Hemodynamics

Chapter 18

Hemodynamics
- The study of blood flow in the body's circulatory system
- Flow is the volume of moving blood at a specific time:
  - measured in units such as liters/min or ml/s
  - or a volume divided by time

Hemodynamics
- Velocity is the speed the fluid is moving:
  - determines how much
  - usually measured in distance/time
  - cm/sec, m/s
- there are 3 forms of flow:
  - pulsatile
  - phasic
  - steady

Pulsatile Flow
- Occurs when blood moves through the vessels in a variable velocity:
  - accelerates and decelerates as a result of cardiac contractions.
- Occurs most often in the arterial system

Phasic Flow
- Occurs when blood moves through the vessels in a variable velocity:
  - accelerates and decelerates as a result of respiration.
- Occurs most often in the arterial system

Steady Flow
- Occurs when blood moves through the vessels at a constant speed and velocity:
  - there is no acceleration and deceleration as a result of cardiac contractions or respirations.
  - Is always present, is located in the venous system
Laminar Flow

Vs.

Turbulent Flow

Laminar Flow

- The root lamina means layer
- It exists when the flow is streamlined and parallel
- Is commonly found in normal physiologic vessels
- Two types
  - Plug flow
  - Parabolic flow

Plug Flow

- Is where all the layers are flowing in the same direction at the same time
- Seldom occurs naturally

Parabolic Flow

- Looks like a bullet shape with the highest velocities in the center and the slowest adjacent to the vessel wall
- This is how blood normally flows

Turbulent Flow

- Presents as a chaotic flow pattern where the unidirectional flow patterns are no longer present
- Often referred to as eddy currents
- Associated with pathology
- Converts flow energy to sound or vibrations
- Sound conversion results in a murmur or bruit
- Vibration conversion results in a thrill

Energy Gradient

- Blood flows from one location to another when the energy of the fluid is greater in one area than another
- Think of it as a pressure gradient
- Forms of energy associated with blood include kinetic, pressure and gravitational
- Total energy within the circulation is the sum of all three

Kinetic

- Associated with moving objects
- Determined by the objects mass and the speed in which it moves
- Think of it heavy objects that are moving fast have a lot of energy
- While light objects moving at the same speed has less kinetic energy
Pressure Energy

• A form of potential energy
• It is the ability to do work
• The major form of energy in the circulatory system
• Provides blood to flow by overcoming the resistance to stand still or resist

Gravitational Energy

• Much like kinetic energy this is a form of stored energy
• All elevated objects have stored gravitational energy that can do work
• Let's use a blood in a leg artery as an example.
• If the patient stands what happens?
• If the patient lies down what happens?

How is energy lost in circulation?

• Energy is initially produced by the heart in the left ventricle during systole
• As it flows through the circulation three factors affect the flow resulting in energy loss
  – Viscous
  – Friction
  – Inertial

Viscous energy loss

• Viscosity what is it?
• The higher the viscosity the greater the energy loss.
• It takes more energy to overcome the stickiness or thickness of the blood.
• It is measured in units of Poise.
• The hematocrit is the % of RBC’s in blood
  – Decrease the HCT and reduce the viscosity of blood

Friction loss

• This is the conversion of fluid energy to heat.
• Occurs as blood cells rub against each other
• Or when they slide across the wall of the vessels

Inertial Energy Loss

• Relates to the resistance of fluid to change in velocity
• Energy is lost anytime there is a change in the speed of fluid
• Occurs during 3 events
  – Pulsatile flow
  – Phasic flow
  – Velocity changes
Stenosis

- What is it?
- It can change the direction of flow as it enters or exits the restriction.
- It can increase the velocity in the stricture
- Creates post stenotic turbulence
- Creates pressure gradients
- Can convert pulsatile flow to steady flow

Pressure – Flow relationships

- Vessel elasticity cardiac pulsatility and composition of blood contribute to the complex nature of flow in vessels
- A more simplified way of understanding this is
  \[ \text{Pressure gradient} = \text{flow} \times \text{resistance} \]

Pressure – Flow relationships

Pressure gradients increase
- Flow increases
- Resistance increases
Flow increases when
- Pressure gradient increases
- Resistance decreases

Ohm’s Law

- While this has nothing to do with blood flow how electricity flows in a wire has some similarity

  \[ \text{Pressure gradient} = \text{flow} \times \text{resistance} \]
  \[ \text{Voltage} = \text{current} \times \text{resistance} \]

Venous Hemodynamics

- Veins are thin-walled and easily collapsible
- Only partially filled and have low pressure
- Normally they are a flattened hourglass shape

Venous Hemodynamics

- They are a low resistance vessel similar to arteries
- Veins adapt to increased flow variations by expanding when needed to maintain the same low resistance
- This expansion decreases resistance and increases flow to the heart
- They also empty quickly and return to normal shape
Pressure volume relationships

- Transmural pressure determines the shape of the veins and the volume of fluid that can flow through it.
- When low they appear as a hourglass.
- As pressure increases the shape changes to an oval, then round.
- Venous pressure changes dramatically only when they are stretched beyond their max point.

Hydrostatic pressure

- Is related to the pressure or weight of blood pressing on a vessel.
- Measured at separate heights.
- Measured the same as BP in mmHg.
- Is clinically related to the patients condition.
- Measurements can change depending on where you take the measurement and the position of the patient.

Supine measurements

- When lying down all parts of the circulatory system has a hydrostatic pressure of zero.
- This means any measurement taken anywhere in the system reflects the true pressure in that area.

The artery BP in the arm is 120 mmHg supine

- What is the hydrostatic pressure in the entire arterial circulation?
  - It is 0 mmHg
- What is the arterial pressure at the knees?
  - It is 140 mmHg
- What is the arterial pressure in the carotid artery?
  - It is 140 mmHg

What about standing

- Everything changes when the pressure is taken in a standing patient.
- Pressure at the heart is at zero while above it has a negative pressure and below it has a higher pressure.

What about standing

- How is this expressed mathematically?
  
  Measured pressure = circulatory pressure + hydrostatic
Arterial BP at the level of the heart in a standing patient is 150 mmHg

- Hydrostatic pressure in all areas of circulation
- The Art. BP in the feet
- What about the waste

Arterial BP at the level of the heart in a standing patient is 150 mmHg

- Now lets determine the knee area
- The arm at the level of the heart
- That pressure in the wrist when held at the level of the ear

The Effects of Respirations on Venous Pressure

- Has a pronounced effect because the pressure in the venous system is low
- Respirations also alter the pressure in both the abdominal and thoracic cavities
- Creates pressure gradient differences

Inspiration

- The diaphragm moves caudal into the abdominal cavity creating a negative pressure in the thoracic cavity
- Produces a suction like effect
- Increases flow from the SVC and IVC increase
- Flow into the abdominal cavity decrease

Expiration

- The diaphragm moves up increasing chest pressure and decreasing abdominal pressure
- Flow from the SVC and IVC decrease
- Flow from the lower extremities into the abdominal cavity increase due to the lower pressure