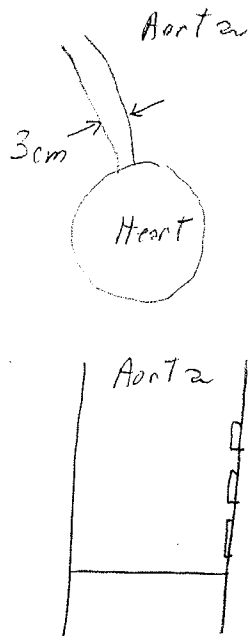


Aorta Modeling for Heart Valve

6/6/00-1



Data

$$\Delta P_{max} = 300 \text{ mm Hg} = 30 \text{ cm Hg}$$

$$Q = 5 \text{ L/min} = 5000 \text{ cm}^3/\text{min}$$

$$D = 3 \text{ cm}, R = 1.5 \text{ cm}$$

$$\sigma_r \geq 1200 \text{ mm Hg} \text{ (Rupture stress)}$$

$$\mu_{\text{Blood}} = 1 \text{ cP} = 0.01 \text{ P} = 0.01 \frac{\text{g}}{\text{cm} \cdot \text{s}}$$

$$A = \pi \frac{D^2}{4} = \pi \frac{3^2}{4} = 7.1 \text{ cm}^2$$

$$C = 2\pi R = 2\pi \cdot 1.5 = 9.4 \text{ cm}$$

stents
Valve (closed)

Treat the Aorta as a rigid capillary and blood as a homogeneous liquid with viscosity of 1 cP.

Some important quantities:

Shear stress at wall, τ_w

$$\tau_w = \frac{R \Delta P}{2L}$$

shear stress at wall
 $L = \text{Length}$

$$\bar{V} = \frac{Q}{\pi R^2}$$

mean velocity

$$\dot{\gamma} = \frac{4Q}{\pi R^3}$$

shear rate at wall

$$\tau_w = \frac{1.5 \text{ cm} \cdot 30 \text{ cm Hg}}{2 (1 \text{ cm})} = 22.5 \text{ cm Hg}$$

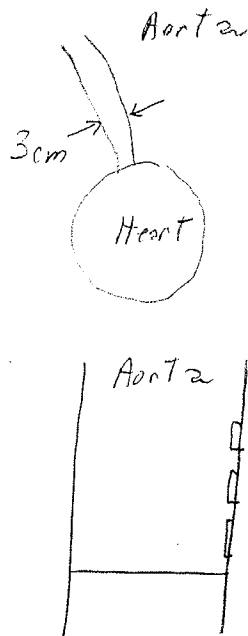
$$Re = \frac{D \bar{V} \rho}{\mu} = \frac{3 \text{ cm} \cdot 12 \frac{\text{cm}}{\text{s}} \cdot 1 \frac{\text{g}}{\text{cm}^3}}{0.01 \frac{\text{g}}{\text{cm} \cdot \text{s}}} = 3600$$

$$\bar{V} = \frac{5000 \text{ cm}^3/\text{min}}{\pi (1.5 \text{ cm})^2} \cdot \frac{1 \text{ min}}{60 \text{ secs}} = 12 \frac{\text{cm}}{\text{s}}$$

$$\dot{\gamma} = \frac{4 (5000 \text{ cm}^3/\text{min}) \cdot \frac{1 \text{ min}}{60 \text{ s}}}{\pi (1.5 \text{ cm})^3} =$$

Aorta Modeling for Heart Valve

6/6/00-1



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stents
Value (closed)

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$$\bar{V} = \frac{5000 \text{ cm}^3/\text{min}}{\pi (1.5 \text{ cm})^2} \cdot \frac{1 \text{ min}}{60 \text{ secs}} = 12 \frac{\text{cm}}{\text{s}}$$

