Chamber Quantitation Guidelines - Update II

Right Heart Measurements

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I have no relevant financial relationships to disclose

Steven Goldstein
I. What to Measure; How to measure

II. Importance of RV Function

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 Afilo, MD, Msc, Lanqi Hua, RDCS, FASE, Mark D. Handschumacher, BSc, Krishnaswamy Chandrasokaran, MD, FASE, Scott D. Solomon, MD, Eric K. Louie, MD, and Nelson B. Schiller, MD

J Am Soc Echocardiogr 2010;23(7):685-713

asecho.org
The RV is Challenging

- Close to chest wall
- Nongeometric shape
- Determining RV-focused view
- RV foreshortening
- Endocardial border definition
- Interrelationship with the LV
- Sensitivity to loading conditions
I. What to Measure
How to Measure

Imaging the Right Heart:
Views, Anatomy, Normal Values
Imaging the Right Ventricle
Use Multiple Acoustic Windows

- Apical 4-chamber view
- RV-focused apical 4-chamber view
- Parasternal long axis view
- Parasternal short-axis view
- RV inflow view

Right Ventricle
Parameters to Perform and Report

- Measure of RV size
- Measure of RA size
- RV systolic function (at least one of following)
  - Fractional area change (FAC)
  - TDI S’
  - Tricuspid annular plane systolic excursion (TAPSE)
- With/without RV index of myocardial performance
- Systolic pulmonary artery pressure
- Estimate of RA pressure (based on IVC)
RV Size

Measuring RV Size

2 measurements - 2.8 cm and 3.6 cm

Endocardial border definition (image quality)

Trabeculations

Foreshortening

May not reflect global size

Measuring RV Size

Challenging/Limitations

- Endocardial border definition (image quality)
- Trabeculations
- Foreshortening
- May not reflect global size

RV VOLUME BY 2D … which A4C view?

Rudsky et al, J Am Soc Echocardiogr 2010;23:685

2D Echocardiography

RV EDD basal: 24-42 mm → now 25-41 mm
RV EDD mid: 20-35 mm
RV EDD long: 56-86 mm

Rudsky et al, J Am Soc Echocardiogr 2010;23:685
Measurement of RV Dimensions

- **Midcavitary dimension (RV2)**
  (middle third of the RV at the papillary muscle level)

- **Basal dimension (RV1)**
  (maximal dimension of the RV in the basal 1/3 of RV)

- **Longitudinal dimension (RV3)**
  (from middle of TV to RV apex)

**Table 8 Normal values for RV chamber size**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Mean ± SD</th>
<th>Normal range</th>
</tr>
</thead>
<tbody>
<tr>
<td>RV basal diameter (mm)</td>
<td>33 ± 4</td>
<td>25-41</td>
</tr>
<tr>
<td>RV mid diameter (mm)</td>
<td>27 ± 4</td>
<td>19-39</td>
</tr>
<tr>
<td>RV longitudinal diameter (mm)</td>
<td>71 ± 5</td>
<td>59-83</td>
</tr>
<tr>
<td>RVOT PLAX diameter (mm)</td>
<td>25 ± 2.5</td>
<td>20-30</td>
</tr>
<tr>
<td>RVOT proximal diameter (mm)</td>
<td>28 ± 3.5</td>
<td>21-35</td>
</tr>
<tr>
<td>RVOT distal diameter (mm)</td>
<td>22 ± 2.5</td>
<td>17-27</td>
</tr>
<tr>
<td>RV wall thickness (mm)</td>
<td>3 ± 1</td>
<td>1-5</td>
</tr>
<tr>
<td>RVOT EDA (cm²)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Man</td>
<td>17 ± 3.5</td>
<td>10-24</td>
</tr>
<tr>
<td>Woman</td>
<td>14 ± 3</td>
<td>8-20</td>
</tr>
<tr>
<td>RV EDA indexed to BSA (cm²/m²)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Man</td>
<td>8.8 ± 1.9</td>
<td>5-12.6</td>
</tr>
<tr>
<td>Woman</td>
<td>8.0 ± 1.75</td>
<td>4.5-11.5</td>
</tr>
<tr>
<td>RV ESA (cm²)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Man</td>
<td>9 ± 3</td>
<td>3-15</td>
</tr>
<tr>
<td>Woman</td>
<td>7 ± 2</td>
<td>3-11</td>
</tr>
<tr>
<td>RV ESA indexed to BSA (cm²/m²)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Man</td>
<td>4.7 ± 1.36</td>
<td>2.0-7.4</td>
</tr>
<tr>
<td>Woman</td>
<td>4.0 ± 1.2</td>
<td>1.6-6.4</td>
</tr>
<tr>
<td>RV EDV indexed to BSA (mL/m²)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Man</td>
<td>61 ± 13</td>
<td>35-87</td>
</tr>
<tr>
<td>Woman</td>
<td>53 ± 10.5</td>
<td>32-74</td>
</tr>
<tr>
<td>RV ESV indexed to BSA (mL/m²)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Man</td>
<td>27 ± 8.5</td>
<td>10-44</td>
</tr>
<tr>
<td>Woman</td>
<td>22 ± 7</td>
<td>8-36</td>
</tr>
</tbody>
</table>


