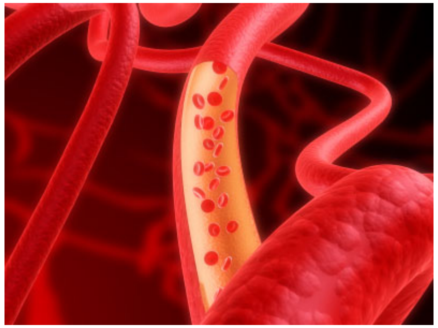
CARDIOVASCULAR PHYSIOLOGY 2



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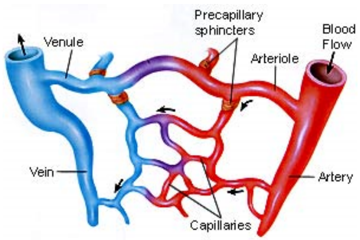
OBJECTIVES OF THIS LECTURE

- Describe the various components of the vasculature
- Describe the unique characteristics of the different types of vessels in terms of both structure and function
- Describe the changes in pressure, velocity of flow and cross-sectional area that are seen across the vasculature
- Understand the use of the Fick principle and the indicator dilution technique in measuring cardiac output.
- Understand how different indicators can be used to measure different volumes

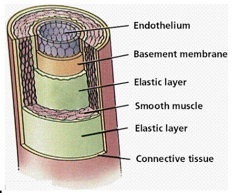
VASCULATURE

Blood travels in a circular pattern through the vasculature
heart → arteries → arterioles → capillaries → venules → veins → heart



ARTERIES

- conduct blood away from heart to tissues
- aorta – internal diameter ±12.5mm, wall thickness ±2mm
- average artery ±4mm in diameter
  ±1mm wall thickness
- walls contain large amounts of elastic tissue –
  withstand relatively high pressures
  stretched during systole, recoil during diastole



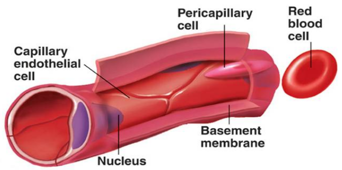
- function – to transport blood under high pressure to tissues i.e. act as pressure reservoir
- low compliance – small increases in blood volume cause large increases in pressure

ARTERIOLES

- conduct blood from small arteries to capillaries
- finest division of arterial tree
- diameter 30-80μm, wall thickness about 6μm
- walls have little elastic tissue and more smooth muscle - control release of blood into capillaries
- contractile activity is regulated mainly by ANS and by local chemical agents and hormones
- major site of resistance to blood flow = resistance vessels

CAPILLARIES

- smallest and most numerous vessels – 10 to 40 billion
- 5-10μm in diameter
- walls 0.5-1μm thick -
  - single layer of endothelial cells & a basement membrane
  - permeable to small molecular substances
  - basement membrane gives rigidity
  - no smooth muscle or elastic tissue



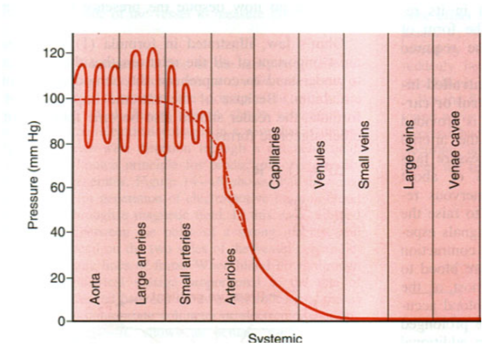
CAPILLARIES

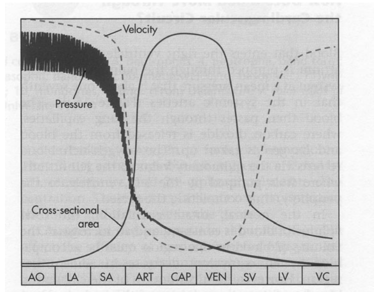
- function - exchange gases, fluid, nutrients, electrolytes, hormones between blood & interstitial fluid
- metabolically active tissues have more capillaries
- >500m^2 of capillaries in systemic circulation
- 90m^2 in lungs
- average velocity of blood flow is 0.1mm/sec

VENULES/ VEINS

- venules collect blood from capillaries
- coalesce to form veins
- venule ±30-40μm in diameter
- vein 5mm in diameter
- low resistance vessels - transport blood back to heart, have one-way valves
- walls thin – venules little or no smooth muscle but veins muscular - contract or expand
- walls have high compliance which allows them to serve as a reservoir of blood (60-65%) - capacitance vessels