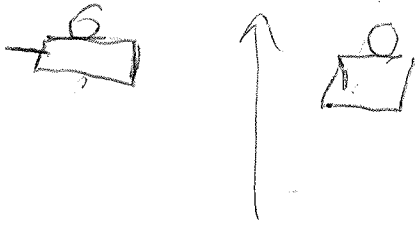
$$\dot{\gamma} = \frac{4 (5000 \text{ cm}^3/\text{min}) \frac{1 \text{ min}}{60 \text{ s}}}{\pi (1.5 \text{ cm})^3} = 30 \text{ s}^{-1}$$

$$Re = \frac{D \bar{V} \rho}{\mu} = \frac{3 \text{ cm} \cdot 12 \frac{\text{cm}}{\text{s}} \cdot 1 \frac{\text{g}}{\text{cm}^3}}{0.01 \frac{\text{g}}{\text{cm} \cdot \text{s}}}$$

$$= 3600$$

for blood, $Re \approx 300$

$$Re \approx 1200$$



6/6/00 - 2

The max. stress on the ceramic when the valve is closed is

$$F_{max} = \Delta P \cdot A = 300 \text{ cm Hg} \cdot 7.1 \text{ cm}^2 \approx 2000 \text{ cm Hg cm}$$

To keep the rupture stress below 120.0 cm Hg, we require a certain amount of stent-ceramic interface area,

$$F_{max} = \sigma_r \cdot A_{stent}$$

If specify that $\sigma_r \approx 300 \text{ mm Hg}$, then we need

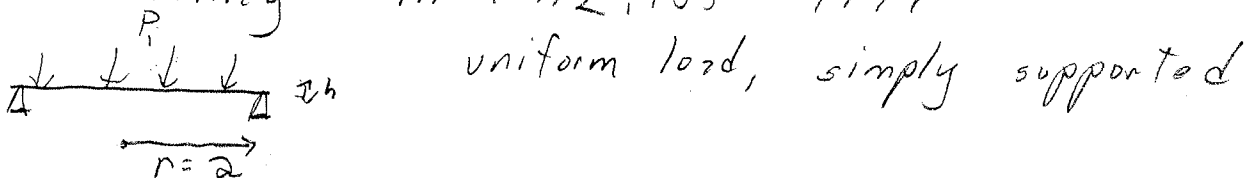
$$2000 \text{ cm Hg} \cdot \text{cm}^2 = 300 \text{ mm Hg} \cdot A_{stent}$$

$$\therefore A_{stent} = 7.1 \text{ cm}^2$$

Convert $P = 300 \text{ mm Hg} \xrightarrow{A} \text{MPa}$

$$300 \text{ mm Hg} \times \frac{1 \times 10^5 \text{ Pa}}{760 \text{ mm Hg}} \times \frac{1 \text{ MPa}}{10^6 \text{ Pa}} = 0.04 \text{ MPa}$$

From Pillkey TA 407.2, P55 1994



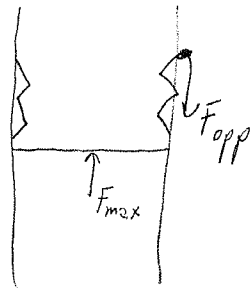
$$\frac{P_1 a^4}{Eh^4} = \frac{1.016}{1-\nu} \frac{w_0}{h} + 0.376 \left(\frac{w_0}{h} \right)^3$$

$w_0 = \text{max. defl.}$

$$\sigma_{rd} = \frac{Eh^2}{a^2} \left[\frac{1.238}{1-\nu^2} \frac{w_0}{h} + 0.294 \left(\frac{w_0}{h} \right)^2 \right]$$

From Excel Spreadsheet "Heart"

6/13/08 1



When valve is closed, the max. force is given by $F_{max} = \Delta P \cdot A$. How is this force transmitted?

I. This stress must be opposed by a stress arising from aorta-stent interaction.

$$F_{opp} = -F_{max} = \sigma_r A_{stent}$$

Since we know the Aorta can withstand 30.0 cm Hg hydrostatic pressure (which is less than 120.0 cm Hg rupture strength), we will use $\sigma_r = 30.0 \text{ cm Hg}$ and

$$\text{Thus } A_{stent} = 7.1 \text{ cm}^2$$

For stents of 1mm width, 10 mm high, and $\alpha = 60^\circ$,



$$\therefore 20 \times 0.1 \text{ cm} \times 1 \text{ cm} = 2 \text{ cm}^2$$

\therefore need 4 stents

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