Post Graduate

Investigation of potential rupture locations for abdominal aortic aneurysms with patient-specific computational fluid dynamic analysis approach

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BACKGROUND

- About 18 million people die each year from cardiovascular disorders, accounting for 31% of all deaths worldwide.
- Abdominal Aortic Aneurysm (AAA) is a serious clinical condition manifested as dilation of the aorta beyond 50% of the normal vessel diameter.
- Current clinical practice is to surgically repair large AAAs with diameter > 5.5 cm. However, the practice is questionable based on small AAA rupture and large AAA no rupture cases.
- Currently there is no accepted technique to quantify the risk of rupture for individual AAAs. It is believed that, rupture locations are where peak wall stresses act. hhemodynamic forces by the flowing blood such as shear stress are also thought to contribute to the formation of aneurysm leading to rupture.

OBJECTIVE

Our aim is performed precise computational analysis for assessment of rupture risk for AAA patients.

METHODOLOGY

Creating patient specific 3D and meshed geometry for FSI analysis

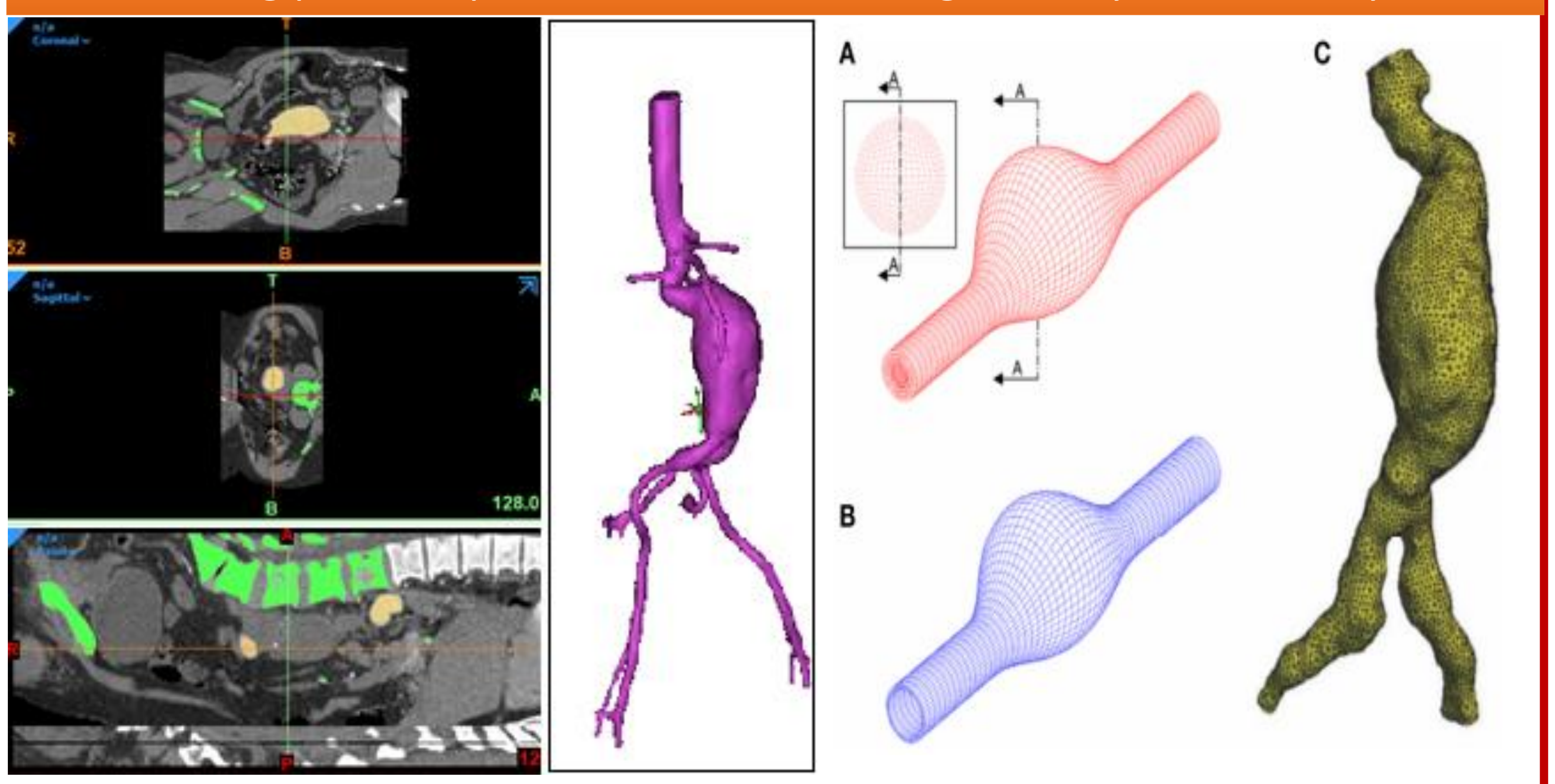


Figure1: Geometry segmentation from CT images; (A) Structured hexahedral fluid mesh using idealized AAA model. (B) Structured hexahedral solid mesh using idealized AAA model. (C) Unstructured tetrahedral fluid mesh using patient-specific AAA model [1].

- Fluid-structure interaction (FSI) simulations of patient-specific models would provide more detailed information about the hemodynamics of the aneurysm.
- We have recruited 20 AAA patients at HMC and collected CT scans and ultrasound images for these patients.
- Using these medical data, we are developing accurate 3D model geometries.

Boundary conditions

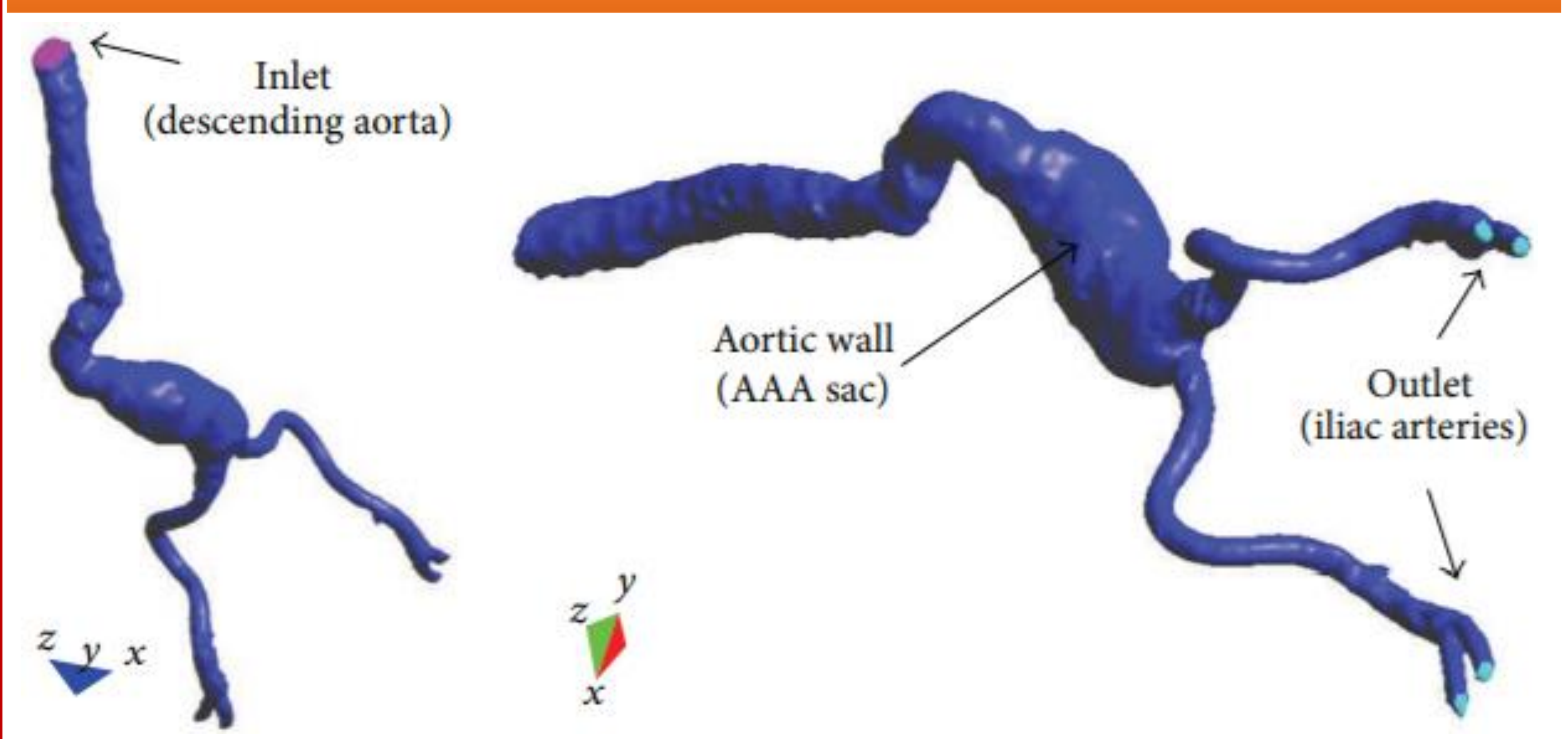


Figure2: Boundary conditions FSI analysis [2].