PRESSURES IN VESSEL TYPES

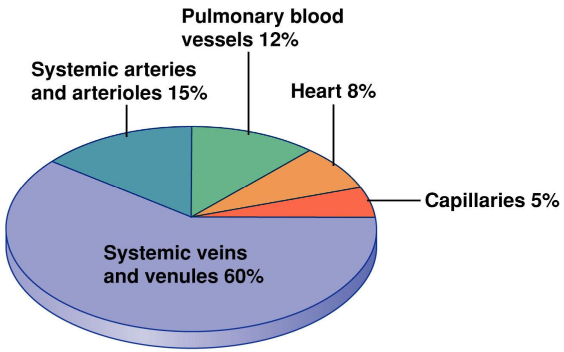




From Berne & Levy: Principles of Physiology

- **pressures – fall progressively**
- **inverse relationship between velocity & cross-sectional area – max c/s area & slowest flow in capillaries**

VOLUMES OF BLOOD IN THE CIRCULATION

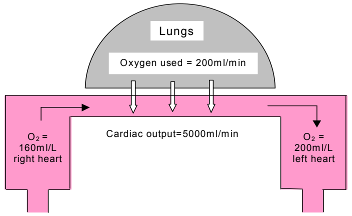


LYMPHATIC VESSELS

- **lymphatic system - an accessory route by which fluid can flow from the interstitial spaces into the blood.**
- **± 3 litres of fluid leaks out of capillaries each day into lymphatic system**
- **ultimately empties into venous system**

MEASURING CARDIAC OUTPUT

FICK PRINCIPLE



- 200ml O_2 absorbed from lungs into pulmonary blood each minute
- blood entering R heart O_2 concentration = 160ml/L
- blood leaving L heart O_2 concentration = 200ml/L

  ∴ each litre picks up 40ml O_2
- so 5 one-litre portions must pass through the pulmonary circulation each minute to absorb 200mls O_2

∴ 5L flows through pulmonary circulation each minute

= cardiac output

$$\text{C.O.} = \frac{O_2 \text{ absorbed per min by lungs (ml/min)}}{\text{arteriovenous } O_2 \text{ difference (ml/L of blood)}}$$

= 200/ (200-160)

= 5L / min

Total blood volume = 5L

TBV is pumped around body each minute

INDICATOR DILUTION TECHNIQUE

- dye injected into large vein or right atrium
- passes through right side of heart, lungs & left side of heart into arterial system
- plot a curve of dye concentration in a peripheral artery over time
- calculate mean concentration of dye & duration of this concentration
- the greater the blood flow (cardiac output), the greater the dilution of the injected dye

For example:
5mg dye injected
average dye concentration in artery 0.25mg/dl
duration of average value 12secs

then ...
need 20 1-deciliter portions to carry 5mg of dye in 12secs (5/0.25 = 20)
CO = 20 decilitres/12sec = 2L/12sec = 10L/min
So,

$$\text{CO (ml/min)} = \frac{\text{mg of dye injected} \times 60}{\text{average conc dye/ml} \times \text{duration of average value in sec}}$$

= 5 x 60 / 0.0025 x 12
= 10L/min

In an average 70kg individual

TBW = 42L

- 28L (2/3) intracellular
- 14L (1/3) extracellular
  - 9L interstitial
  - 5L blood
    - 3L plasma
    - 2L red blood cells

INDICATOR DILUTION TECHNIQUES FOR MEASURING OTHER FLUID VOLUMES

A known amount of indicator (I) is allowed to distribute throughout the unknown volume (V). When complete mixing has occurred, a sample is withdrawn from the volume and the concentration of the indicator (C) is determined. Using the equation

V = I/C, the volume can be calculated.

- Indicator must disperse evenly in compartment
- Indicator must disperse only in compartment being measured
- Indicator must not be metabolised or excreted

Different indicators are used to measure different volumes.

- plasma volume - ^{131}I labelled albumin
  - Evans Blue dye
- extracellular volume – inulin
- interstitial fluid volume = extracellular volume – plasma volume
- total body water - radioactive water (tritium, $^{3}H_2O$)
  - heavy water (deuterium, $^{2}H_2O$)
- red cells - radioactive chromium (^{51}Cr)

An example……….

100mg of dye in 5ml of saline is injected into a subject. Adequate time is allowed for the dye to combine with the protein albumin in plasma.

A blood sample taken 10 minutes after injection of the dye contains 33.3μg dye/ml of plasma.

What is the plasma volume?

Volume = I/C

= 100mg/33.3μg/ml

= 100mg/33.3x10^{-3}mg/ml

= 3003mls