*asecho.org*
Right Ventricle-Focused View

- Adjust from usual focus on LV
- Rotate tsdr until max plane obtained
- Aim to see RV lateral wall

RV Basal Diameter

<table>
<thead>
<tr>
<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>2010</td>
<td>10</td>
<td>24 (21-27)</td>
<td>33 ± 2</td>
<td>42 (39-45)</td>
</tr>
<tr>
<td>2015</td>
<td>12</td>
<td>33 ± 4</td>
<td>41 (25-41)</td>
<td></td>
</tr>
</tbody>
</table>

LRV – lower reference value
URV – upper reference value

Rudski J Am Soc Echocardiogr 2010;23:685-713
### RV Size - Reference Values (cm)

<table>
<thead>
<tr>
<th></th>
<th>Ref Range</th>
<th>Mildly Abnl</th>
<th>Mod Abnl</th>
<th>Severely Abnl</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>RV dimensions</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Basal RV diameter</td>
<td>2.0–2.8</td>
<td><strong>2.9–3.3</strong></td>
<td>3.4–3.8</td>
<td>≥3.9</td>
</tr>
<tr>
<td>Mid-RV diameter</td>
<td>2.7–3.3</td>
<td><strong>3.4–3.7</strong></td>
<td>3.8–4.1</td>
<td>≥4.2</td>
</tr>
<tr>
<td>Base-to-apex length</td>
<td>7.1–7.9</td>
<td><strong>8.0–8.5</strong></td>
<td>8.6–9.1</td>
<td>≥9.2</td>
</tr>
<tr>
<td><strong>RVOT diameters</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Above aortic valve</td>
<td>2.5–2.9</td>
<td>3.0–3.2</td>
<td>3.3–3.5</td>
<td>≥3.6</td>
</tr>
<tr>
<td>Above pulm valve</td>
<td>1.7–2.3</td>
<td>2.4–2.7</td>
<td>2.8–3.1</td>
<td>≥3.2</td>
</tr>
</tbody>
</table>

Foale Br Heart J 56:33(1986) → 41 “normal” adults (age 19–46; 32 yrs)

### RV-Focused View

Case 57

RV thickness = 1 cm

RV Function
Functions of LV and RV ARE Different

RV
Low pressure system
< 1/10 resistance to flow of systemic bed

LV

RV Physiology

• Thin free wall and crescentic shape impart high degree of compliance

• Ability to accommodate large volumes

• Low vascular impedance of pulm circul’n
  (PVR ≈ 1/10 SVR)
Right Ventricular Physiology

- RV suited to eject across low resistance of the pulmonary circuit
- Performs at a lower dP/dt than the LV
- RV wall motion not like LV:
  - LV → all walls and base move more or less equally toward the center
  - RV → base-to-apex shortening more pronounced
- RV ejection is a complex mechanism

RV Ejection is Complex
Several Components

1. Contraction along long-axis (TV toward apex) ++++
2. Inward movement of RV free wall ++
3. Bulging of septum into RV chamber +
4. Circumferential contraction of RV outflow tract +
Visual assessment of RV function is inadequate

RV Systolic Function
Echo Methods of Assessing

- Visual assessment ("gestalt")
- Fractional area shortening
- TAPSE
- Tissue Doppler imaging of RV free wall (S’)
- Tei index
- RV dP/dt from TR signal
- RV strain and strain rate
- RV acceleration time
RV Contraction

- Predominantly longitudinal shortening
- RV outflow tract plays minor role
- Twisting and rotational movements do not contribute significantly
Parameters of RV Function - Feasibility

