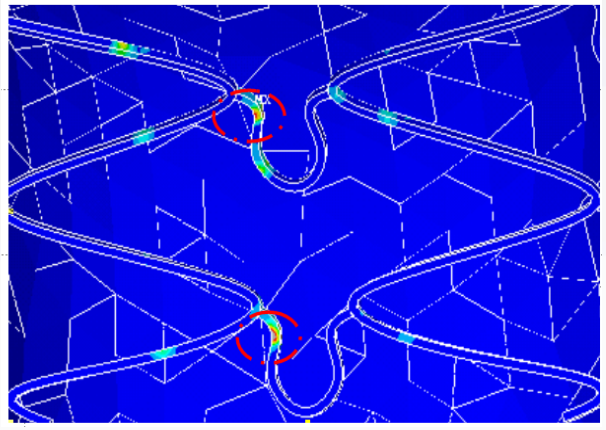


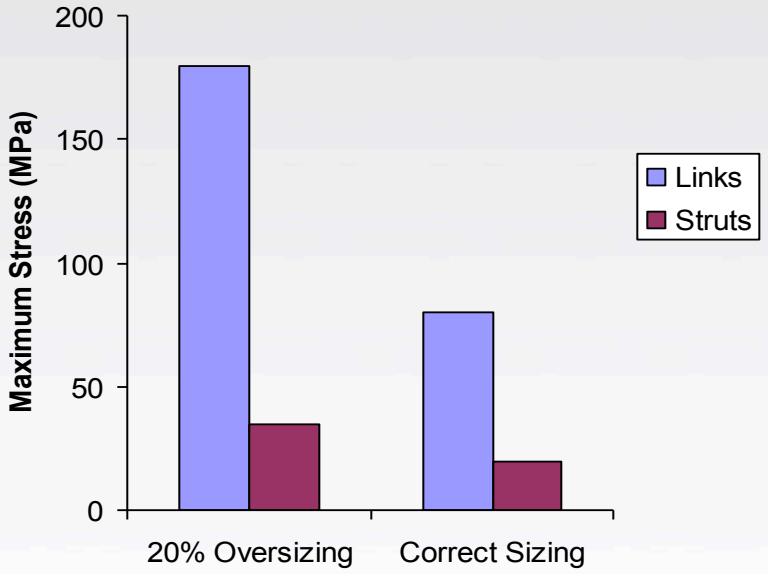


Upper left) 10% oversizing; **Upper right**) 20% oversizing. **Lower left**) 20% oversizing resulted in about 40% and 73% increase in wall stress as compared to 10% oversizing and correct sizing (3.8 vs. 2.7 and 2.2 MPa). The oversizing was for the cases of stenting with longitudinal GM; **Lower right**) % of plaque area with stress > 1 MPa (24%, 37% and 62% for correct sized, 10% and 20% oversized stents, respectively).

