Assessment of Right Ventricle, Tricuspid Valve, and Pulmonary Artery Pressures

April 17, 2015

Lily Zhang
Assistant Professor of Medicine
Baylor College of Medicine
GUIDELINES AND STANDARDS

Guidelines for the Echocardiographic Assessment of the Right Heart in Adults: A Report from the American Society of Echocardiography

Endorsed by the European Association of Echocardiography, a registered branch of the European Society of Cardiology, and the Canadian Society of Echocardiography

Lawrence G. Rudski, MD, FASE, Chair, Wyman W. Lai, MD, MPH, FASE, Jonathan Afilalo, MD, Msc, Lanqi Hua, RDCS, FASE, Mark D. Handschumacher, BSc, Krishnaswamy Chandrasekaran, MD, FASE, Scott D. Solomon, MD, Eric K. Louie, MD, and Nelson B. Schiller, MD, Montreal, Quebec, Canada; New York, New York; Boston, Massachusetts; Phoenix, Arizona; London, United Kingdom; San Francisco, California

(J Am Soc Echocardiogr 2010;23:685-713.)
Importance of RV Dysfunction in Various Disease States

- Primary Pulmonary Arterial Hypertension
- Pulmonary Thromboembolism
- Secondary
  - Left heart failure
  - Left sided valve diseases
  - Myocardial infarction with RV involvement
- Congenital Heart Diseases
- ARVD/Other Systemic Diseases
2D Assessment

Right ventricle

- Structurally complex cavity:
  - crescent shape
  - irregular endocardial surface due to heavy trabeculation: difficult to delineate endocardial border
  - location behind the sternum: inadequate image quality

- Fits no simple geometric figure:
  - failure to standardize RV volume determination

