DOPPLER HEMODYNAMICS (1)
QUANTIFICATION OF PRESSURE GRADIENTS and INTRACARDIAC PRESSURES

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DOPPLER HEMODYNAMICS

Pressure gradients and intracardiac pressures

Volumetric measurement
- stroke volume (SV)
- regurgitant volume/fraction (RV/RF)

Valve orifice areas
- stenotic orifice area (AVA, MVA)
- (effective) regurgitant orifice area (EROA)
Quantification of pressure gradients

Simplified Bernouilli equation:
Pressure gradient (in mmHg) = $4(V_{\text{max}})^2$
Evaluation of RV Systolic Pressure

RV systolic pressure = TR gradient + RA pressure
Assessing Hemodynamics

RA pressure (using IVC size)

RA pressure = 5 mmHg

RA pressure > 15 mmHg

Clinical: CVP

<table>
<thead>
<tr>
<th>RAP (mm Hg)</th>
<th>Diameter (cm)</th>
<th>Inspiratory Collapse</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume Depletion</td>
<td>&lt;1.2</td>
<td>Total</td>
</tr>
<tr>
<td>0-5 Normal RAP</td>
<td>1.2 - 1.7</td>
<td>≥ 50%</td>
</tr>
<tr>
<td>6-10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11-15</td>
<td>&gt;1.7</td>
<td>≤ 50%</td>
</tr>
<tr>
<td>&gt; 15</td>
<td></td>
<td>None</td>
</tr>
</tbody>
</table>
Patient # 1

This 40 yo man has a TR Vmax of 3 m/sec.
IVC diameter 15 mm.
Respiration change > 50%.

What is his estimated RV pressure?

1. 30-35 mmHg
2. 36-40 mmHg
3. 41-45 mmHg
4. 46-50 mmHg
5. > 50 mmHg
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What is his estimated RV pressure?

1. 30-35 mmHg
2. 36-40 mmHg
3. 41-45 mmHg (Estimated RAP = 5 mmHg)
4. 46-50 mmHg
5. > 50 mmHg
Evaluation of RV Diastolic Pressure

In the absence of TS:
RV diastolic pressure = RA pressure

In the presence of TS:
RV diastolic pressure = RA pressure - TS gradient
Evaluation of PA Systolic Pressure

PA systolic pressure = TR gradient + RA pressure

In the presence of PS:
PA systolic pressure = RV systolic pressure - PS gradient

2 m/s
16 mmHg
Evaluation of PA Diastolic Pressure

PA end-diastolic pressure = PR gradient + RA(V) pressure
The study suggests:
1. Severe PS
2. Right heart failure
3. Pulmonary hypertension
4. Constrictive Pericarditis
Answer: Pulmonary hypertension
Note the end-diastolic gradient of 2.5 m/sec, indicating a gradient of 25 mmHg between the PA and RV
CW Doppler of MR Jet
BP 120/80 mmHg. MR velocity is 7.7 m/sec

The most likely diagnosis is:
1. Aortic stenosis
2. Aortic insufficiency
3. High cardiac output
4. Pulmonary hypertension
Answer: Severe aortic stenosis
CW Doppler of MR Jet

BP 120/80 mmHg. MR velocity is 7.7 m/sec

The velocity of the MR jet indicates an LV-LA gradient of 237 mmHg; therefore the aortic gradient is at least 117 mmHg.
Evaluation of LV Systolic Pressure

In pts without valve disease:
LV systolic pressure = systolic BP

In pts with AS or LVOT obstr.:
LV systolic pressure = systolic BP + Peak-to-Peak gradient
Aortic Valve Gradients

1. Peak-to-Peak Gradient (PP)
2. Maximum Instantaneous Gradient (MIG)
3. Mean Gradient

The PP gradient is 70% of the MIG

In pts with AS or LVOT obstr.:
LV systolic pressure =
systolic BP + Peak-to-Peak gradient

In pts with AR:
LV end-diastolic pressure =
diastolic BP - AR gradient
CW Doppler of Aortic Valve Flow

BP is 150/80 mmHg

The LV pressure is:
1. 84/16 mmHg
2. 214/44
3. 214/16
4. 195/16
CW Doppler of Aortic Valve Flow

BP is 150/80 mmHg

**ANSWER: 4. 195/16 mmHg**

LV (sys) = Sys. BP (150) + 70% Ao gradient (45) = 195 mmHg

LV (dias) = Dias. BP (80) - Ao dias. gradient (64) = 16 mmHg
Evaluation of LV Diastolic Pressure

