Right Heart Hemodynamics: Echo-Cath Discrepancies

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*No off-label use of device
Pulmonary artery systolic pressure by Doppler echo

PASP is equivalent to right ventricular systolic pressure in the absence of obstruction to flow between the RV and PA

\[ \text{PASP} = 4 \cdot \text{TRVmax}^2 + \text{estimated RAP} \]

- Modified Bernoulli equation = best validated Doppler technique for assessment of PASP
PULMONARY PRESSURE ASSESSMENT

Pulmonary artery systolic pressure by echo

Yock et al. Circulation 1984
Echo Doppler vs right heart catheterization

- Doppler gradients are highly influenced by loading conditions and RV function
- Changes in Doppler PASP don’t parallel clinical improvement and prognosis
- Echo overestimates PASP and underestimates PEDP, which results in an overestimation of the mean PAP

unnecessary RHCs

Mukerjee D. Rheumatology 2004; 43: 461-6
PULMONARY PRESSURE ASSESSMENT

Pulmonary artery systolic pressure by echo

Surinder et al. Heart 2011
1. Obtain a technically adequate CW Doppler tracing

Suboptimal TR CW Doppler tracing
1. Obtain a technically adequate CW Doppler tracing
1. Proper alignment of the CW Doppler beam

Suboptimal alignment
- underestimation of RV-RA Δp
→ missed diagnosis of PH
PULMONARY PRESSURE ASSESSMENT

1. Obtain a complete envelope of the Doppler tracing

Addition of saline or blood-saline contrast agent to enhance Doppler signal
2. Importance of respiratory breathhold

- Peak gradient at end expiration
- Underestimation if not
3. Avoid overestimation of pulmonary pressure

Only the well-defined, dense spectral profile should be traced
4. Avoid underestimation of pulmonary pressure

\[ \text{mRAP} = 15 \text{ mmHg} \]

\[ \text{TR } V_{\text{max}} = 1.7 \text{ m/s} = 11 \text{ mm Hg} \]
4. Avoid underestimation of pulmonary pressure

sPAP = 30 mmHg
Mean and diastolic pulmonary artery pressures

\[ PAPm = 4 \times V_1^2 + MRAP \]

\[ PEDP = 4 \times V_2^2 + MRAP \]

Masuyama T et al. Circulation 1986
PULMONARY PRESSURE ASSESSMENT

Qualitative assessment of pulmonary regurgitant flow

- High PASP → right atrial contraction usually does not make any notable change in the RV-PA pressure gradient (no ‘a’ dip in the CW Doppler signal of PR)

Normal PASP

Elevated PASP

“A” dip

PULMONARY PRESSURE ASSESSMENT

RV outflow acceleration time

- RV AT cutoff for normal PAP: > 120 ms
- RV AT ≤ 100 ms identifies elevated PAP (Sn= 78%, Sp = 100%)
- RV AT ≤ 70 ms predicts severe PH

\[
PAPm = 79 - 0.45 \times RV-AT
\]

\[
PAPm = 90 - 0.62 \times RV-AT
\]

Mahan G et al. Circulation 1983
Dabestani A et al. Am J Cardiol 1987
Qualitative assessment RV outflow tracing

- To distinguish proximally located obstructions in the pulmonary arterial vasculature from distal obstructions
- Mid-systolic notch occurs significantly later in systole in pts with PPH than in those with proximal pulmonary embolism

\[
NR = \frac{t_1}{t_2}
\]

**Notch ratio (NR) = \(\frac{t_1}{t_2}\)**

Hardziyenka M et al. Eur Heart J 2007
The critical role of mean right atrial pressure

*Easier* - fixed value (mRAP = 10 mmHg)

*OR*

*More accurate* - estimation based on:
- caval respiratory index
- hepatic venous flow
- superior vena cava flow
- tricuspid inflow
- tissue Doppler of RV free wall (E/Ea, IVRT)

Most important for intermediate TR jet velocities

(RAP may discriminate between normal and abnormal PASP)
PULMONARY PRESSURE ASSESSMENT

