



## Professional Ultrasound Services

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## Doppler Ultrasound

### The Doppler Effect

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#### 1. Definition

- a. History: first described by Johannes Doppler in 1848
  - i. Astronomer noted a change in light frequency based on movement of stars and galaxies toward or away from earth; red shift away from, blue shift toward the earth
- b. Change in frequency of a wave based in interaction with motion
- c. Examples of sound Doppler shifts:
  - i. Moving freight train
  - ii. Ambulance siren
- d. Demonstration with recorder and moving teacher

#### 2. Ultrasound Frequency Change

- a.  $\Delta F = \text{Doppler shift}$
- b. The change in frequency between the received ultrasound frequency and the source, or transmitted frequency .
- c.  $F_D = F_r - F_0$ ;  $F_r$  = received frequency,  $F_0$  = source frequency
- d. Value of Doppler frequency is determined by direction of movement
  - i. Higher frequency approaching the source; lower frequency moving away from source.
    1. Positive Doppler shift = movement toward
    2. Negative Doppler shift = movement away
  - ii. 5.0MHz transmitted; 5.5MHz received = +0.5 MHz Doppler shift  
**TOWARD**
  - iii. 5.0MHz transmitted; 4.5MHz received = -0.5MHz Doppler shift  
**AWAY**

#### 3. Source of Doppler Signals

- a. Uses primarily Rayleigh scattered information
  - i. Scatters from structures smaller than a single wavelength
  - ii. RBCs are 8-10 $\mu\text{m}$  in diameter
  - iii. 5.0MHz sound wave measures .31mm = 310 $\mu\text{m}$
- b. Factors affection scattered intensity
  - i. Dimension of scatterer: larger size = larger scattering
  - ii. Number of scatterers present: more RBCs = more scattering
  - iii. Difference in acoustic impedance: greater difference = greater scattering
  - iv. Frequency of incident beam: higher frequency = higher scatter

#### 4. Clinical Applications of Doppler Technology

- a. Displays movement of red blood cells
  - i. **Hemodynamics:** word derived from two Greek words meaning blood and power
  - ii. **Definition of hemodynamics:** the forces and motion of blood flow and the science concerned with the study of the circulation of blood
- b. Types of hemodynamic information provided by Doppler displays:
  - i. **Presence** of flow
  - ii. **Direction** of flow: **always** relative to the transducer
  - iii. Identification of flow **patterns:** arterial, venous, fistula, etc
  - iv. Measurements of arterial flow, i.e. **velocity.** Only with spectral Doppler display

#### 5. Conversion into velocity

- a. Raw Doppler data is **frequency** information ( $\Delta F$ )
- b. Doppler data displayed on contemporary ultrasound systems is displayed as **velocity** information.
- c. Velocity and frequency are mathematically related and can be converted using the **Doppler Formula:**

$$F = \frac{2F_0 V \cos\theta}{C}$$

$$V = \frac{F - F_0 C}{2F_0 \cos\theta}$$

$F_D$  = shifted frequency  
 $F_0$  = source frequency  
 $C$  = speed of sound in soft tissue  
 $V$  = velocity of reflectors  
 $\cos\theta$  = incident angle

### Doppler Display Formats

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#### 1. Continuous Wave

- a. Clinical Applications: vascular surgery, OB/GYN, general practice simple vascular assessment.
- b. Instrumentation: simplest form of Doppler device
  - i. In continuous wave systems, a separate crystal is used for sending and receiving. The region which is common to the ultrasonic field sent out by the transmitting transducer and the sensitive area of the receiving transducer is called the **SENSITIVITY ZONE**
  - ii. Provides a continuous, audio display of Doppler shifted frequencies.
  - iii. A transmitter continuously excites one crystal while another crystal continuously receives echoes resulting from reflection and scattering.
  - iv. Reflector and scatterers anywhere in the sensitivity zone of the transducer contribute to the Doppler signal.
  - v. Doppler signal represents velocity of all RBC's in sample area.