In the absence of MS:
LVDP = approx. LA pressure

In pts with AR:
LV end-diastolic pressure = diastolic BP - AR gradient
Calculation of LA pressure

\[ \text{LAP} = \frac{E}{e'} + 4 \]

\[ \begin{align*}
\text{E} &= 55 \text{ cm/sec} \\
\text{e'} &= 6 \text{ cm/sec} \\
\end{align*} \]

\[ \frac{E}{e'} = 9.2 \]

\[ \text{LAP} = \frac{55}{6} + 4 = 13 \text{ mmHg} \]

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\text{E} &= 55 \text{ cm/sec} \\
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\[ \frac{E}{e'} = 8: \text{LA pressure nl} \]

\[ \frac{E}{e'} = 15: \text{LA pressure high} \]
Relation of E/E’ to PCWP

\[ Y = 1.9 + 1.24 \times X \]

\[ R = 0.87 \]

\[ N = 60 \]

Nagueh et al, 1997
Estimating LA Pressure by $E/e'$ may be inaccurate in:

- Mitral stenosis
- Mitral annular calcification
- Prosthetic MV
- Mitral regurgitation
- Diffuse severe LV dysfunction
Assessment of LA pressure in pts with MS

LA diastolic pressure = LVDP + transmitral gradient

MV gradient 16mmHg  MV gradient 4mmHg
Noninvasive Hemodynamic Study
53-year-old male with dyspnea

BP 100/65
HR 70, regular
No JVD
Apical diastolic rumble
Basal systolic ejection murmur radiating to the neck
Normal IVC Size 1.6 cm
>50% Respiratory Variation
Normal IVC Size 1.6 cm
>50% Respiratory Variation
RV Pressures

RV systolic = RA pressure (6) + TR gradient (40) = 46 mm Hg

In the absence of TS, RV diastolic pressure = RA pressure
PA Pressure

Systolic = RV systolic (46)

Diastolic = PR gradient (20) + RA pressure (6) = 26 mmHg

2.2 m/sec
LVEDP = aortic diastolic pressure (65) – AR gradient (55) = 10 mmHg

→ 3.7 m/sec
LV systolic pressure = aortic systolic pressure (100) + 70% of AV gradient (64) = 164 mmHg
LA pressure = LV diastolic (10) + MV mean gradient (13) = 23 mmHg
How to measure \( \frac{dP}{dt} \)?

1. Optimize CW MR jet with clear initial slope (high-filter setting)
2. Decrease velocity range to max envelope from baseline to 4 m/s
3. Increase sweep speed to 100 mm/s
4. Draw horizontal lines at 1 m/s and 3 m/s
5. Draw vertical line from intercept at MR to these points
6. Measure “time” (ms)
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Measurement of LV $dP/dt$ from MR jet

$dp/dt$ mmHg/sec = \frac{\Delta P \text{ mmHg} \times 1.000}{\Delta t \text{ (msec)}}$

\[= \frac{4 \left(V^2 - V_2^2\right) \times 1.000}{\Delta t \text{ (msec)}} = \frac{4 \left(3^2 - 1^2\right) \times 1.000}{\Delta t \text{ (msec)}} = \frac{32.000}{\Delta t \text{ (msec)}}\]

Normal LV $dP/dt = > 1000$ mmHg/sec

Normal $t < 32$ msec
Time to reach MR velocity from 1 to 3 m/sec is 25 msec.

\[ \frac{32.000}{25 \text{ msec}} = 1200 \text{ mmHg/sec} \]
Conclusions

Normal and abnormal hemodynamics can be evaluated non-invasively by Doppler Echocardiography.

Invasive evaluation may be needed for details not seen on echo, or when the clinical impression is not consistent with the echo-Doppler findings.
Estimation of LV Filling Pressure

**MVF and PVF** (Pozzoli et al., 1996)

\[ 1.85 \times DR - 0.1 \times SF + 1.9 \]

**MVF and color M-mode** (Garcia et al., 1997)

\[ 5.27 \times E/Pv + 4.66 \]

**MVF and TDI annulus (sinus tachycardia)** (Nagueh et al., 1997)

\[ 1.47 \times E/e' + 1.55 \]

**MVF and TDI mitral annulus (atrial fibrillation)** (Sohn et al., 1999)

\[ 0.82 \times (E/e') + 6.49 \]
Diastolic dysfunction and atrial fibrillation

- (Analyse 60-80 bpm RR intervals)
- (Acceleration rate E wave)
- $\text{DT} < 150 \text{ ms}$
- $\text{E/e’ ratio} > 15$
- Color M-mode: $\text{Pv} < 40 \text{ cm/sec}$