Biomechanics and Plaque Progression in Human Coronary Arteries

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**Recommended Citation**

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Study Overview

Methods: Subject Population

Patients referred to Cath Lab for evaluation of CAD

Evaluation of coronary arteries by angiography, physiology, IVUS, and CFD

Atorvastatin 80mg a day for 6 months

Repeat angiography, physiology, and IVUS at 6 months
Imaging Methods: Angiography, IVUS
Computational Methods

One IVUS Segment (0.5mm thickness)

Calcium and Necrotic Core
Atherosclerosis Progression by Virtual Histology IVUS

Baseline

6 months Later
Analysis of Pooled Baseline Data

- WSS averaged over cardiac cycle to obtain mean WSS on surface
- WSS then averaged around circumference to obtain WSS as a function of axial location
- Image data for each slice were obtained to show lumen area (LA), plaque area (PA), vessel area (area within IEL), and plaque burden (PB)
Lumen Area vs Plaque Burden
Pooled Baseline Data – 18 Subjects

\[ y = -1.7076x + 55.179 \]
\[ R^2 = 0.2344 \]
WSS vs Lumen Area
Pooled Baseline Data – 18 Subjects

\[ y = -0.106x + 12.851 \]
\[ R^2 = 0.1593 \]
WSS vs Plaque Burden
Pooled Baseline Data – 18 Subjects

WSS vs PB - ALL

\[ y = 0.4266x + 26.775 \]

\[ R^2 = 0.2074 \]
Conclusions – Baseline

In patients with symptomatic coronary artery disease, population data show:

• Trends between WSS, lumen area, and plaque burden follow intuition

• Statistical work ongoing to determine significance, etc.

• Considerable individual variability
Results – Longitudinal

Change in Plaque Area Over Six Months
Low WSS (<10 dynes/cm²); Intermediate (10-25); High (>25)

Results – Longitudinal
Change in Plaque Composition in Low (<10), Intermediate (10-25), and High (>25) WSS Segments over 6 Months

In patients with coronary artery disease:

- Coronary segments with low WSS develop greater total plaque progression as well as more constrictive remodeling compared to intermediate or high WSS segments.

- Coronary segments with intermediate (physiologic) WSS show overall plaque regression.

- Coronary segments with high WSS demonstrate no significant change in total plaque area, but suggest a plaque phenotype transformation (increase in necrotic core and calcium, and decrease in fibrous and fibro-fatty tissue).
Some Common Misconceptions

• WSS can be estimated from looking at angiographic images so why do CFD?
• Blood pressure, viscosity and non-Newtonian rheology matter a lot
• IVUS, angiography, CFD are very accurate
• A correlation shows a cause-effect relationship
• Data taken at a single time point can be generalized
So why bother with WSS anyway?

- Evidence that WSS relates to atherogenesis
- Evidence that WSS relates to plaque progression
- WSS, along with the intravascular pressure field, creates mechanical forces on plaques
- Knowing an individual’s WSS patterns may suggest pre-emptive and/or therapeutic measures
Acknowledgements and Disclosures

- Pfizer Inc.
- Volcano Therapeutics
- St. Jude Medical
- Toshiba
- Forrest Pharmaceuticals
- Emory University Research Committee
- Wallace H. Coulter Biomedical Sciences Grant
- Georgia Research Alliance
A Big Happy Birthday to Shmuel
and
A Big Thank You to David!