- RV size estimation requires integration of multiple views and qualitative and quantitative assessment
<table>
<thead>
<tr>
<th>Dimension</th>
<th>Studies</th>
<th>n</th>
<th>LRV (95% CI)</th>
<th>Mean (95% CI)</th>
<th>URV (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>RV mid cavity diameter (mm) (Figure 7, RVD2)</td>
<td>12</td>
<td>400</td>
<td>20 (15-25)</td>
<td>28 (23-33)</td>
<td>35 (30-41)</td>
</tr>
<tr>
<td>RV basal diameter (mm) (Figure 7, RVD1)</td>
<td>10</td>
<td>376</td>
<td>24 (21-27)</td>
<td>33 (31-35)</td>
<td>42 (39-45)</td>
</tr>
<tr>
<td>RV longitudinal diameter (mm) (Figure 7, RVD3)</td>
<td>12</td>
<td>359</td>
<td>56 (50-61)</td>
<td>71 (67-75)</td>
<td>86 (80-91)</td>
</tr>
<tr>
<td>RV end-diastolic area (cm²) (Figure 9)</td>
<td>20</td>
<td>623</td>
<td>10 (8-12)</td>
<td>18 (16-19)</td>
<td>25 (24-27)</td>
</tr>
<tr>
<td>RV end-systolic area (cm²) (Figure 9)</td>
<td>16</td>
<td>508</td>
<td>4 (2-5)</td>
<td>9 (8-10)</td>
<td>14 (13-15)</td>
</tr>
<tr>
<td>RV end-diastolic volume indexed (mL/m²)</td>
<td>3</td>
<td>152</td>
<td>44 (32-55)</td>
<td>62 (50-73)</td>
<td>80 (68-91)</td>
</tr>
<tr>
<td>RV end-systolic volume indexed (mL/m²)</td>
<td>1</td>
<td>91</td>
<td>19 (17-21)</td>
<td>33 (31-34)</td>
<td>46 (44-49)</td>
</tr>
<tr>
<td>3D RV end-diastolic volume indexed (mL/m²)</td>
<td>5</td>
<td>426</td>
<td>40 (28-52)</td>
<td>65 (54-76)</td>
<td>89 (77-101)</td>
</tr>
<tr>
<td>3D RV end-systolic volume indexed (mL/m²)</td>
<td>4</td>
<td>394</td>
<td>12 (1-23)</td>
<td>28 (18-38)</td>
<td>45 (34-56)</td>
</tr>
<tr>
<td>RV subcostal wall thickness (mm) (Figure 5)</td>
<td>4</td>
<td>180</td>
<td>4 (3-4)</td>
<td>5 (4-5)</td>
<td>5 (5-6)</td>
</tr>
<tr>
<td>RVOT PLAX wall thickness (mm) (not shown)</td>
<td>9</td>
<td>302</td>
<td>2 (1-2)</td>
<td>3 (3-4)</td>
<td>5 (4-6)</td>
</tr>
<tr>
<td>RVOT PLAX diameter (mm) (Figure 8)</td>
<td>12</td>
<td>405</td>
<td>18 (15-20)</td>
<td>25 (23-27)</td>
<td>33 (30-35)</td>
</tr>
<tr>
<td>RVOT proximal diameter (mm) (Figure 8, RVOT-Prox)</td>
<td>5</td>
<td>193</td>
<td>21 (18-25)</td>
<td>28 (27-30)</td>
<td>35 (31-39)</td>
</tr>
<tr>
<td>RVOT distal diameter (mm) (Figure 8, RVOT-Distal)</td>
<td>4</td>
<td>159</td>
<td>17 (12-22)</td>
<td>22 (17-26)</td>
<td>27 (22-32)</td>
</tr>
<tr>
<td>RA major dimension (mm) (Figure 3)</td>
<td>8</td>
<td>267</td>
<td>34 (32-36)</td>
<td>44 (43-45)</td>
<td>53 (51-55)</td>
</tr>
<tr>
<td>RA minor dimension (mm) (Figure 3)</td>
<td>16</td>
<td>715</td>
<td>26 (24-29)</td>
<td>35 (33-37)</td>
<td>44 (41-46)</td>
</tr>
<tr>
<td>RA end-systolic area (cm²) (Figure 3)</td>
<td>8</td>
<td>293</td>
<td>10 (8-12)</td>
<td>14 (14-15)</td>
<td>18 (17-20)</td>
</tr>
</tbody>
</table>

CI, Confidence interval; LRV, lower reference value; PLAX, parasternal long-axis; RA, right atrial; RV, right ventricular; RVD, right ventricular diameter; RVOT, right ventricular outflow tract; 3D, three-dimensional; URV, upper reference value.
Right ventricle

Normal dimensions
Right ventricle

Linear dimensions

- PLAX RVOT : 3.3 cm
- PSAX RVOT : 2.7 cm
- **Basal diameter** 4.2 cm
- Mid level diameter 3.5 cm
- Longitudinal dimension 8.6 cm
Normal RV < 2/3 LV

RV dilatation:
- Linear dimensions
- Mild: enlarged but RV area < LV area
- Moderate: RV area = LV area
- Severe: RV area > LV area
What structure is this?

- Anterior leaflet
- Posterior leaflet
- Septal leaflet
- Ostium of CS
- Ostium of IVC
- Eustachian Valve
2D Assessment

*Right atrial size*

- Major-axis (vertical line) <5.3cm
- Minor-axis (horizontal line) <4.4cm
- RA area <18cm²
RV function

- Subjective:
  - thickening of the RV wall and inward motion of the RV free wall in multiple views
  - integrate findings from various views
- RV fractional area change
- Tricuspid annular descent (TAPSE)
- Tissue Doppler
- Tei Index
RV function

RV fractional area change

- RV fractional area change = \( \frac{RVD \text{ area} - RVS \text{ area}}{RVD \text{ area}} \)
- Normal: >35%

- Relatively high correlations (0.69–0.88) between echo and MRI estimated RV size