The governing equations in fluid domain:

$$\rho_f \frac{\partial \mathbf{v}}{\partial t} + \rho_f (\mathbf{v} - \mathbf{w}) \cdot \nabla \mathbf{v} - \nabla \cdot \boldsymbol{\tau}_f = \mathbf{f}_f^{B}$$

$$\nabla \cdot \mathbf{v} = 0$$

where ρ_f: mass density of fluid, $\mathbf{v}$: fluid velocity vector, t: time, $\mathbf{w}$: the velocity of the fluid domain (i.e. moving coordinate velocity primarily due to FSI), $\boldsymbol{\tau}_f$: fluid stress tensor, $\mathbf{f}_f^{B}$: body forces term.

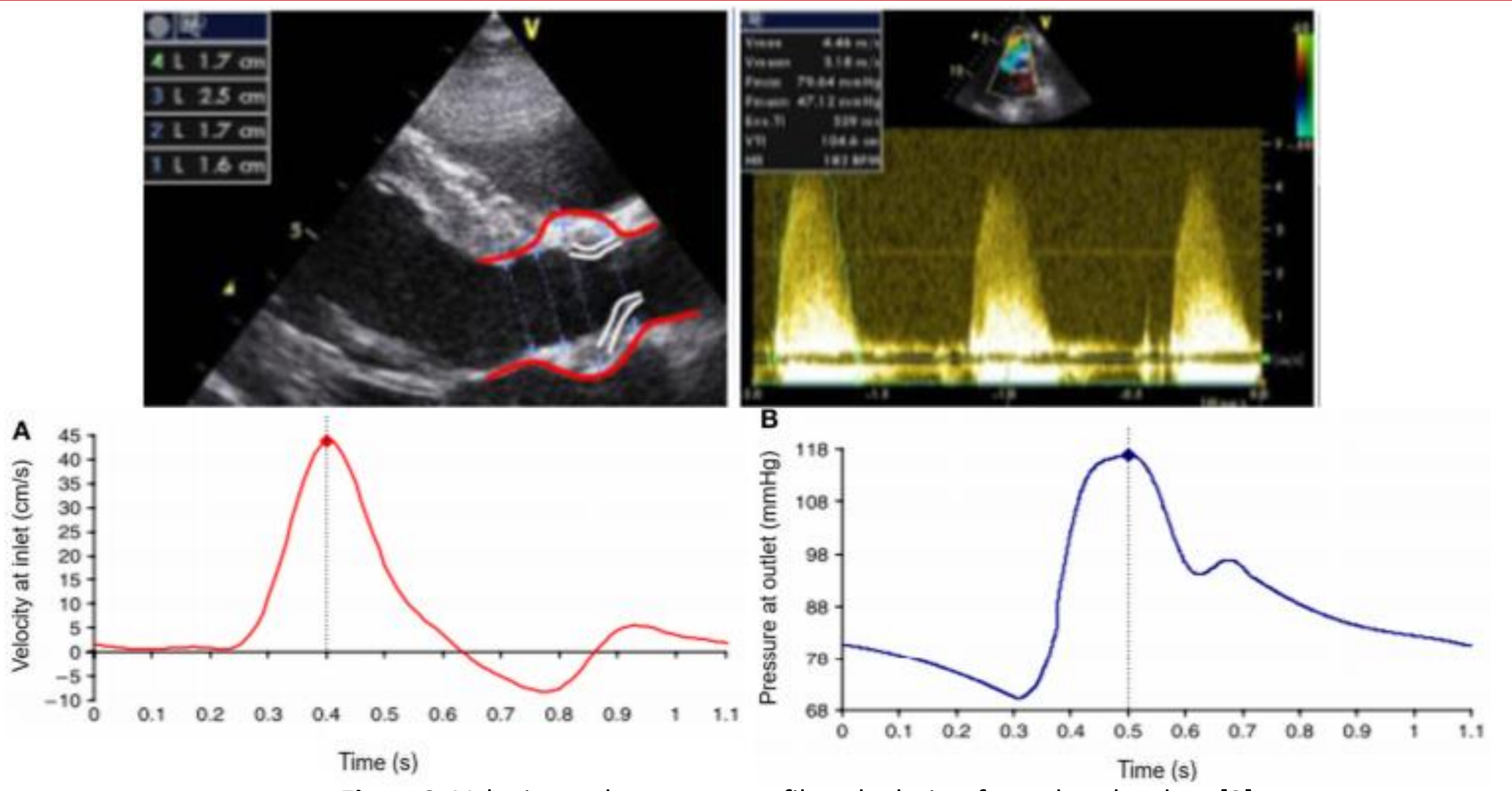


Figure3: Velocity and pressure profile calculation from doppler data [3].