- c. Audio characteristics:
  - i. Presence of flow
  - ii. Flow Characteristics
    - 1. **Arterial: pulsatile:** dramatic change in audible pitch as blood moves at different velocities during cardiac cycle.
      - a. Cardiac pump creates large flow changes in both volume and velocity
      - b. "Hissing cat" sound
    - 2. **Venous: continuous or phasic:** subtle, if any, change in audible pitch over time. Constant flow, may cease in some veins during respiratory inspiration.
      - a. No cardiac pump to create energy changes. Pressure changes in the chest and abdomen cause phasicity. Leg muscle "pump" returns blood to heart from lower extremities.

## 2. Color Flow Doppler

- a. Definition: a real-time map of color-coded hemodynamic information superimposed on a gray scale anatomic image.
- b. Color characteristics:
  - i. **HUE:** the color reflected or transmitted from an object. Commonly identified by the name of the color, i.e., red, blue, green, yellow.
  - ii. **SATURATION:** the strength, or purity, of a color. Represents the amount of hue present in each pixel.
- c. Clinical Applications:
  - i. Presence or absence of flow in a particular structure
  - ii. Differentiate between vascular and non-vascular structures
  - iii. Flow direction: relative to transducer. INVERT controls can affect proper directional display.
  - iv. Color Bar: hue at top of bar represents flow TOWARD transducer; hue at bottom of bar represents flow AWAY from transducer
  - v. Flow direction: relative to a known adjacent vessel; i.e., common carotid artery vs. vertebral artery.
  - vi. Flow characteristics: venous vs. arterial
    - 2. Difference may be less obvious with color flow than with spectral Doppler
    - 3. Venous: non-pulsatile. Response to provocative maneuvers.
    - 4. Arterial: pulsatile with cardiac cycle
  - vii. Flow velocity: relative velocities displayed with color:
    - 1. Increased saturation (darker hue) = slower flow
    - 2. Decreased saturation (lighter hue) = faster flow

## 3. Pulsed (Spectral) Doppler

- a. Definition: Pulsed Doppler is an ultrasound application that allows the acquisition of Doppler signals from specific depths within the human body.

- b. **Gating:** The engineering principle that allows this selective acquisition of Doppler data from a given depth is called **gating** and it involves controlling the timing of both the transmitted pulse and the received echo information.
- c. Spectral waveform: a two-dimensional representation of blood flow (velocity and smoothness) over time.

## 2. Clinical Applications:

- a. Presence or absence of flow in a particular structure.
- b. Differentiate between vascular and non-vascular structures.
- c. Flow direction: relative to transducer. INVERT controls can affect proper directional display
- d. Flow direction: relative to a known adjacent vessel; i.e., common carotid artery vs. vertebral artery. EXAMPLES: subclavian steal, hepato-fugal flow in portal hypertension, reverse component in umbilical artery in growth restricted fetuses
- e. Flow characteristics: venous vs. arterial.
  - i. Venous: continuous, non-pulsatile, changes with respiration (phasic).
  - ii. Arterial: pulsatile with cardiac cycle
    - 1. Peak systolic (PSV)
    - 2. End diastolic (EDV)

## 2. Spectral Interpretation

- a. Spectrum Analyzer: breaks a Doppler signal down into its basic frequency components.
  - b. Fast Fourier Transform (FFT): a computer driven mathematical model that calculates all sign, velocity and amplitude components present in each Doppler signal.
  - c. Information is displayed as a real-time “graph” moving from left to right across the screen and flow display components include:
    - i. Time: represented by the horizontal (x) axis. In arterial displays, this axis is helps interpret or describe blood flow patterns during different phases of the cardiac cycle.
    - ii. Velocity: plotted on the vertical (y) axis.
    - iii. Amplitude: the relative strength of each velocity is displayed as a shade of gray
    - iv. Direction: relative to transducer
      - 1. ABOVE baseline: flow TOWARD transducer
      - 2. BELOW baseline: flow AWAY from transducer
  - d. Interpretive methodology:
    - i. Is there flow?
    - ii. What general pattern does it have, arterial or venous?
    - iii. Is it a clean spectrum or a broadened one?
    - iv. What is the predominant direction of flow? Toward, Away, or both
    - v. Measurements:
      - 1. Peak systolic velocity - PSV (cm/sec)
      - 2. End diastolic velocity – EDV (cm/sec)
- ### 3. Ratios and Indices