Influence of Slippery Pacemaker Leads on Lead-Induced Venous Occlusion

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Introduction

- Pacemakers are used to treat arrhythmias.
- Pacemaker implantation:
  between 1993-2009, 2.9 M patients in US
- Venous occlusion:
  15-30% for adults and 20% for children

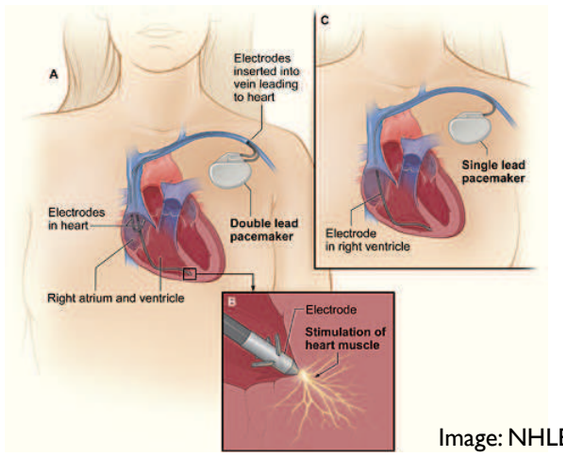
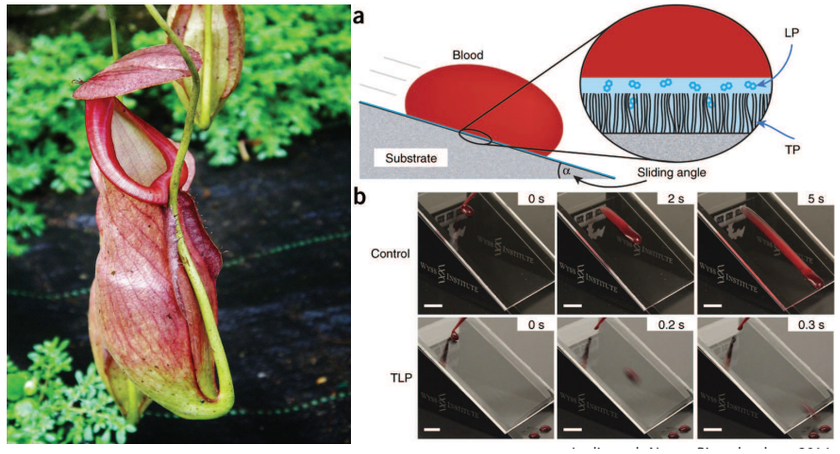


Image: NHLB, NIH

- Does lead size matter? Maybe.
- Small-diameter lead: increased rate of lead failure
- Simulations show flow stasis is concentrated around leads.
- What if slippery?
  - Pitcher plant inspired omniphobic surface coating (SLIPS)



Leslie et al. (2014).Nature Biotechnol.

Computational Approach

- Navier-Stokes equations:

$$\rho\left(\frac{\partial \mathbf{u}}{\partial t}+\mathbf{u}\cdot\nabla\mathbf{u}\right)=\nabla\cdot\boldsymbol{\sigma}$$
$$\nabla\cdot\mathbf{u}=0$$

where $\sigma=-p\mathbf{I}+\mu(\nabla\mathbf{u}+\nabla(\mathbf{u})^T)$.

- Slip boundary conditions:

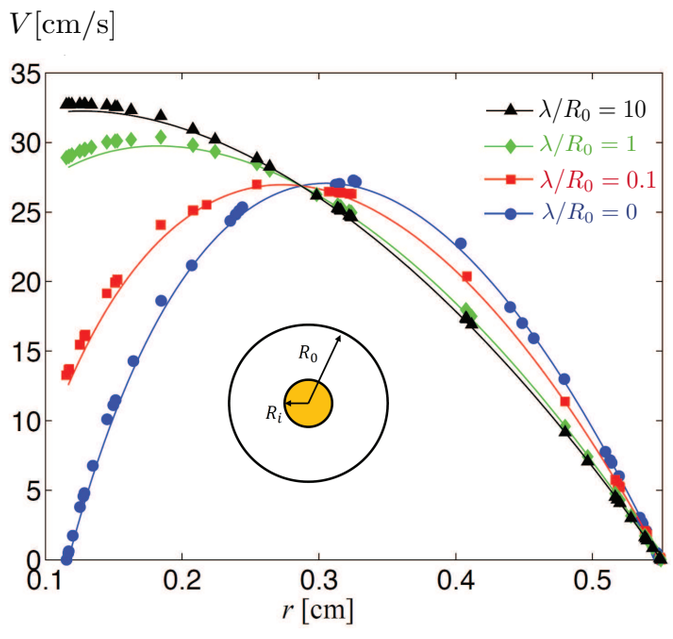
$$\mathbf{u}_{\parallel}=\lambda\mathbf{n}\cdot\boldsymbol{\sigma}\cdot(\mathbf{I}-\mathbf{nn})/\mu$$

