Pulmonary Hypertension: Echocardiographic Evaluation of Pulmonary Hypertension and Right Ventricular Function

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Disclosures:

Nothing to disclose
Overview

- Is pulmonary hypertension present?
- What is the etiology of pulmonary hypertension?
- Is pulmonary vascular resistance elevated?
- What is the impact on right ventricular function?
Pulmonary Hypertension Defined

- By right heart catheterization
  - Mean PA pressure > 25 mm Hg at rest
  - Mean PA pressure > 30 mm Hg with exercise

- By echocardiography
  - PA systolic pressure estimate > 40 mm Hg
Modified Bernouille Equation

\[ \text{PASP} = 4 \times (\text{TRJ vel})^2 + \text{RAP} \]
Accuracy of Estimated PA Pressure

- REVEAL registry data of 1883 patients with PAH and TTE/RHC – Spearman correlation 0.56 for PASP

![Graph showing correlation between Echo PASP and Invasive PASP](image-url)
Sources of Error

\[ \text{PASP} = 4 \times (\text{TRJ vel})^2 + \text{RAP} \]

- Incomplete TR jet
- Right atrial pressure estimation
Pitfalls In PASP Estimates

TR Gradient = 21 mm Hg

TR Gradient = 36 mm Hg

TR Gradient = 60 mm Hg
Right Atrial Pressure Estimation

**Figure 2:** Non-invasive estimation of right atrial (RA) pressure from inferior vena cava (IVC) collapsibility assessed from the subcostal view. Top row: small IVC with greater than 50% collapse (RAP 3 mm Hg). Bottom row: dilated IVC with minimal collapsibility (RAP 15 mm Hg). RAP may be assumed at 8 mm Hg when the IVC is not well visualized. See table below:

<table>
<thead>
<tr>
<th>RAP Estimate</th>
<th>3 mm Hg</th>
<th>8 mm Hg</th>
<th>8 mm Hg</th>
<th>15 mm Hg</th>
</tr>
</thead>
<tbody>
<tr>
<td>IVC Diameter</td>
<td>&lt;2.1 cm</td>
<td>&lt;2.1 cm</td>
<td>&gt;2.1 cm</td>
<td>&gt;2.1 cm</td>
</tr>
<tr>
<td>% Collapse</td>
<td>&gt;50</td>
<td>&lt;50</td>
<td>&gt;50</td>
<td>&lt;50</td>
</tr>
</tbody>
</table>
Right Atrial Pressure

• Correlation between invasive RAP and echo-estimated RAP was even worse than for PAP, R=0.36

• Pitfalls include overestimation – in obese patients, ventilated patients
So Is Pulmonary Hypertension Present?

- Look at the right ventricle
- The right ventricle undergoes changes in structure and function in response to changes in RV afterload
- Thus, the right ventricle ‘bears witness’ to the cardiopulmonary interaction in the RV-PA circuit and changes in the RV can give the clinician insight into presence and severity of PH
Right ventricular dilation
Right ventricular hypertrophy
WHO Classification of Pulmonary Hypertension

- **Group I**: Idiopathic PAH, Connective Tissue Disease Associated, Diet Drug Associated, Porto-Pulmonary hypertension. HIV associated. Familial PAH, Hemolytic Anemia, Congenital heart disease
- **Group II**: Left heart disease
- **Group III**: Chronic Respiratory disease
- **Group IV**: Chronic Thromboembolic Disease
- **Group V**: Miscellaneous (Sarcoidosis, Langerhans disease, LAM)
What is the Etiology of PH

- PAP 80 mm Hg

PCWP 4
PVR 8 WU
CO 3 L/min

PCWP 30
PVR 2 WU
CO 6 L/min
RV Geometry
RV On Standard Echo Views
For quantitative assessment of RV function, to date 2 types of quantitative assessment have been used:

- Single plane measurements of the motion of the tricuspid annulus
  - TAPSE
  - Tissue Doppler S’
  - RV longitudinal strain
- RV fractional area change from apical 4 chamber view
Right ventricle 4 chamber view
Typical Measures – TAPSE, TDs’
RV Fractional Area Change
RV Function Pitfalls

- TAPSE and TD PSV
  - Measurement/Alignment

- RV fractional area change and strain
  - Endocardial definition

- 3-D
  - Imaging entire RV in 1 view
  - Temporal and spatial resolution
What Else Can Echo Tell Us?

- Hemodynamics
  - PASP estimates
  - Direct and indirect assessment of PVR
  - Evidence of ventricular interactions

- Valvular Assessment
PASP Estimates

TR Gradient=21 mm Hg

TR Gradient=60 mm Hg

TR Gradient=36 mm Hg
The Holy Grail of Echo in PAH

- Non-invasive estimation of PVR
  - Quantitative formulas
    - *Abbas formula*: \( \frac{TRV}{TVI_{RVOT}} \times 10 + 0.16 \)
    - *Dahiya formula*: \( \frac{(RVSP-E/e')}{RVOT \ VTI} \)
  - Qualitative Assessment
    - Notching in the PW Doppler in the RVOT
Notching
• In PHTN —> lost A wave
• Brief mid-systolic closure —> Flying W sign
M- Mode of Pulmonary Valve

- A wave present (due to the right atrial contraction)
- Valve opens and stays open in systole
Pulmonary Hypertension
Why Right Ventricular Function Is Important

- Right ventricular failure is the greatest cause of morbidity and mortality in PAH

- The right ventricle undergoes stereotypical changes in structure and function in response to changes in RV afterload

- Thus, the right ventricle ‘bears witness’ to the cardiopulmonary interaction in the RV-PA circuit and changes in the RV can give the clinician insight into progression of disease and response to therapy
Modalities For Assessment of RV Function

- Right heart catheterization
  - Right atrial pressure
  - Cardiac index
  - Stroke volume index
  - Stroke work index (mean PAP – mean RAP) x SVI

- Drawbacks
  - Invasive
  - Indirect assessment of RV function
  - Load, volume and operator dependent
Echocardiography

- Complex, triangular/crescent shape of the RV makes assessment of RV volumes and RVEF problematic by standard 2-D echocardiography.
Echocardiography

• Moreover, the inter observer variability in assessment of RV function is significantly higher than in assessment of LV function

• So why use echocardiography to assess RV function?
Echocardiography

• Widely available
• Can be performed on almost any patient including critically ill patients
• No radiation, magnetic field or contrast required
• Repeated assessment feasible
  – Quantitative assessment is possible using echocardiographic surrogates for RVEF
  – Can provide valuable information regarding hemodynamics and estimates of PVR
Conclusions

• Assessment of RV function is critical in PAH
• Knowledge of the capabilities and limitations echocardiography can maximize utility of the echo-Doppler examination
• While MRI is the current gold standard for RV assessment, echocardiography is the ‘workhorse’ in most centers for evaluating RV function