50 patients with ARDS in ICU with mechanical ventilation

<table>
<thead>
<tr>
<th>Parameter</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>RVEDA/LVEDA</td>
<td>72</td>
</tr>
<tr>
<td>RV-FAC</td>
<td>62</td>
</tr>
<tr>
<td>TAPSE</td>
<td>96</td>
</tr>
<tr>
<td>TDI-S'</td>
<td>96</td>
</tr>
</tbody>
</table>

Fichet Echocardiography 2012;29:513-21

RV Function

<table>
<thead>
<tr>
<th>RV FAC</th>
<th>RV MPI</th>
</tr>
</thead>
<tbody>
<tr>
<td>![Images of End-Diastole and End-Systole]</td>
<td>![Images of RVET, ICT, IRT]</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>TAPSE</th>
<th>TV Annular S'</th>
</tr>
</thead>
<tbody>
<tr>
<td>![Images of TAPSE measurement]</td>
<td>![Images of Ea, Aa]</td>
</tr>
</tbody>
</table>
**RV Function**

**Tricuspid Annular Plane Systolic Excursion**

- Descent of RV base toward relatively fixed apex
- Represents function of longitudinal muscles
- Apical 4-chamber view
- 2D-echo and TEE

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**Tricuspid Annular Plane Systolic Excursion (TAPSE)**
Advantages of TAPSE

- Highly feasible and easy
- Highly reproducible
- Numerical
- Not affected by dropout or trabeculations
- Reflects longitudinal RV shortening

TAPSE - Limitations

- Angle dependency
- Atrial fibrillation $\rightarrow$ $\downarrow$TAPSE; $\rightarrow$ NSR $\uparrow$TAPSE
- Patients on ventilators
- Highly dependent on RV loading conditions (may become pseudo-normalized)
- Ventricular interdependence
Strong Correlation between FAC and TAPSE

\[ y = 0.0283x + 0.6891 \]

\[ R = 0.73 \]

\[ P < 0.0001 \]

TAPSE good
FAC bad

TAPSE bad
FAC good
Correlation between RV EF (CMR) and TAPSE (Echo)

![Graph showing the correlation between RV ejection fraction by MRI and TAPSE.](image)


RVF Is Not the Sole Determinant of TAPSE

![Bar chart showing TAPSE values for different conditions.](image)

Lopez-Candeles Am J Cardiol 2006;98:973-977
### Recommended Measures of RV Function
**Summary of Reference Limits (2015)**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Abnormal</th>
</tr>
</thead>
<tbody>
<tr>
<td>TAPSE</td>
<td>&lt;1.7 cm</td>
</tr>
<tr>
<td>Pulsed Doppler peak velocity (S’)</td>
<td>&lt;9.5 cm/s</td>
</tr>
<tr>
<td>(at the annulus)</td>
<td></td>
</tr>
<tr>
<td>Pulsed Doppler MPI</td>
<td>&gt;0.43</td>
</tr>
<tr>
<td>Tissue Doppler MPI</td>
<td>&gt;0.54</td>
</tr>
<tr>
<td>FAC</td>
<td>&lt;35 %</td>
</tr>
</tbody>
</table>

MPI = myocardial performance index

### Prognostic Value of TAPSE in CHF
(Idiopathic or Ischemic Cardiomyopathy)

**Event-free survival**

- tapse > 14
- tapse ≤ 14

* death or emergency transplantation

Ghio Am J Cardiol 2000;85:837-42
TAPSE Predicts Survival in Pulmonary Hypertension

Relation between Mortality and TV Annulus Motion in RV Infarction

Forfia Am J Respir Crit Care 2006;174(9):1034-41

Samad Am J Cardiol 2002;90:778
Recommended Apical 4-Chamber View (1*)

Sensitivity of RV size to angular change
RV Fractional Area Change

\[ \text{FAC} = \frac{32 - 16}{32} = 50\% \]

Recommended Measures of RV Function

Summary of Reference Limits (2015)

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</tr>
<tr>
<td><strong>FAC</strong></td>
<td>&lt;35 %</td>
</tr>
</tbody>
</table>

MPI = myocardial performance index
S’ (TDI)

Pulsed Tissue Doppler Imaging
Tricuspid Annular Velocity Profile
TDI of Tricuspid Annulus
(normal RV systolic function)

Evaluation of RV Systolic Function
TDI of Tricuspid Annulus

- Simple rapid method
- Feasibility high (>95%)
- Primarily reflects function of longitudinal myocardial fibers
- Peak systolic annular velocity correlates with RV ejection fraction (MUGA)
- Normal peak systolic velocity > 9.5 cm/s
Evaluation of RV Systolic Function
Limitations of TDI of Tricuspid Annulus

