Control of blood tissue blood flow

Faisal I. Mohammed, MD, PhD
Objectives

• List factors that affect tissue blood flow.

• Describe the vasodilator and oxygen demand theories.

• Point out the mechanisms of autoregulation.

• Describe how angiogenesis occurs.

• Inter-relate how various humoral factors
Local Control of Blood Flow

- Each tissue controls its own blood flow in proportion to its needs.

- Tissue needs include:
  1) delivery of oxygen to tissues
  2) delivery of nutrients such as glucose, amino acids, etc.
  3) removal of carbon dioxide hydrogen and other metabolites from the tissues
  4) transport various hormones and other substances to different tissues

- Flow is closely related to metabolic rate of tissues.
### Variations in Tissue Blood Flow

<table>
<thead>
<tr>
<th>Tissue</th>
<th>Percent</th>
<th>ml/min</th>
<th>ml/min/100 gm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brain</td>
<td>14</td>
<td>700</td>
<td>50</td>
</tr>
<tr>
<td>Heart</td>
<td>4</td>
<td>200</td>
<td>70</td>
</tr>
<tr>
<td>Bronchi</td>
<td>2</td>
<td>100</td>
<td>25</td>
</tr>
<tr>
<td>Kidneys</td>
<td>22</td>
<td>1100</td>
<td>360</td>
</tr>
<tr>
<td>Liver</td>
<td>27</td>
<td>1350</td>
<td>95</td>
</tr>
<tr>
<td>Portal (21)</td>
<td>(1050)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arterial (6)</td>
<td>(300)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Muscle (inactive state)</td>
<td>15</td>
<td>750</td>
<td>4</td>
</tr>
<tr>
<td>Bone</td>
<td>5</td>
<td>250</td>
<td>3</td>
</tr>
<tr>
<td>Skin (cool weather)</td>
<td>6</td>
<td>300</td>
<td>3</td>
</tr>
<tr>
<td>Thyroid gland</td>
<td>1</td>
<td>50</td>
<td>160</td>
</tr>
<tr>
<td>Adrenal glands</td>
<td>0</td>
<td>.525</td>
<td>300</td>
</tr>
<tr>
<td>Other tissues</td>
<td>3.5</td>
<td>175</td>
<td>1.3</td>
</tr>
<tr>
<td>Total</td>
<td>100.0</td>
<td>5000</td>
<td>---</td>
</tr>
</tbody>
</table>
Acute Control of Local Blood Flow

- Increases in *tissue metabolism* lead to increases in blood flow.
- Decreases in *oxygen availability* to tissues increases tissue blood flow.
- Two major theories for local blood flow are:
  1) *The vasodilator theory*
  2) *Oxygen demand theory*
Effect of Tissue Metabolic Rate on Tissue Blood Flow

![Graph showing the relationship between tissue metabolism and blood flow. The graph indicates that as the rate of metabolism increases, the blood flow also increases. There is a normal level point marked on the graph.](image)
Effect of Tissue Oxygen concentration on Blood Flow

Tissue Oxygen Concentration \(\downarrow\)
Blood Flow

Blood flow (x normal)

Arterial oxygen saturation (per cent)

100 75 50 25
Relationship between Pressure, Flow, and Resistance

- $F = \Delta P / R$

- Flow ($F$) through a blood vessel is determined by:
  1) The *pressure difference* ($\Delta P$) between the two ends of the vessel
  2) *Resistance* ($R$) of the vessel
Vasodilator Theory for Blood Flow Control

Local Vasodilators: Adenosine, CO2, Lactic acid, ADP compounds, Histamine, K+ ions, H+ ions, Prostacyclin, Bradykinin, and Nitrous oxid (NO)
Oxygen Demand Theory for Blood Flow Control

TISSUE METABOLISM
OR
OXYGEN DELIVERY TO TISSUES

TISSUE OXYGEN CONCENTRATION

ARTERIOLE RESISTANCE

BLOOD FLOW
Autoregulation of Blood Flow

Autoregulation - ability of a tissue to maintain blood flow relatively constant over a wide range of arterial pressures.
Blood Flow Autoregulation Theories

- **Metabolic theory** suggests that as arterial pressure is decreased, oxygen or nutrient delivery is decreased resulting in release of a vasodilator.

- **Myogenic theory** proposes that as arterial pressure falls the arterioles have an intrinsic property to dilate in response to decreases in wall tension.

