Association Between Intraluminal Thrombus and Abdominal Aortic Aneurysm Rupture

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Background

• AAAs rupture when wall stress > wall strength.

• Peak and Mean Wall stress (PWS, MWS) can be calculated using finite element analysis (FEA) and computational fluid dynamics (CFD) and are influenced by aneurysm anatomy: (shape, diameter, thrombus).*


Engineering Considerations

• Advances in Mathematical Modeling and Computer hardware and software allow FEA and CFD to more efficiently be combined with CT data and a custom MATLAB program (MathWorks, Natick, MA) to mimic AAA shapes, diameters, flow dynamics and measures of AAA intraluminal thrombus.

Methodology: FEA, CFD and ILT
Questions
1. In addition to a relative increase in wall stress might rAAAs also have decreased wall strength?
2. Does aortic aneurysm intraluminal thrombus (ILT) affect AAA wall stress and wall strength?
3. Is AAA ILT associated with AAA rupture?
4. Can AAA ILT serve as marker of AAA rupture risk?

Intraluminal Thrombus (ILT): “Pillow” or “Cesspool”
- Pillow: ILT acts as a buffer to decrease wall stress.
- “Cesspool”: ILT creates a pro-inflammatory environment where neutrophils, cytokines, MMPs, and reactive oxygen species are sequestered and act to decrease wall strength.

FEA and ILT spatial dimensions to calculate PWS and MWS and measures of ILT in:
- 8 patients with small (<60mm) rAAA
- 13 patients with small (<60mm) non-rAAA
- 13 patients with large (>60mm) rAAA
- 14 patients with large (>60mm) non-rAAA

Mean Wall Stress vs AAA Diameter
Mean wall stress was lower in small rAAAs, p<0.01, suggesting decreased wall strength in small rAAAs.

Peak Wall Stress vs AAA Diameter
Peak wall stress was lower in small rAAAs, p<0.01, suggesting decreased wall strength in small rAAAs.

ILT Volume vs AAA Diameter
ILT volume correlated moderately with AAA diameter, R² = 0.56.
ILT thickness vs AAA Diameter

ILT thickness correlated with AAA diameter, $R^2 = 0.77$

ILT Normalized for AAA diameter

Normalized for diameter, mean ILT thickness and percent ILT volume, small rAAAs had higher thrombus burdens than large non-rAAAs and small non-rAAAs

ILT and Wall Stress

ILT decreases wall stress with inverse relationship between normalized ILT thickness and % ILT volume.

Conclusions

• AAAs rupture when wall stress exceeds wall strength.
• ILT decreases wall stress but is also associated with a potential decrease in wall strength.
• Small AAAs, and likely large AAAs with increased ILT, are at increased risk of rupture compared to other small or large AAAs.

Questions?

Wall strength vs Wall stress

• In addition to a relative increase in wall stress might rAAAs also have decreased wall strength?
• Might AAAs also rupture as a result of decreased wall strength?
• What is the role of intraluminal thrombus in the stress/strength interaction?