- Primarily reflects function of longitudinal myocardial fibers

- Influenced not only by myocardial function, but also by translational and rotational motion of the whole heart (but, LV translational motion and rotation in the long-axis is not important)

- Peak systolic TV annular velocity is load dependent

Kaplan-Meier Curves for Subgroups Stratified by Pulsed Wave Systolic Tissue Doppler Imaging (PSV_{tdi})
## RV Systolic Function

<table>
<thead>
<tr>
<th>Metric</th>
<th>2010</th>
<th>2015</th>
</tr>
</thead>
<tbody>
<tr>
<td>TAPSE</td>
<td>&lt; 16 mm</td>
<td>&lt; 17 mm</td>
</tr>
<tr>
<td>S’</td>
<td>&lt;10 cm/s</td>
<td>&lt; 9.5 cm/s</td>
</tr>
<tr>
<td>RIMP (PW Doppler)</td>
<td>&gt;0.40</td>
<td>&gt;0.43</td>
</tr>
<tr>
<td>RIMP (DTI)</td>
<td>&gt;0.55</td>
<td>&gt;0.54</td>
</tr>
<tr>
<td>FAC</td>
<td>&lt;35%</td>
<td>&lt;35%</td>
</tr>
</tbody>
</table>

Rudski J Am Soc Echocardiogr 2010;23:685-713
**TEI Index of Myocardial Performance Right Ventricle (RIMP)**

- Doppler-derived index of myocardial performance of RV (RIMP)
- Represents global RV function independent of ventricular geometry
- Indicated for patients with increased TR velocity ≥ 3.0 m/sec

**Calculation of TEI Index (RIMP)**

- Optimize right heart Doppler signals
- Measure pulm valve ejection time (PVET)
- Measure atrioventricular closure-opening (TV C-O)
- Calculate RIMP

\[
RIMP = \frac{TV \ C-O - PVET}{PVET}
\]
Calculation of TEI Index (RIMP)

\[
RIMP = \frac{TV\ C-O - PVET}{PVET}
\]

Example of RIMP Calculation

Measurements

<table>
<thead>
<tr>
<th>TVC – TVO</th>
<th>PVET</th>
</tr>
</thead>
<tbody>
<tr>
<td>440 msec</td>
<td>280 msec</td>
</tr>
</tbody>
</table>

\[
RIMP = \frac{TV\ C-TVO - PVET}{PVET} = \frac{440 \text{ msec} - 280 \text{ msec}}{280 \text{ msec}} = 0.57
\]

Normal values for RIMP

- >0.43 (PW Doppler)
- >0.55 (TDI)
Clinical Implication of ↑RIMP

- The higher the RIMP, the more abnormal the RV
- RIMP predicts survival in PHTN

IVC
Estimation of RV Pressure

<table>
<thead>
<tr>
<th>IVC diameter</th>
<th>Normal (0-5 [3] mm Hg)</th>
<th>Intermediate (5-10 [8] mm Hg)</th>
<th>High (10-20 [15] mm Hg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Collapse with sniff</td>
<td>≤ 21 cm</td>
<td>≤ 21 cm &gt;21 cm</td>
<td>&gt;21 cm</td>
</tr>
<tr>
<td></td>
<td>&gt;50%</td>
<td>&lt; 50% &gt;50%</td>
<td>&lt; 50%</td>
</tr>
</tbody>
</table>

Rudski J Am Soc Echocardiogr 2010;23:685-713

Estimation of RA Pressure

Limitation of IVC Assessment

Caveats

Dilatation of the IVC with normal RAP has been observed in athletes and in patients on mechanical ventilation
Secondary Indices of Elevated RA Pressure
(Use to downgrade or upgrade RV pressure)

• Restrictive filling
• Tricuspid E/e’ > 6
• Hepatic vein → diastolic predominance

Caution: • Athletes
• Patients on ventilators
RV Function
3D-Echo

- Possible to visualize entire RV and re-slice it in short-axis cuts
- Eliminates need for simple geometric model
- Resolution and wall delineation marginal, but improving
3D-Echo for RV Volumes

- Avoid RV trabeculae and moderator band
- 3DE tends to underestimate RV volumes compared to cardiac MRI

Interobserver Variability

Intraobserver variability = 1.23 mL or 2.0% of mean

Interobserver variability = 1.86 mL or 4.0% of mean


Intraobserver variability = 1.23 mL or 2.0% of mean

Case 7

RV infarct → McConnell's sign

The End