ARTERIAL & VENOUS BLOOD FLOW

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Medical Sciences, UWI

LECTURE OUTLINE

I. Circulatory system: Structure vs Function

II. Determinants of blood flow & resistance

III. Determinants of blood pressure

IV. Venous blood flow
Total Blood Volume: about 5.5 L

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BLOOD FLOW

FLOW (Q cm$^3$/s) = $\Delta P / R$

RESISTANCE (R) = $\Delta P / Q$

$\Delta P$ = Pressure Difference between the two ends of the vessel

Fluid Viscosity vs Density

- Viscosity describes a fluid's internal resistance to flow. (i.e. measure of friction between adjacent layers of fluid)
  - Water is "thin" (low viscosity)
  - Vegetable oil is "thick" (high viscosity)

- Density of fluid = Mass/Volume
  - Density of water = 1 g/cm$^3$
  - Density of vegetable oil = 0.9 g/cm$^3$
DETERMINANTS OF RESISTANCE
(POISSEUILLE’S LAW)

- **WHEN:**
  1. **TUBE** = CYLINDRICAL
  2. **FLUID** = NEWTONIAN (i.e. homogenous, without suspended particles / cells) e.g. Water
  3. **FLOW** = STEADY (NON-PULSATILE) & LAMINAR

- \[ R = \frac{8 \eta l}{\pi r^4} \]
- \[ Q = \frac{\Delta P}{R} \]
- \[ Q = \frac{\Delta P \pi r^4}{8 \eta l} \]

DETERMINANTS OF TURBULENT FLOW

- **FLUID VISCOSITY** (\( \eta \))
- **FLUID DENSTY** (\( \rho \))
- **VESSEL DIAMETER** (\( D \))
- **VELOCITY OF MOVEMENT** (\( v \text{ cm/s} \))

- **REYNOLD’S No. (Nr)** = \( \frac{\rho D v}{\eta} \)
  - \( Nr < 2000 \rightarrow \text{LAMINAR FLOW (cm}^3/\text{s)} \)
  - \( Nr > 3000 \rightarrow \text{TURBULENT FLOW} \rightarrow \text{MURMUR} \)

- Severe anaemia causes murmur \( \rightarrow \) low viscosity,
- Valve stenosis and atherosclerosis cause murmur \( \leftrightarrow \) increase in velocity \( > \) decrease in diameter
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DETERMINANTS OF BLOOD PRESSURE

• MEAN ARTERIAL PRESSURE (MAP) = \( CO \times TPR \)

• MAP = DP + \( \frac{1}{3} \) PULSE PRESSURE (SP - DP)

• MAP = \( \frac{2}{3} \) DP + \( \frac{1}{3} \) SP

(e.g. BP = 120/90 → MAP = 100 mmHg)
Intravascular pressure varies along the vascular tree

Note: BP values in Pulmonary Circulation are much lower than those in the Systemic Circulation

WINDKESSEL EFFECT OF AORTA & ARTERIES facilitates uninterrupted blood flow in vessels

<table>
<thead>
<tr>
<th></th>
<th>ARTERIES</th>
<th>ARTERIOLES</th>
<th>CAPILLARIES</th>
<th>VENULES</th>
<th>VEINS</th>
</tr>
</thead>
<tbody>
<tr>
<td>WALL</td>
<td>Muscular</td>
<td>Muscular</td>
<td>Endothelial</td>
<td>Non-muscular</td>
<td>Slightly muscular</td>
</tr>
<tr>
<td>% BLOOD</td>
<td>15</td>
<td>5</td>
<td>65</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MAP</td>
<td>100</td>
<td>30</td>
<td>20</td>
<td>10</td>
<td>&gt; 2</td>
</tr>
<tr>
<td>TOTAL X-S AREA</td>
<td>Smallest</td>
<td>Largest</td>
<td>Smallest</td>
<td></td>
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</tr>
<tr>
<td>BLOOD VELOCITY</td>
<td>Fastest</td>
<td>Slowest</td>
<td>Fast</td>
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Total Blood Volume: about 5.5 L
FACTORS AFFECTING BLOOD PRESSURE
(BP = CO X TPR)

• RESISTANCE TO BLOOD FLOW (TPR)
  – VESSEL DIAMETER (decreases with atherosclerosis, excitable vessel smooth muscle, diminished NO effect)
  – BLOOD VISCOSITY (increases with blood haematocrit)
  – VESSEL LENGTH (increases with obesity)
  – VESSEL ELASTICITY (decreases with age & arterosclerosis)

• CARDIAC OUTPUT (CO)
  – BLOOD VOLUME (increases with ↑salt intake & retention)
  – HEART RATE (increases with symp. stimulation e.g. stress)
  – STROKE VOLUME (increases with ↑salt intake & retention)

Posture affects transmural arterial pressure but not the perfusion pressure

Modified from:
Dr. D. Penney;
www.coheadquarters.com/PennLibr
AUTOREGULATION OF BLOOD FLOW IN AN ORGAN

• FLOW (Q) cm³/s = Δ P / R

• However, for a particular organ, increasing MAP →
  – No change in blood flow (Autoregulation)
     • when MAP is 60 - 140 mmHg
     • due to automatic increase in vessel resistance
  – ↑ blood flow when MAP < 60 mmHg
  – ↑ blood flow when MAP > 140 mmHg

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VENOUS CIRCULATION

- Veins are compliant, low-resistance vessels that act as blood reservoirs.
- Compliance of veins $\approx 20x$ that of arteries.
- Veins hold 60 - 80% of the total blood volume
  - If blood is added or removed from the CVS the venous volume will change far more than the arterial volume
- Compliance is greatest in splanchnic and cutaneous veins and least in skeletal muscle
COMPLIANCE vs DISTENSIBILITY

• Vascular Compliance $= \frac{\Delta V}{\Delta P}$

• Vascular Distensibility $= \frac{\Delta V}{\Delta P} \times P$

  $= \text{Compliance} \times P$

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DETERMINANTS OF VENOUS RETURN

- Cardiac pumping
- Skeletal muscle pumping during movement
- Respiratory pump
- Functional venous valves
- Venoconstriction (↔ Sympathetic stimulation)
- Circulating blood volume

EFFECTS OF EXTERNAL PRESSURE ON THE VEINS

- Inspiration → ↓ Intra-thoracic pressure →
  distention of veins in the chest →
  - ↑ right atrial filling →
    ↑ stroke volume from right ventricle
  - ↓ Left atrial filling →
    ↓ stroke volume from left ventricle

- Expiration causes opposite effects
- *The differences cancel out in one respiratory cycle.*
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