- Implemented in Simvascular package
- Residence time:

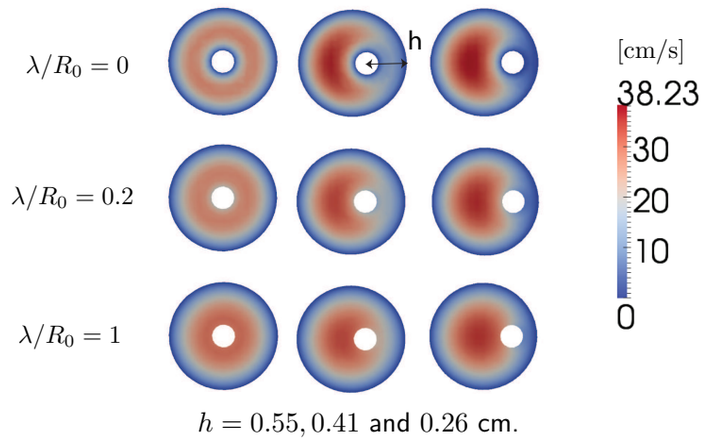
$$\frac{\partial\tau}{\partial t}+\mathbf{u}\cdot\nabla\tau-\nabla\cdot\kappa\nabla\tau=H$$

Validation

- Simulation setting:
  $Q=16cc/s,\ R_o=0.55cm,\ R_i=0.117cm$

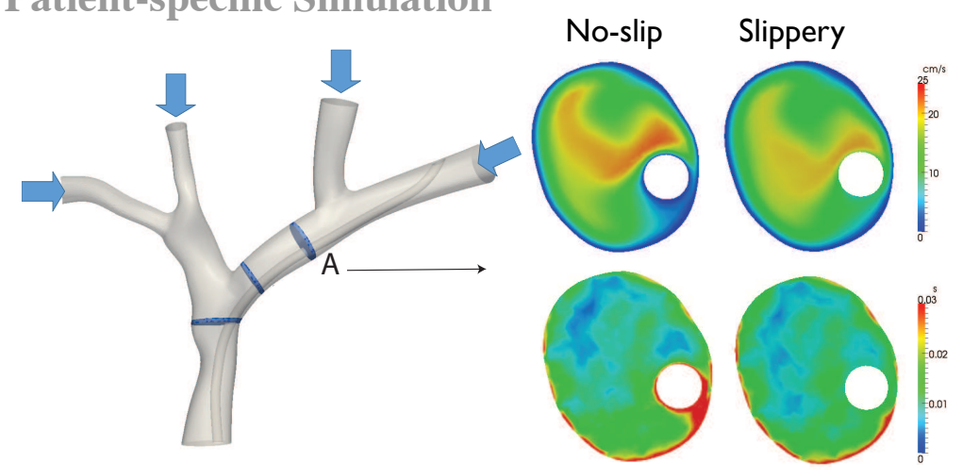


Eccentric Cylinders



$h = 0.55, 0.41$ and 0.26 cm.

Patient-specific Simulation



- The influence of a slippery hydrodynamic condition on pacemaker lead surface is evaluated in idealized and patient-specific scenarios.
- The slippery surface condition reduces the residence time in close proximity of the lead, suggesting its possibility of mitigating risks of lead-induced thrombosis.

References:

1. National Heart, Lung, and Blood Institute, NIH
2 Leslie et al. (2014).*Nature Biotechnol.* 32,1134-1140.