Ultrasound QC Workshop
Doppler

AAPM

Orlando, FL

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Doppler QC

- Different than ultrasound imaging – able to measure physical parameters or qualities related to blood flow
- Doesn't judge image quality but rather the accuracy of measured hemodynamic values
  - Volumetric flow rate
  - Peak velocity
  - Pressure
- Is Doppler system performance up to par for clinical use…what are the effects of transducer degradation?

Some difficulties

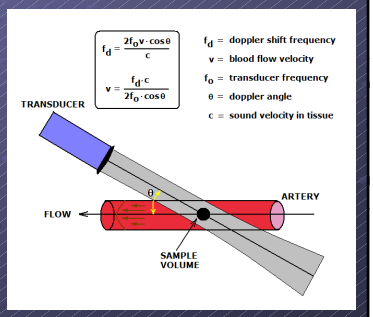
- Great variability among different machines
- Measurement differences and therefore ultimate accuracy is machine dependent
- Operator variability
- Recognizing system performance change due to component degradation

Doppler system performance

- Detectability of flow – single most critical aspect of Doppler system performance
  - Sensitivity – minimum detectable signal level (system signal to noise ratio)
    - Relates directly to depth of penetration
  - Dynamic range – clutter to noise ratio
    - Major determinant of detectability when solid structures are present
  - Frequency range – range of detectable Doppler shift frequencies
    - Relates to minimum and maximum detectable velocities
- Defective transducer is a major determinant of accurate detectability of flow

Doppler shift frequency measurement

- Doppler sample volume guided by real-time B-mode imaging to proper location
- Accuracy dependent upon:
  - Machine components
  - Signal processing
  - Doppler angle
  - Sample volume and location
  - Automatic vs. manual control of displayed parameters



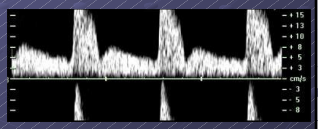
Overestimation of velocity

- If >60 deg, minor errors in Doppler angle determination results in large velocity errors
- Preferred Doppler angle range is 20-60 degrees

Doppler Angle (degrees)	Set Angle (degrees)	Actual Velocity (cm/sec)	Estimated velocity (cm/sec)	% Error
0	5	100	100.4	0.4
30	35	100	105.7	5.7
45	50	100	110.0	10.0
60	65	100	118.3	18.3
75	80	100	149.1	49.1

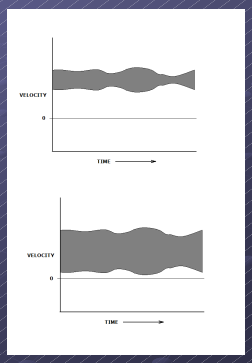
Aliasing

- Wrapping of spectral waveform to opposite direction of flow
- Caused by sampling at less than the Nyquist rate (PRF must be at least 2x the maximum Doppler shift frequency)
- To eliminate, increase the PRF (velocity scale, sample volume depth)



Spectral broadening

- Determined by
  - Velocity profile in vessel
  - Size of sample volume
- Reynolds number
  - <2000 will insure laminar flow
- Parabolic flow
  - Broad bandwidth of Doppler shift frequencies
  - Broad range of velocities
- Defective transducer will
  - Degrade displayed velocity accuracy
  - Increase noise



Types of Doppler test objects

- Flow (fluid)
  - Tubes carrying a blood-mimicking fluid in a scattering and attenuating medium
- String
  - A vessel containing a string or belt moved by a motor and pulleys
- Electronic/acoustic
  - Direct injection of a signal into the signal processing chain or direct coupling to a transducer input

Fundamental QC tests

- Measurement of flow volume and velocity
- Maximum penetration
- Sensitivity at varying depths
- Flow location
- Directional discrimination

Typical clinical applications

APPLICATION	FLOW			TARGET VESSEL	
	Volume cm^3/min	Velocity cm/sec	Acceleration cm/sec^2	Size (mm)	Depth (cm)
Cardiac	>1000	>100	>1000	>20	5-10
Systemic arterial	200-1000	50-100	100-1000	2-10	1-5
Cerebral arterial	50-200	20-50	100-1000	2-10	3-8
Systemic venous	200-1000	<20	<50	10-20	1-5
Arterial stenosis	<50	>100	100-2000	<2	1-10
Small vessel	<5	<1	<100	<2	1-10

Flow Doppler test object and pumping system

Hands-on demonstration

- Set up flow Doppler test object and pumping system variables
- Choose region of interest using B-mode image
- Manipulate "gate"
  - Angle – the Doppler angle
  - Size - % of vessel sampled
  - Position – location of gate within the vessel
- Compare performance of functional vs. degraded transducer

Typical results with defective transducer

- Errors in velocity measurement
- Spectral broadening
- Increased noise
- Phase ambiguity