Pressure, Blood Flow, Compliance and Resistance

By

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Learning Objectives

- Describe the interrelationship of pressure, flow and resistance.

- Describe the laminar blood flow and causes of its turbulence .
- Define vascular distensibility and compliance and identify the difference between arterial and venous compliance
- Identify the standard units of BP measurements

- Identify the units for measurements of resistance
- Relate these factors to control of arterial pressure

Arteries

Away from the heart

Thick, muscular walls

Very elastic

Arterioles

Diameter varies in response to neural stimuli and local chemical influences.

Capillaries
Consist of a single tunica interna
Gas, nutrient, and waste exchange
Brain capillaries
Blood-brain barrier
Capillary beds
Precapillary sphincter
Shunting of blood
Digestion

Venous System

Toward the heart

Venules—porous—free movement of fluids and white blood cells.

Veins

3 tunics—but thin

Venous valves

Varicose veins

Incompetent valves

hemorrhoids

- Maintenance of Blood Pressure
  - – Neural control
    - Shunting and vasoconstriction.
  - – Vasomotor center
  - – Baroreceptors
    - Carotid and aorta
  - – Chemoreceptors
  - – Higher brain centers
  - – Hormones
    - Catecholoamines
    - Atrial natrietic peptide
    - ADH
  - – Alcohol
  - – Histamine—other vasodilators

Atherosclerosis

Damage to the tunica interna

Viral

Bacterial

Hypertension

Reinjury

Inflammation

LDLs—”bad cholesterol”

Foam cells

Fatty streak stage

Arteriosclerosis

Hypertension

Stroke

Heart attack

Coronary bypass

Angioplasty

tPA—tissue plasminogen activator

Clot buster

HDL—removes cholesterol from vessel walls.

Arteries

Aorta—largest artery

Ascending
Descending
Right and left coronary arteries
Common carotid arteries—branch to form internal and external carotids

External—supply tissues of the head except the brain and orbits.

Internal—supply the orbits and most of the cerebrum.

Vertebral arteries—branch to the cervical spinal cord, neck, cerebellum, pons, and inner ear.

Veins to Know

Know the veins on the preceding chart plus:

The veins of the arms—cephalic, axillary, brachial, radial, ulnar.

The veins of the legs—external iliac, femoral, popliteal, anterior tibial, posterior tibial, great saphenous vein, hepatic portal vein.

The great saphenous vein is a superficial vein. Connect with many of the deep veins of the legs and thighs.
Be able to identify these veins on a diagram. Also know the locations served by these arteries.

Basic Circulatory Function

- Rate of blood flow to tissues changes based on need.

  - *e.g.*, during exercise, blood flow to skeletal muscle increases.

- In most tissues, blood flow increases in proportion to the metabolism of that tissue.

- Cardiac output is mainly controlled by venous return.
- Generally, arterial pressure is controlled independently of local

blood flow or cardiac output control.

Normal Blood Pressures in Vasculature

Ohm's Law Applied to Blood Flow

Blood Pressure

BP is the force exerted by the blood against the vessel wall.

- Typically measured as mm Hg.
- *E.g.*, 100 mm Hg is the force needed to push a column of Hg to a level of 100 mm.

Resistance

- Resistance is the impediment to blood flow.
- Not measured directly, but determined from pressure and flow measurements.

  - If ΔP = 1 mm Hg and F = 1 ml/sec, then R = 1 PRU (peripheral resistance unit).
  - In the adult systemic circulatory system, ΔP = 100 mm Hg, and F = 100 ml/sec; so R = 1 PRU.

- In the pulmonary system, ΔP = 14 mm Hg and F = 100 ml/sec; so R = 0.14 PRU.

Conductance

Conductance is the opposite of resistance:

Conductance = 1/resistance

Conductance may be easier to conceptualize than resistance and is sometimes easier to use in calculating the total resistance of parallel vessels.

Vessel Diameter and Blood Flow

– Changes in Resistance

Laminar Flow

Poiseuille's Law

Turbulant Flow

Adding Resistance in Series and Parallel

Effect of Viscosity on Resistance and Blood Flow

Summary of Blood Flow Physics

Vascular Distensibility

Vascular distensibility i s the ability of the v ascular system to exp and with increased pr essure, which

-

Increases blood blow as pressure increases.

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In arteries, averages o ut pulses.

-

Allows veins to act as reservoirs

Calculate Distensibility

- Fractional increase in volume per rise in pressure:

Vascular =

$$\frac{\text{Increase in Volume}}{\text{Incr in P x orig Vol}}$$

Distensibility

If 1mm Hg increases a vessel from 10mm to 11mm, the distensibil ity would be 0.1 per mm Hg or 10% per mm Hg.

Distensibility of Arteries and Veins

Artery walls are much stronger than those of veins and thus, much *less* distensible.

The larger distensibility of veins allows them to act as blood reservoirs.

Vascular Compliance

The quantity of blood that can be stored in a particular portion of the vasculature for a rise in pressure:

Vascular compliance =
Increase in volume

Increase in pressure Compliance = distensibility x volume

Veins

- Can distend to hold large amounts of blood.
- Contraction of skeletal muscles can constrict the veins and propel blood to the heart and increase cardiac output.
- The contraction-induced constriction and the valves prevent the venous pressure from building up on the feet of standing adults.

Veins as Blood Reservoirs

> 60% of blood in the circulatory system is in the veins. When blood is lost, sympathetic stim ulation causes veins to constrict and make up for the lost blood. Conversely, veins can distend

to hold excess blood if too much is given during a transfus ion.

Blood Volume

Distribution of H_2O within the body:

Intracellular compartment:

2/3 of total body H_2O within the cells.

Extracellular compartment:

1/3 total body H_2O.

80% interstitial fluid.

20% blood plasma.

Maintained by constant balance between H_2O loss and gain.

Capillaries

Exchange nutrients an d waste with tissues.

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10 billion capillaries w
ith 500 – 700 m^2
total surface area in
whole body.

THANK YOU