SABS I: Vascular Physiology

ARTERIES & ARTERIOLES

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II. Arteries and Arterioles

A. Fundamental Facts

1. A high arterial pressure is required to provide adequate blood flow to the tissues.
2. The pressure in the arteries at a given point in time depends largely on the volume of blood in the arteries and arterial compliance.

II. Arteries and Arterioles

A. Fundamental Facts

3. The total peripheral resistance is determined primarily by the extent to which the arterioles are constricted.
4. Under most conditions, blood flow is matched to the changing metabolic needs of tissues by changes in arteriolar diameter.
5. Arteriolar diameter, total peripheral resistance, and tissue blood flow is determined by local and extrinsic control mechanisms.

II. Arteries and Arterioles

B. Pressure in the Arterial System

1. Importance of pressure

- If too low: inadequate tissue perfusion → hypoxia → necrosis, death
- If too high: vessel damage, stroke, atherosclerosis

2. Regulated by the CNS and renal function

II. Arteries and Arterioles

B. Pressure in the Arterial System

3. Effect of compliance (C) and volume (V) on pressure

- $C=\Delta V/\Delta P$
- Compliance decreases with age
- $\Delta P=\Delta V/C$

4. Intermittent input to continuous output

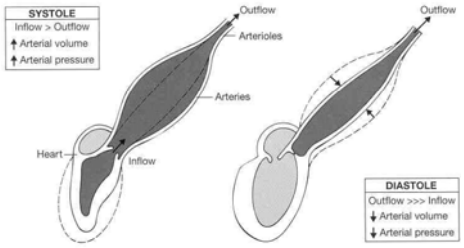
II. Arteries and Arterioles

B. Pressure in the Arterial System

5. Arterial pressures

- Systolic pressure (P_{sys}): highest pressure during ventricular ejection or systole
- Diastolic pressure(P_{dias}): lowest pressure during ventricular relaxation or diastole

Arterial Pressures

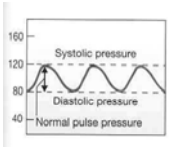


II. Arteries and Arterioles

B. Pressure in the Arterial System

5. Arterial pressures

- pulse pressure (P_p): P_{sys}- P_{dias}



- Mean arterial pressure (MAP): average pressure over one or more complete heart cycles

II. Arteries and Arterioles

B. Pressure in the Arterial System

6. Measurement and estimation of arterial pressures

- Direct measurement by arterial cannulation
  - invasive
  - requires use of transducer and amplifiers
  - most accurate

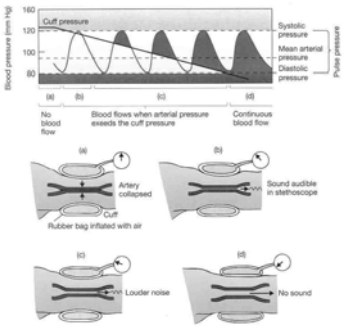
II. Arteries and Arterioles

B. Pressure in the Arterial System

6. Measurement and estimation of arterial pressures

- Auscultatory method
  - non-invasive
  - can be done with automated system
  - accuracy within 10% of direct measurements when properly performed
  - Subject to considerable error due to anxiety (white coat hypertension) or improper methodology

Ausculatory Method



II. Arteries and Arterioles

B. Pressure in the Arterial System

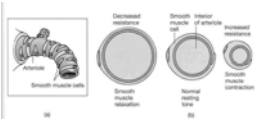
6. Measurement and estimation of arterial pressures

- Estimation of mean arterial pressure (MAP)
  - $P_{dias}+1/3(P_p)$
  - at resting heart rate
  - ~2/3 of heart cycle occurs during diastole

II. Arteries and Arterioles

C. Total Peripheral Resistance

1. Definition: total vascular resistance of the peripheral circulation (aorta back to heart)
2. Major site of resistance: arterioles and small arteries
3. Arteriolar tone: effect on resistance



II. Arteries and Arterioles

C. Total Peripheral Resistance

1. Arteriolar tone: effect on resistance

	r	r^4	R
Control	1.0	1.00	1.0
50% constriction	0.5	0.06	16
50% dilation	1.5	5.06	0.2

II. Arteries and Arterioles

D. Short-term Regulation of Arteriolar Resistance

1. Examples

- Autoregulation: the maintenance of nearly constant organ blood flow over a wide range of perfusion pressures
- Reactive hyperemia: increase in blood flow after a period of deprivation

II. Arteries and Arterioles

D. Short-term Regulation of Arteriolar Resistance

1. Examples

- Functional hyperemia: increase in blood flow related to an increase in tissue metabolism
  - Skeletal muscle: 8-20X increase with exercise
  - Intestine: 1.5-2.0X increase during absorption (postprandial hyperemia)
  - Cardiac muscle: 5-6X increase
  - Cerebral blood flow can be increased 20-40%

II. Arteries and Arterioles

D. Short-term Regulation of Arteriolar Resistance

1. Examples

- Dilation of collateral arteries
- Increase in skin blood flow during heat stress

As tissue needs change, how are transportation and exchange altered?