- RV tracing may be improved using intravenous contrast agents.
RV function

Tricuspid annular descent

- RV ejects blood primarily by shortening of the longitudinal axis

Tricuspid annular plane systolic excursion (TAPSE index) measured in apical 4-chamber view and M-mode cursor through lateral tricuspid annulus

Normal > 16 mm
Pulmonary Hypertension

Doppler Assessment

1. Pulmonary artery pressures:
   - PASP
   - PADP
   - mean PAP
   - RAP

2. Pulmonary vascular resistance

3. RVOT TVI
Doppler Assessment

Pulmonary artery systolic pressure

- Peak TR velocity
  - Measured with continuous wave Doppler
  - reflects RV to RA pressure difference during systole

\[
RVSP - RAP = 4(V_{Tr})^2
\]
\[
RVSP = 4(V_{Tr})^2 + RAP
\]
  - In the absence of pulmonic stenosis: RVSP=PASP

- Good correlation between echo and RHC derived PAP
Inaccurate RAP estimate

Presence of pulmonic stenosis (RVSP $\neq$ PASP)

Severe TR: Doppler envelope may be cut off because of early equalization of RV and RA pressures $>$ underestimation of PASP

Over-estimation when given saline to enhance TR
Pulmonary Hypertension

*Doppler Assessment*

1. Pulmonary artery pressures:
   - PASP
   - PADP
   - mean PAP
   - RAP

2. Pulmonary vascular resistance

3. RVOT TVI
Pulmonary regurgitant velocity reflects PA to RV pressure difference during diastole.

\[ \text{PADP} \text{- RVDP} = 4(V_{\text{PI}})^2 \]
\[ \text{PADP} = 4(V_{\text{PI}})^2 + \text{RAP} \]
1. **Pulmonary artery pressures:**
   - PASP
   - PAPD
   - mean PAP
   - RAP

2. **Pulmonary vascular resistance**

3. **RVOT TVI**
Doppler Assessment

Mean pulmonary artery pressure

- Mean PAP = \(4(V_{\text{peak PI}})^2 + RAP\)
What is SPAP?? Assuming peak and end PI velocities are 3.75m/s and 3m/s, RAP 15
Pulmonary Hypertension

*Doppler Assessment*

1. Pulmonary artery pressures:
   - PASP
   - PADP
   - mean PAP
   - RAP

2. Pulmonary vascular resistance

3. RVOT TVI
Doppler Assessment

Right atrial pressure

- IVC diameter
- IVC collapsibility
- Hepatic venous Doppler
Right atrial pressure

**IVC Diameter and Collapsibility**

- Imaged supine position; subcostal view.

- IVC diameter
  - best measured between 5 and 30 mm from the IVC and RA junction.

- IVC should be captured for 3-5 beats during quiet respiration and during a “sniff” maneuver.

- IVC diameter varies with respiration, with minimal size at end inspiration.
Right atrial pressure

Hepatic venous Doppler

- PW Doppler cursor placed in hepatic vein parallel to flow
- Waves:
  - Systolic forward flow
  - Diastolic forward flow pulse
  - Atrial systole; reversal of flow
- Increase in RAP: pressure gradient between the hepatic veins and the RA decreases, thus lowering the forward systolic flow.
New 2010 Guidelines to Estimate RAP

For simplicity and uniformity of reporting, specific values of RA pressure, rather than ranges, should be used in the determination of SPAP. IVC diameter ≤ 2.1 cm.