- Certain tissues have *other mechanisms* for blood flow control the kidneys have a feedback system between the tubules and arterioles and the brain blood flow is controlled by carbon dioxide and hydrogen ion conc.
Laplace's Law: Myogenic mechanism

TENSION = PRESSURE x RADIUS
(dynes/cm) (dynes/cm²) (cm)

(to maintain tension constant)

UP PRESSURE → UP TENSION → DOWN RADIUS

UP PRESSURE → UP TENSION → DOWN RADIUS

DOWN PRESSURE → DOWN TENSION → UP RADIUS

(to maintain tension constant)
Long-term Regulation of Blood Flow

- Long-term regulatory mechanisms which control blood flow are more effective than acute mechanism.

- Long-term local blood flow regulation occurs by changing the degree of vascularity of tissues (size and number of vessels).

- Oxygen is an important stimulus for regulating tissue vascularity.
Long-term Regulation of Blood Flow
Angiogenesis

- Angiogenesis is the growth of new blood vessels.

- Angiogenesis occurs in response to angiogenic factors released from:
  1) ischemic tissue
  2) rapidly growing tissue
  3) tissue with high metabolic rates

- Most angiogenic factors are **small peptides** such as vascular endothelial cell growth factors (VEGF), fibroblast growth factor (FGF), and angiogen.

- Example of angiogenesis is **Retrolental Hyperplasia**
Humoral Regulation of Blood Flow

- **Vasoconstrictors**
  - Norepinephrine and epinephrine
  - Angiotensin
  - Vasopressin
  - Endothelin

- **Vasodilator agents**
  - Bradykinin
  - Serotonin
  - Histamine
  - Prostaglandins
  - Nitric oxide
Blood Flow: Skeletal Muscle Regulation

- Muscle blood flow can increase tenfold or more during physical activity as vasodilation occurs
  - Low levels of epinephrine bind to $\beta$ receptors
  - Cholinergic receptors are occupied
- Intense exercise or sympathetic nervous system activation result in high levels of epinephrine
  - High levels of epinephrine bind to $\alpha$ receptors and cause vasoconstriction
  - This is a protective response to prevent muscle oxygen demands from exceeding cardiac pumping ability
Arteriole Resistance: Control of Local Blood Flow

(a) Active hyperemia

↑ Tissue metabolism

↑ Release of metabolic vasodilators into ECF

Dilation of arterioles

↓ Resistance creates ↑ blood flow

O₂ and nutrient supply to tissue increases as long as metabolism is increased

(b) Reactive hyperemia

↓ Tissue blood flow due to occlusion

Metabolic vasodilators accumulate in ECF

Dilation of arterioles, but occlusion prevents blood flow

Remove occlusion

↓ Resistance creates ↑ blood flow

As vasodilators wash away, arterioles constrict and blood flow returns to normal
Blood Flow: Brain

- Blood flow to the brain is constant, as neurons are intolerant of ischemia
- Metabolic controls – brain tissue is extremely sensitive to declines in pH, and increased carbon dioxide causes marked vasodilation
- Myogenic controls protect the brain from damaging changes in blood pressure
  - Decreases in MAP cause cerebral vessels to dilate to insure adequate perfusion
  - Increases in MAP cause cerebral vessels to constrict
Blood Flow: Brain

- The brain can regulate its own blood flow in certain circumstances, such as ischemia caused by a tumor.
- The brain is vulnerable under extreme systemic pressure changes.
  - MAP below 60mm Hg can cause syncope (fainting).
  - MAP above 160 can result in cerebral edema.
Blood Flow: Skin

- Blood flow through the skin:
  - Supplies nutrients to cells in response to oxygen need
  - Aids in body temperature regulation and provides a blood reservoir

- Blood flow to venous plexuses below the skin surface:
  - Varies from 50 ml/min to 2500 ml/min, depending upon body temperature
  - Is controlled by sympathetic nervous system reflexes initiated by temperature receptors and the central nervous system
Blood flow in the pulmonary circulation is unusual in that:

- The pathway is short
- Arteries/arterioles are more like veins/venules (thin-walled, with large lumens)
  - They have a much lower arterial pressure (24/8 mm Hg versus 120/80 mm Hg)
- The autoregulatory mechanism is exactly opposite of that in most tissues
  - Low oxygen levels cause vasoconstriction; high levels promote vasodilation
  - This allows for proper oxygen loading in the lungs
Blood Flow: Heart

- Small vessel coronary circulation is influenced by:
  - Aortic pressure
  - The pumping activity of the ventricles
- During ventricular systole:
  - Coronary vessels compress
  - Myocardial blood flow ceases
  - Stored myoglobin supplies sufficient oxygen
- During ventricular diastole, oxygen and nutrients are carried to the heart
Thank You