II. Arteries and Arterioles

D. Short-term Regulation of Arteriolar Resistance

2. Major control mechanisms

- Local control: regulation at the level of tissue and vessel
- Extrinsic control: regulation by mechanisms/factors external to the local tissue
  - Neural (*primarily by the sympathetic nervous system)
  - Humoral

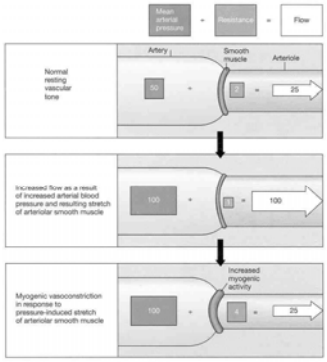
II. Arteries and Arterioles

D. Short-term Regulation of Arteriolar Resistance

Local Control Mechanisms

- Myogenic vascular control: response of the vessel to a change in distending pressure
  - Ca^{+2} channels in vascular smooth muscle cells are sensitive to stretch
  - ↑P → activation, vasoconstriction
  - ↓P → relaxation, vasodilation

Myogenic Vascular Control



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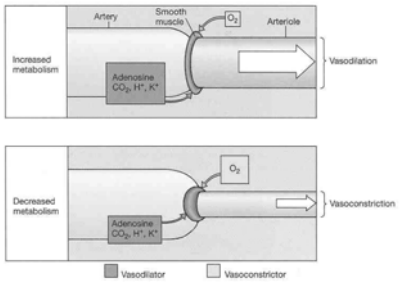
D. Short-term Regulation of Arteriolar Resistance

Local Control Mechanisms

- Metabolic vascular control: a change in arteriolar diameter associated with a change in metabolism.
  - ↑metabolism → ↑ adenosine, ↑ K^+, ↑ CO_2, ↑ H^+, ↓O_2
  - ↓ metabolism → ↓ adenosine, ↓ K^+, ↓ CO_2, ↓ H^+, ↑ O_2

Metabolic Vascular Control



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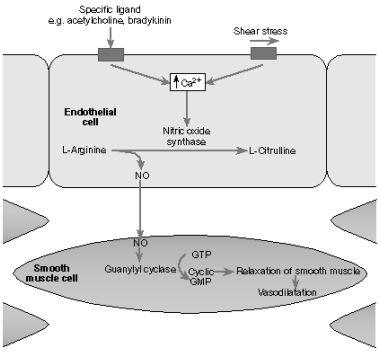
D. Short-term Regulation of Arteriolar Resistance

Local Control Mechanisms

- Flow-dependent diameter changes:
  - ↑shear stress → ↑Nitric oxide (NO) production (Endothelium)
  - ↑NO → ↑cGMP production → smooth muscle relaxation

Flow-dependent Vascular Control



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D. Short-term Regulation of Arteriolar Resistance

Local Control Mechanisms

- Chemical mediators of inflammation
  - Histamine
  - Bradykinin
  - Serotonin
  - Prostaglandins
  - Leukotrienes

II. Arteries and Arterioles

D. Short-term Regulation of Arteriolar Resistance

Extrinsic Control Mechanisms

- Neural Control
  - Innervation: Sympathetic nervous system
    - Exceptions: vessels in heart and brain have limited if any innervation

(Note: Innervation of vessels by parasympathetic neurons occurs only in a few organs and has minimal effect on total peripheral resistance)

II. Arteries and Arterioles

D. Short-term Regulation of Arteriolar Resistance

Extrinsic Control Mechanisms

- Neural Control
  - Neurotransmitter: norepinephrine
  - Receptors: alpha adrenergic receptors
  - Basal Tone: sympathetic nerve activity can be increased and decreased from resting state; resulting in vasoconstriction and vasodilation.

II. Arteries and Arterioles

D. Short-term Regulation of Arteriolar Resistance

Extrinsic Control Mechanisms

- Hormonal Control
  - Renin-angiotensin system: angiotensin II is one of the most potent vasoconstrictors. This system can be important in high blood pressure.

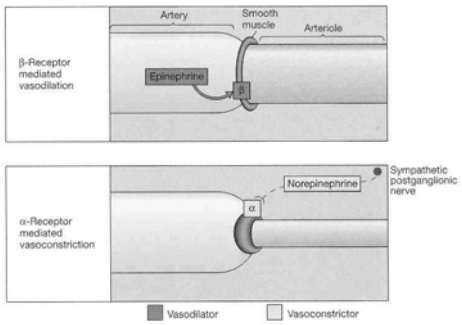
II. Arteries and Arterioles

D. Short-term Regulation of Arteriolar Resistance

Extrinsic Control Mechanisms

- Hormonal Control
  - Epinephrine
    - Released from the adrenal medula upon stimulation of the sympathetic nervous system.
    - Receptors: beta adrenergic receptors located primarily on vessels in heart, skeletal muscle, and liver.
    - Receptor activation results in relaxation/vasodilation of arterioles and venules

Receptor-mediated Vascular Control



II. Arteries and Arterioles

Summary of effects of alpha and beta adrenergic receptor activation in response to increased sympathetic nerve activity (SNA)

- ↑SNA → ↑ release of norepinephrine (NE) and epinephrine (Epi)
- ↑NE → vasoconstriction and ↑ resistance in most organs (not heart or brain)
- ↑Epi → vasodilation in heart and opposes activity of NE in skeletal muscle

II. Arteries and Arterioles

E. Long-term Regulation of Arteriolar Resistance

1. Changes in tissue vascularity (number of vessels)
   - Angiogenesis: formation of new capillaries
   - Arteriolar rarefaction: loss of arterioles
   - Arteriolar proliferation
2. Changes in vessel size (inner diameter)
   - Arteriogenesis: structural development of existing vessels to become new or larger arteries.
   - Collateralization: structural development of existing vessels which provide alternative blood supply route after occlusion of another artery