



## Professional Ultrasound Services

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### Hemodynamics: The Movement of Blood

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1. Definition: Hemodynamics relates the forces and motion of blood flow and the science concerned with the study of the circulation of blood.
  - a. Function of Arterial Circulation: the sole function of the circulatory system is transportation. It carries to and from all living cells:
    - i. Oxygen, nutrients
    - ii. Metabolic wastes
    - iii. Hormones, antibodies, leukocytes
    - iv. Medications
    - v. Heat
  - b. Forces:
    - i. Cardiac pump
    - ii. Gravity
    - iii. Hydrostatic Pressure
    - iv. Pressure gradient
  - c. Blood:
    - i. Nature of blood
      1. Viscosity
      2. Inertia
    - ii. Volume of blood
  - d. Motion
    - i. Size of blood vessel
    - ii. Condition of blood vessel
      - a. Smoothness of lumen
      - b. Elasticity of muscular layer (tunica media)
    - iii. Destination of blood
2. Arterial flow characteristics: Doppler display
  - a. Pulsatility
  - b. Flow velocity: normal PSV values in human typically <140cm/sec.
    - i. Elevated - may indicate arterial stenosis
  - c. Resistivity (Flow resistance patterns): a measure of the ease with which blood can flow into human tissue.
    - i. Varies with type of tissue and metabolic rate
    - ii. May increase with stiffening of artery walls
    - iii. Increased in certain types of pathology such as renal disease, intrauterine growth restriction (IUGR).
  - d. Arterial flow patterns

- i. Laminar: normal flow in straight arteries. Parallel stream lines with higher velocities in center, lower velocities toward vessel wall.
  - ii. Flow disturbance: alteration in parallel stream lines but still in forward direction.
  - iii. Turbulence: a random, chaotic flow pattern with breakdown of parallel stream lines and flow in many directions.
  - iv. Post-stenotic changes: classical changes systolic and diastolic velocities and waveform shape due to hemodynamic changes associated with a significant reduction in the luminal diameter of an artery.
  - v. Phasicity
    - 1. Monophasic: unidirectional waveform; all flow forward
    - 2. Biphasic: bi-directional waveform; forward and reverse
    - 3. Triphasic: tri-directional waveform; forward, reverse, forward
- 3. Venous flow characteristics: Doppler display**
- a. Normal venous Doppler signals possess the following characteristics:
    - i. Spontaneity: Signals are automatically obtained at the site at the proper sites.
    - ii. Phasic with respiration: Flow velocity varies with stages of respiration. During inspiration venous signals stop, during expiration venous signals return in an augmented state.
    - iii. Augmentation: Distal compression of the veins result in increased flow volume and velocities in the more proximal vessel.
    - iv. Competency: Proximal compression or a Valsalva maneuver will not cause retrograde flow toward the foot.
    - v. Pulsatility: Normally there is not pulsatility in venous Doppler signals. When present, pulsatile venous signals indicate venous or pulmonary hypertension, chronic heart failure and excessive fluid and/or the presence of an arterio-venous fistula. Blood flows back to the heart with little resistance as it moves from smaller to larger veins. Energies from cardiac activity can be transmitted to veins under certain circumstances due to reflected pressure and flow alterations. This produces an alteration in the venous Doppler signal and may be seen under the following circumstances:
      - 1. In veins in close proximity to the right atrium
      - 2. In the vena cava
      - 3. In well hydrated patients (the large volume of blood distend the venous system)
      - 4. In patients with congestive heart failure (CHF)
  - b. Effects of respiration: Respiratory activity has a definite influence on venous flow. During inspiration there is a decrease in intra-thoracic pressure and an increase in intra-abdominal pressure due to diaphragmatic movement. The increased blood pressure on vena cava impedes flow from the lower extremities. During

expiration there is an increase in intra-thoracic pressure and a decrease in intra-abdominal pressure. The release of the inspiratory pressure on the vena cava allows lower extremity venous blood to flow freely back toward the heart. It is this relationship that makes the Valsalva maneuver so useful when performing venous studies.

- Inspiration =  $\uparrow$  pressure =  $\downarrow$  flow
- Expiration =  $\downarrow$  pressure =  $\uparrow$  flow
- Valsalva =  $\uparrow$  pressure =  $\downarrow$  flow
- “Sniff” =  $\uparrow$  pressure =  $\downarrow$  flow

#### 4. Dynamics of Blood Flow (Read Chapter 12 Hemodynamics)

- a. Anatomic Considerations
  - i. Arteries and arterioles
  - ii. Capillaries
- b. Principles of Arterial Flow Dynamics
  - i. Laminar flow and turbulence
  - ii. Average velocity
  - iii. Poiseuille-Hagen Formula
  - iv. Viscosity and resistance
  - v. Law of Laplace
  - vi. Velocity and flow of blood
  - vii. Arterial pressure
  - viii. Effect of gravity
- c. Principles of Venous Flow Dynamics
  - i. Venous pressure and flow
  - ii. Thoracic pump
  - iii. Effects of heartbeat
  - iv. Muscle pump