- Patient specific blood pressure and velocity profiles created from doppler measurements.

EXPECTED RESULTS

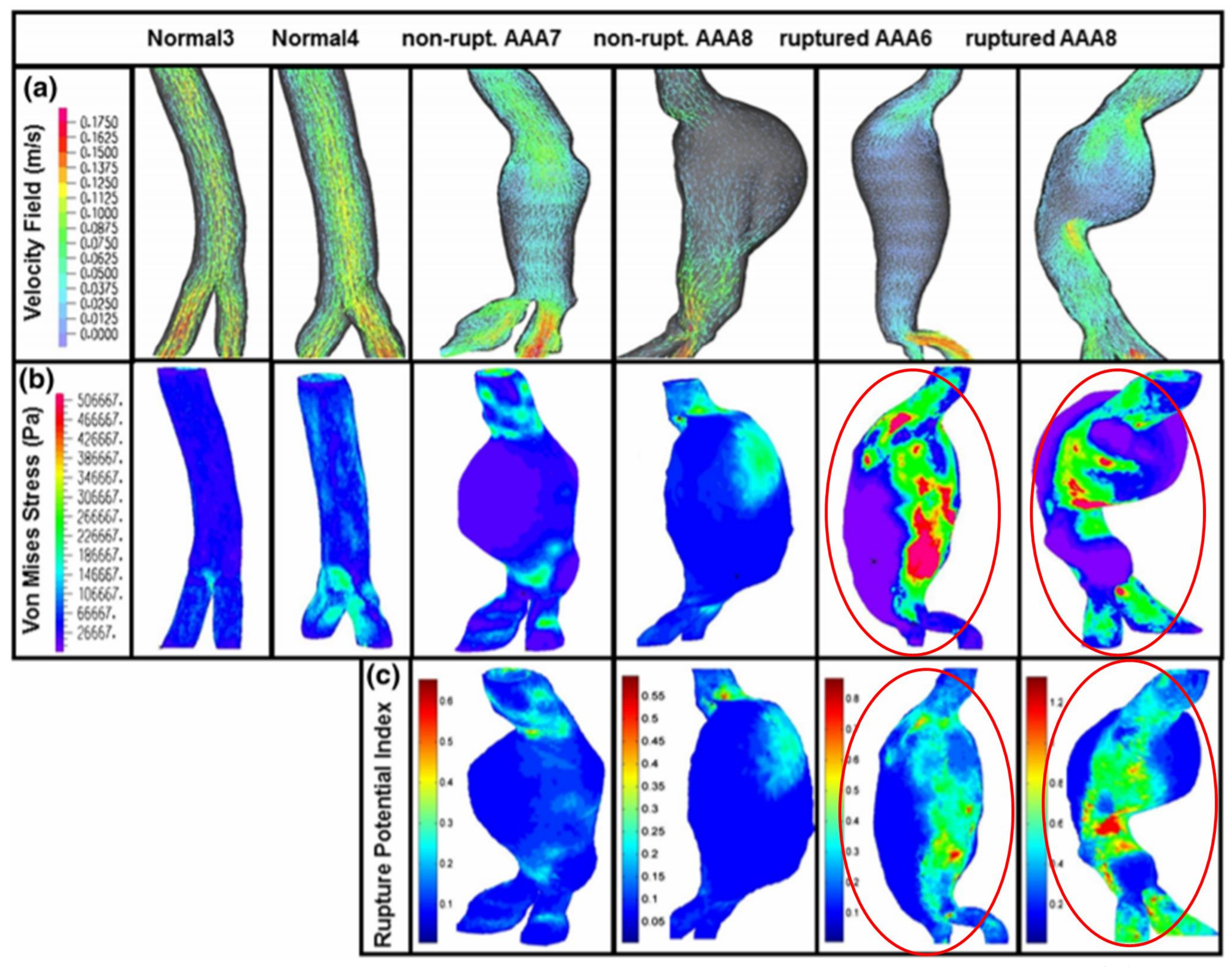
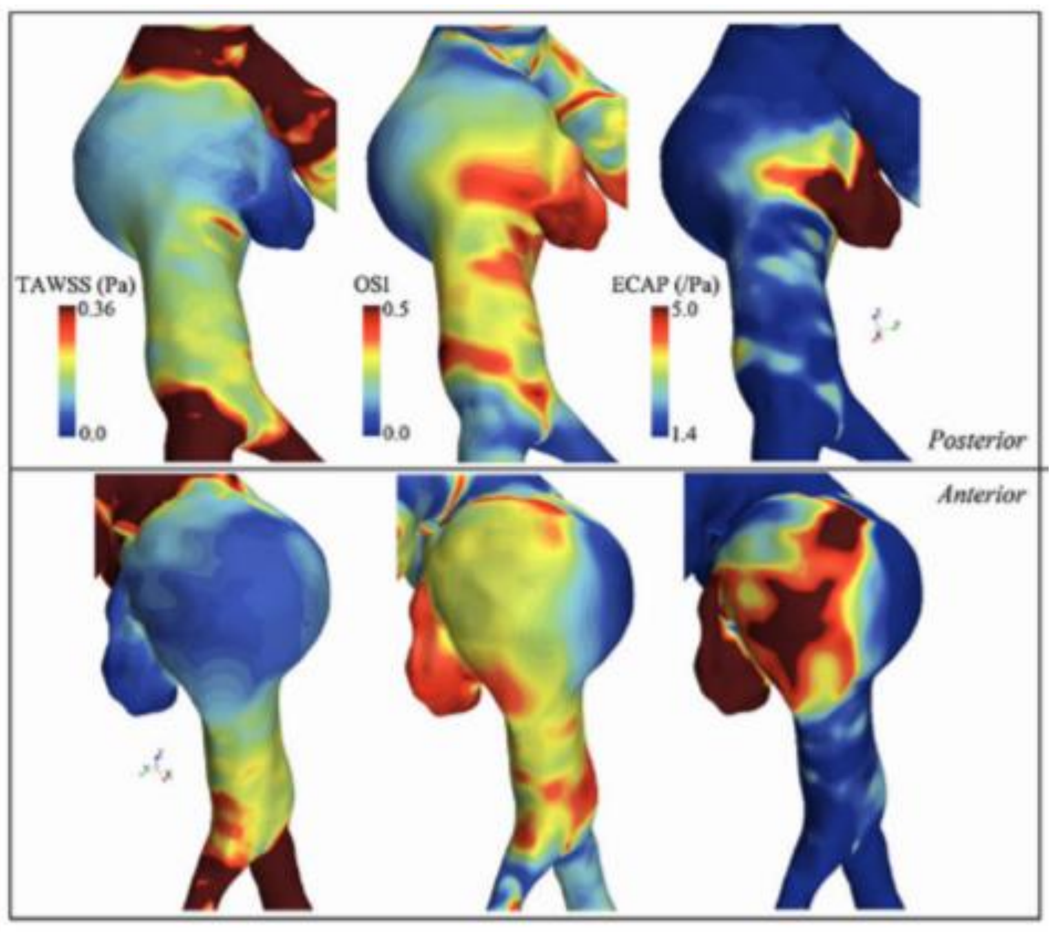


Figure3: Representative cases from each group, normal, non raptured and raptured AAA. (a) Velocity vector fields 0.15 s after peak systole. (b) Von Mises stress in the aortic wall for the isotropic material model formulation. (c) RPI (Rapture Potential index) for the pathological cases [4].



$$TAWSS = \frac{1}{T}\int_{t-T}^{t} |WSS|\, dt$$

$$OSI = \frac{1}{2}\left(1 - \frac{\left|\frac{1}{T}\int_{t-T}^{t} WSS dt\right|}{\frac{1}{T}\int_{t-T}^{t} |WSS|\, dt}\right)$$

$$ECAP = \frac{OSI}{TAWSS}$$

Figure4: TAWSS (Time averaged WSS), OSI, and ECAP contour plots on a patient specific AAA model. ILT formation is more likely to be observed in high ECAP regions. Rupture risk and aneurysm growth rate increase at regions with high OSI and low TAWSS [5].

- TAWSS (Time Averaged Wall Shear Stress) [6],[7]
- OSI (Oscillatory Shear Index) [8]
- ECAP (Endothelial Cell Activation Potential) [9]

Are the important hemodynamic parameters to detect potential rapture locations.

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