Table 3: Estimation of RA pressure on the basis of IVC diameter and collapse

<table>
<thead>
<tr>
<th>Variable</th>
<th>Normal (0-5 [3] mm Hg)</th>
<th>Intermediate (5-10 [8] mm Hg)</th>
<th>High (15 mm Hg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>IVC diameter</td>
<td>≤2.1 cm</td>
<td>≤2.1 cm</td>
<td>&gt;2.1 cm</td>
</tr>
<tr>
<td>Collapse with sniff</td>
<td>&gt;50%</td>
<td>&lt;50%</td>
<td>&gt;50%</td>
</tr>
</tbody>
</table>

Secondary indices of elevated RA pressure:
- Restrictive filling
- Tricuspid E/E' > 6
- Diastolic flow predominance in hepatic veins (systolic filling fraction < 55%)
RA Pressure

Exceptions

• Atrial fibrillation
  – Use IVC diameter and collapsibility only.

• Ventilated patients
  – dilated IVC does not correlate with RAP
  – if < 1.2cm, 100% specific for RAP < 10mmHg

• Young patients/athletes
  – IVC may be dilated and systolic wave may be blunted in setting of normal RAP
Pulmonary Hypertension

Doppler Assessment

1. Pulmonary artery pressures:
   - PASP
   - PADP
   - mean PAP
   - RAP

2. Pulmonary vascular resistance

3. RVOT TVI
Question

• How do you calculate pulmonary vascular resistance?
  A. PASP-CVP/C0
  B. Mean PAP-PCWP/C0
  C. MAP-CVP/C0
  D. PCWP-Mean PAP/C0
Doppler Assessment

Pulmonary vascular resistance

- Distinguishing high PAP due to increased pulm flow versus from pulm HTN due to elevated PVR.
- Heart/liver transplant eval.
- CHF
- Congenital heart disease

- $\text{PVR} = \frac{[\text{Mean Pulmonary Artery Pressure} - \text{PCWP}]}{\text{CO}}$

- $\text{PVR (woods units)}$ can be estimated using: $\text{TR peak velocity} / \text{RVOT TVI} \times 10 + 0.16$
Doppler Assessment

**RVOT TVI**

- **Normal:**
  - pulm flow contour is symmetric
  - peak velocity occurs in mid-systole (137 +/- 24 msec).

- **Pulmonary HTN:**
  - Pulmonary hypertension: mid-systolic notching of RVOT TVI.
  - Peak velocity occurs earlier in systole (97 +/- 20 msec).
  - Pulmonary artery flow acceleration time (AT): measured using PW in RVOT from onset of flow to peak velocity.
• AT inversely correlates to mean PAP.
• As PAP increases, acceleration time decreases (normal > 120 msec).
• If ACT < 90 msec → PAP is > 60 mmHg
• mPAP = 79 – (0.45 x RVOT AT in msec)
  – If HR<60 or>100 then time must be adjusted
Question

- In which setting can the ACT time be normal despite significant pulmonary hypertension?
  A. Severe PI
  B. Peripheral pulmonary artery stenosis
  C. Elevated RVEDP
  D. Significant RV dysfunction
Question

Which of the following is true?

A. In the setting of pulmonic stenosis, pulmonary artery systolic pressure (sPAP) can be estimated as:
   \[ sPAP = 4v^2 + RAP \]  
   \( v = \text{peak TR jet velocity} \)

B. In the presence of a VSD, sPAP can be calculated as
   \[ LVSP - 4v^2 \]  
   \( v = \text{peak velocity of flow through VSD} \)

C. PA diastolic pressure can be calculated as \[ 4v^2 + RAP \]  
   \( v = \text{peak early diastolic pulmonary regurgitant velocity} \).

D. RVOT acceleration time can be used to calculate sPAP.
Pulmonary Hypertension

2D Assessment

1. RA size
2. RV size
3. Septal flattening
Interventricular septum

Normal motion

- LV maintains a round shape throughout the cardiac cycle
- Reflects higher pressures in the LV compared to the RV in systole and diastole
Pulmonary Hypertension
Question

Which of the following is not prognostic indicator of survival in PHTN?

A. Presence and size of pericardial effusion
B. Elevated Tei index
C. RA size
D. RVOT TVI AT<62ms
E. TR severity
F. Pulmonary artery pressure
Thank You !