Estimated mean right atrial pressure

<table>
<thead>
<tr>
<th>IVC Diameter (cm)</th>
<th>Resp. Change (%)</th>
<th>RAP (mm Hg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 2.1</td>
<td>&gt;50%</td>
<td>3 (0-5)</td>
</tr>
<tr>
<td>&gt;2.1</td>
<td>&lt;50%</td>
<td>15 (10-20)</td>
</tr>
<tr>
<td>Otherwise</td>
<td></td>
<td>8 (5-10)</td>
</tr>
</tbody>
</table>

Caveats:
- younger individuals, athletes
- positive pressure mechanical ventilation
- patient cooperation
- out-of-plane respiratory motion of IVC
- prominent Eustachian valve

Mean right atrial pressure (hepatic venous flow)

- Systolic filling fraction: \( \text{SFF} = \frac{\text{VTI}_S}{\text{VTI}_S + \text{VTI}_D} \)
  - dichotomous separation of RAP > 8 mm Hg by a SFF < 55% (Sn= 86%, Sp= 90%)

Nagueh SF et al. Circulation 1996;93:1160-1169

• Peak A > peak S predicts increased RAP
Mean right atrial pressure (superior vena cava)

SVC flow pattern is related to RAP and RV function

- **Normal**: $1 \leq X/Y \leq 2$
- **Predominant systolic wave**: $X/Y > 2$
- **Predominant diastolic wave**: $X/Y < 1$

Sensitivity and Specificity of Each of the Three Flow Velocity Patterns for a Different Right Heart Hemodynamic Profile

<table>
<thead>
<tr>
<th>SVC Flow Pattern</th>
<th>Hemodynamic Profile</th>
<th>Sensitivity</th>
<th>Specificity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>RVEF ≥ 30% and RAP ≤ 5 mmHg</td>
<td>86</td>
<td>78</td>
</tr>
<tr>
<td>“Predominant systolic wave”</td>
<td>RVEF &lt; 30% and RAP ≤ 8 mmHg</td>
<td>69</td>
<td>81</td>
</tr>
<tr>
<td>“Predominant diastolic wave”</td>
<td>RVEF &lt; 30% and RAP &gt; 8 mmHg</td>
<td>52</td>
<td>95</td>
</tr>
</tbody>
</table>
Mean right atrial pressure (superior vena cava)

Specificity = 95% for elevated mean RAP (>8 mmHg) in the setting of RV systolic dysfx (RVEF <30%)
Mean right atrial pressure (right ventricular filling)

- E/A ≥ 1.1 predicts mean RAP > 8 mmHg  
  (Sn = 66%, Sp = 92%)
- E/Ea > 6 predicts mean RAP > 10 mm Hg  
  (Sn = 79%, Sp = 73%)

Patient with Severe PAH and elevated RAP

Nagueh SF et al. Circulation 1996;93:1160-1169
Nageh MF et al. Am J Cardiol 1999;84:1448-51
Mean right atrial pressure (right ventricular IVRT)

- RV rIVRT inversely correlates with mean RAP, $r = -0.92$ (95% CI 0.82-0.97)

- RV rIVRT $< 59$ ms $\rightarrow$ mean RAP $> 8$ mm Hg ($Sn = 80\%$, $Sp = 87.7\%$)

Pulmonary systolic pressure in PDA

PASP

= Systolic BP – peak gradient

= 125 – 100 = 25 mmHg
Pulmonary systolic pressure in VSD

\[
PASP = \text{Systolic BP} - \text{peak gradient} = 130 - 29 = 91 \text{ mmHg}
\]

\[
PAPm = 29 \text{ mmHg}
\]
Conclusions

Doppler echocardiography provides several complementary methods and indices to reliably assess pulmonary artery pressure and right heart hemodynamics.

Accurate noninvasive assessment of the various components of flow-pressure-resistance interactions using echo requires:
- technical skill
- comprehensive assessment;
- multi-parameter approach;
- knowledge of potential pitfalls, and
- integrating the findings in the proper clinical context.