Stress distributions on stent struts

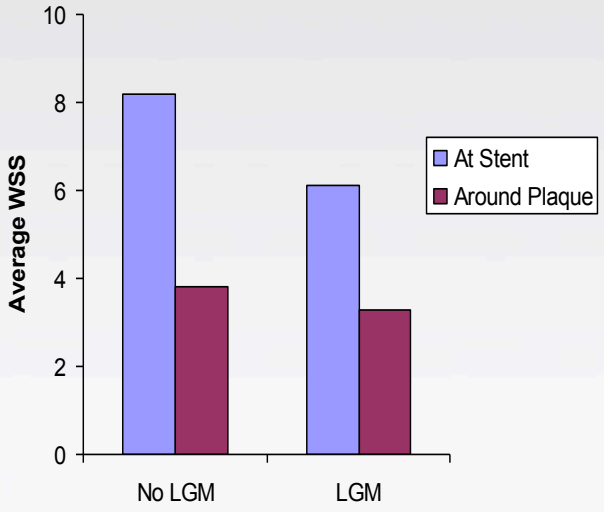


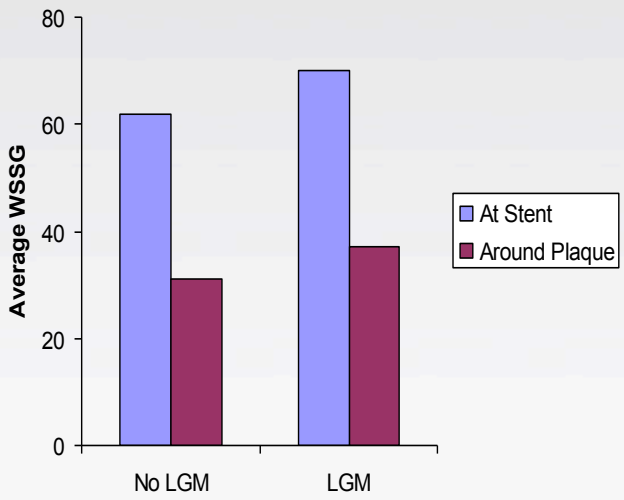


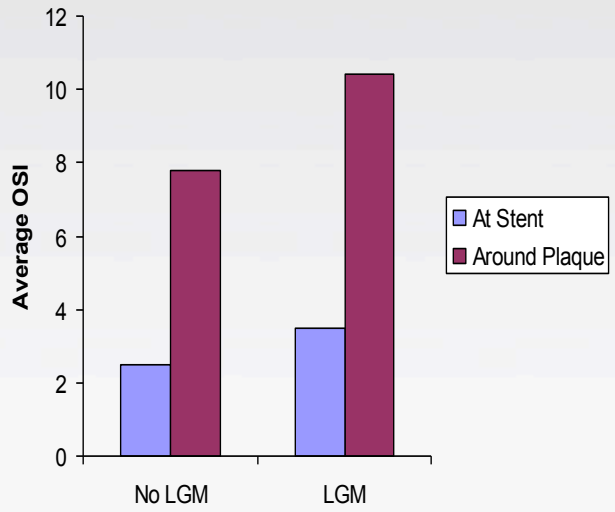


The stresses concentrate at the struts in contact with plaque for the cases of stenting with longitudinal GM. The linkages between the struts have much higher stress than in the main struts.

Wall Shear Stress and Gradients for LGM

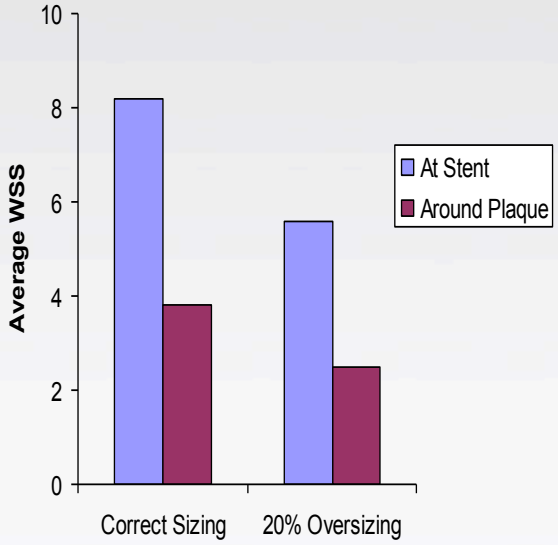


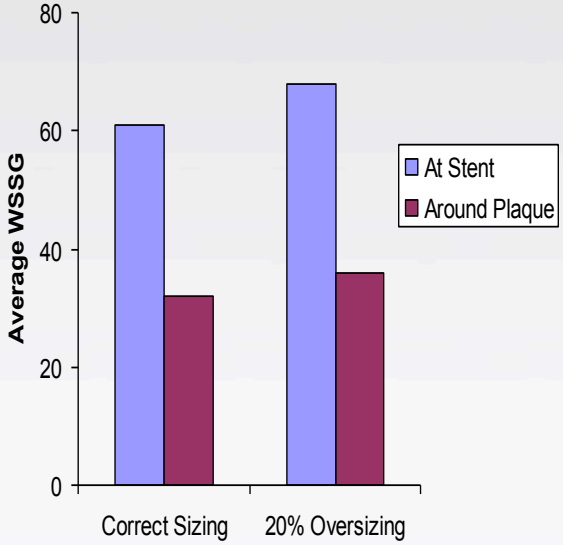


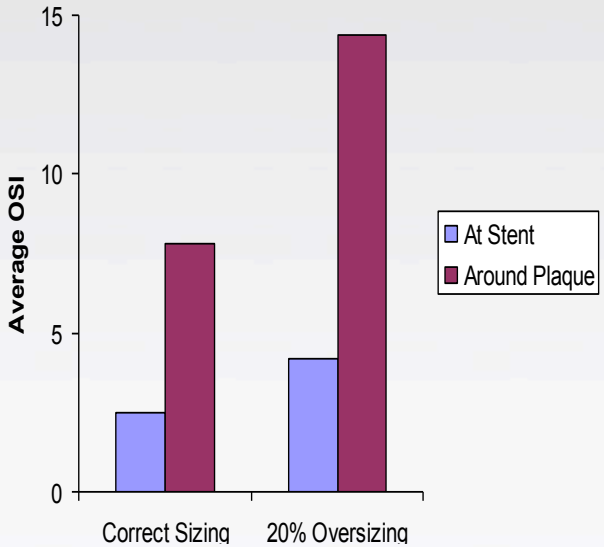


The WSS (Dyne/cm^2) at stented region and around the plaque were lower for the case of LGM compared to non LGM. The WSSG (Dyne/cm^3) and OSI (%) at stented region and around the plaque were higher for the case of LGM compared to non-LGM.

Wall Shear Stress and Gradients for RGM







WSS (Dyne/cm^2) at stented region and around the plaque were lower for the case of RGM compared to non-RGM. WSSG (Dyne/cm^3) and OSI (%) at stented region and around the plaque were higher for the case of RGM compared to non RGM.

Conclusions

- The simulations predict that longitudinal geographic miss increases CWS, WSSG and OSI, but decrease WSS, consistent with clinical findings (e.g., STTLR trial).

- The simulations predict that radial geographic miss increases CWS, WSSG and OSI, but decrease WSS, consistent with clinical findings (e.g., STTLR trial).

- The reason for the wall stress increase is due to the asymmetrical and uneven stent deployment. The stresses concentrate at the links of the struts which may predispose to fracture.

- These findings are likely exaggerated in bifurcations due to the more complex geometry and flow conditions.