The Doppler Examination
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OUTLINE

Principles/Physics
Use in valvular assessment
  ◦ Aortic stenosis (continuity equation)
  ◦ Aortic regurgitation (pressure half time)
  ◦ Mitral stenosis (pressure half time)
  ◦ Mitral regurgitation (PISA)
Use in pulmonary hypertension assessment
  ◦ Bernoulli equation
Use in diastolic function assessment
  ◦ Tissue Doppler
Miscellaneous helpful Doppler signals
Doppler Principles

Sound waves transmitted into tissue and reflected back to probe.

Doppler shift calculated from change in frequency.

\[
\Delta f = f_r - f_o = 2f_o \frac{v \cos \theta}{c}
\]

- \( f_o \) = transmitted frequency
- \( f_r \) = reflected frequency
- \( v \) = velocity of red blood cells
- \( c \) = speed of ultrasound in blood
Doppler measurement is best when beam is parallel to direction of blood flow.

**Angle of Doppler beam in relationship to direction of blood flow**

$$F_d = \frac{2f_0}{c} V \cos \Theta$$

**Figure 5**
Doppler Principles

Toward = Red
Away = Blue

Doppler effect with moving structures

Reflected Sound from Target

A
Target stationary

B
Target moving toward transducers

C
Target moving away from transducers

Doppler shift or frequency \( f(d) = f(r) - f(t) \)
Continuous Wave – Best for high velocities (but signal overlap from lack of specificity)
Pulsed Wave – Less overlapping of signals (but aliasing at high velocities)
Continuous Wave – Use in Aortic Stenosis, Tricuspid Regurgitation (Pulmonary Artery pressure assessment), LV outflow tract
Pulsed wave – Use in shunt evaluation, pulmonary vein, hepatic vein, deciphering MR from AS
Aortic Stenosis Doppler shape can vary depending on severity (delay in blood exiting the heart) but are rounded not jagged

Mild  Moderate  Severe
Angels at which to evaluate aortic outflow velocity by Doppler in evaluation of aortic stenosis: Parasternal, apical 3, and supraclavicular notch most parallel to flow (usually)
Aortic Stenosis severity by Gradient Bernoulli Equation: Peak gradient = $4v^2$

Mild
Continuity Equation = What goes in must come out (Valve area calculation)
Area1 \times TVI1 = Area2 \times TVI2
Area1 = (Area2 \times TVI2)/ TVI1
Severity of aortic stenosis by valve area calculation: continuity equation

\[ AVA = \frac{(CSA_{LVOT} \times VTI_{LVOT})}{VTI_{AS}} \]

LVOT measurement critical as \( CSA = \pi r^2 \)
Aortic stenosis caveats

Dimensionless Index = TVILVOT/TVIAV
- <25% consistent with severe AS

Low gradient AS
- Low ejection fraction leads to low gradient
- True stenosis or pseudo stenosis determined by low dose dobutamine testing
  - True stenosis – gradient increases but area calculation and dimensionless index unchanged
  - Pseudo stenosis (or poor surgical candidate) – area calculation and dimensionless index increase
LV outflow tract Doppler shape in Hypertrophic Cardiomyopathy with obstruction exhibits a jagged waveform (Apical 3 chamber or Parasternal long)

Peak gradient = 4 x 32 = 36
Pressure half time (PHT) is the time it takes for the pressure gradient across a valve to reduce by half.

Useful in Aortic regurgitation and mitral stenosis.
Vena contracta = regurgitant jet width: severe =>50% LVOT width
PISA (proximal isovelocity surface area) measurement (often flawed) can calculate regurgitant orifice area: severe = ROA >0.3cm²

Severity of AR by color Doppler:
Aortic Regurgitation: Apical 5 chamber,
Rate of degradation of signal measures severity

Pressure half time (PHT) <250ms indicates severe AR
Severity of aortic regurgitation by Doppler of descending aorta
Mitral stenosis: Valve area using PHT
MVA = 220/PHT
Mitral Regurgitation severity by color Doppler

Visual clues (subjective): jet reaches the top of the atrium, eccentric jet wrapping around the atrium, width of regurgitant jet
PISA (objective, but often difficult to assess): ROA >0.4cm²
The PISA Method for Quantification of Mitral Regurgitation

Color Doppler of MR jet in an Apical Window

Hemisphere surface
Area = \(2\pi(PISA)^2\)

Effective Regurgitant Orifice Area (EROA)

MR jet

Continuous Wave Doppler of MR Jet

VTI

\(\text{MR peak Velocity}\)

\(\text{MR peak Velocity}\)

\[\text{Area}_1 \times \text{Velocity}_1 = \text{Area}_2 \times \text{Velocity}_2\]

\[2\pi(PISA)^2 \times \text{Aliasing Velocity} = \text{EROA} \times \text{MR peak velocity}\]

\[\text{ERoa} = 2\pi(PISA)^2 \times \text{Aliasing Velocity}\]

\[\text{MR peak velocity}\]

Volume = Area \times VTI

Regurgitant Volume = \(\text{ERoa} \times \text{MR VTI}\)
Severity of mitral regurgitation:
Pulmonary vein flow pattern
Systolic > Diastolic = None - Mild
Systolic < Diastolic = Moderate
Systolic reversal = Severe
Pulmonary Hypertension: Estimation of Pulmonary pressures by Bernoulli equation with TR jet velocity

\[ 4 \times (TR \text{ velocity})^2 = RVP - RAP \]
Multiple recordings in multiple views: use maximum if reliable waveform
§ Parasternal RVOT, apical 4 chamber
§ If “shaggy” signal, often inaccurate measurement
Improve shaggy signal with peripheral agitated saline contrast injection
Assess RAP by IVC size + collapse
PASP = 4v2 + RAP
DIASTOLOGY
Mitral Inflow
Mitral annular V

Passive relaxation of the myocardium and Contribution of atrial contraction
Cardiac output without a catheter

Stroke Volume = Area_{LVOT} \times TVI_{LVOT} \quad (NL=18-22\text{cm/sec})

Area = \pi r^2 = D^2 \times 0.785

SV = D^2 \times 0.785 \times TVI_{LVOT}

CO = SV \times HR
Respiratory variation in mitral and tricuspid inflow in the setting of pericardial effusion (severity of hemodynamic effect)
Mitral 25% inspiratory increase
Tricuspid 30% expiratory increase
Atrial septal defect Color Doppler

Primum

Secundum
Continuous Wave Doppler across the VSD

Off-axis view allows best alignment to defect

High velocity signal recorded (> 4.5 m/s), indicating a restrictive VSD.
Thank you for your attention!