Computational Modelling of Lymphatic Valve Mechanics

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The Lymphatic System

• Responsible for fluid balance and homeostasis

• Important in immune cell transport (cancer metastasis)

• Lymphoedema – debilitating disease with no known cure
Role of Nitric Oxide (NO)

- Diastolic relaxation sensitive to endothelium derived NO
- Shear forces produced by flow activate eNOS and NO is produced by EC’s
- *Convection of NO will influence vascular tone*

Fluid pumped against favourable pressure gradient
  - *intrinsic* pumping

High NO concentration found [HERE](image from Texas A&M Health Science Center)

Adapted from Bohlen et al 2009

![Fluorescent Staining](image from Texas A&M Health Science Center)
Project Goals

More complete characterisation of the lymphatic valve is necessary.

1) Develop computational models to describe detailed flow profiles near the lymphatic valve structure.

2) Determine NO concentrations produced along the lymphatic valve and relate to properties of flow.
In-vivo Geometry Model

Confocal Imaging
- isolated rat mesenteric lymphatic vessel
- focus on valve
- 2D images along z-direction
- 2.5 µm apart

Image Reconstruction
- Scan IP/FE (Simpleware, Exeter, UK)
- Smoothing and filtering
- Reconstruct fluid region

Meshing
- Star-CCM+
- Trimmer (predominantly hexahedral)
- Prism layer
- ~400,000 elements
- mesh independence to resolve WSS less than 6% RMS difference

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Image from Texas A&M Health Science Center
In-vivo Geometry Model

Boundary Conditions
- Velocity Inlet (0.5-7 mm/s)
- Zero-pressure outlet
- Shear-dependent NO flux at vessel wall
- Constant inlet concentration with zero flux at outlet
- Analogy to heat transfer
- Sink term for NO
- Re<1

\[
R_{NO} = \frac{R_{NO,max}}{1 + y \exp(-W_o \cdot WSS_{axial})}
\]

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**In-vivo Geometry Model**

**NO Production**

- Higher production in elevated areas of axial WSS

**NO Concentration**

- Higher in areas of flow stagnation (despite very low production in these areas)

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Future Work

• Fully dynamic model (both idealised and image-based)

• Compare to results of previous static model and determine influence of valve motion on distributions of NO concentration.
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References


