Quantitation of right ventricular dimensions and function

Tomasz Kukulski, MD PhD
Dept of Cardiology, Congenital Heart Disease and Electrotherapy
Silesian Medical University
Silesian Center for Heart Disease, Zabrze
Adults Echo Laboratory

I HAVE NO DISCLOSURE
Scope of presentation

- RV anatomy & morphology
- RV Size and shape measurements
- RV Functional measurements
- Echo Imaging methods: which technique?
- Strengths and limitations
Limitations in the assessment of RV morphology and function

- Complex RV geometry
- Increased RV endocardial trabeculation - endocardial borders are difficult to define
- Retrosternal position
- Load dependency of the majority of functional parameters
RV function – important facts

- RV outflow tract generates 81% of RV End-diastolic volume
- RV inflow tract generates 87% of RV Stroke volume
- Longitudinal fiber shortening of the inflow part is significantly higher than outflow part
Distinct RV structure & shape

From Rushmer RF, *Cardiovascular dynamics*, WB Saunders Co. 1970
Mechanisms of blood ejection

From Rushmer RF, *Cardiovascular dynamics*, WB Saunders Co. 1970
Determinants of RV function

- RV Preload
- RV Afterload
- contractility
- rhytm
- Synchronicity
- IAS, IVS shunts
- TR, PR
Right ventricle-focused view

Maximizing RV chamber size *

RV-focused view should be indicated in the ECHO report

# RV Chamber Measurements

![RV Chamber Diagram](image1.png)

**Table 2: Chamber dimensions**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Figure</th>
<th>Value 1</th>
<th>Value 2</th>
<th>Value 3</th>
<th>Value 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>RV basal diameter (mm)</td>
<td>7</td>
<td>10</td>
<td>376</td>
<td>24</td>
<td>33</td>
</tr>
<tr>
<td>RV mid cavity diameter (mm)</td>
<td>7</td>
<td>12</td>
<td>400</td>
<td>20</td>
<td>28</td>
</tr>
<tr>
<td>RV longitudinal diameter (mm)</td>
<td>7</td>
<td>12</td>
<td>359</td>
<td>56</td>
<td>71</td>
</tr>
<tr>
<td>RV end-diastolic area (cm²)</td>
<td>8</td>
<td>20</td>
<td>200</td>
<td>192</td>
<td>12</td>
</tr>
<tr>
<td>RVOT PLAX wall thickness (mm) (not shown)</td>
<td>9</td>
<td>302</td>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>RVOT PLAX diameter (mm)</td>
<td>8</td>
<td>12</td>
<td>405</td>
<td>18</td>
<td>25</td>
</tr>
<tr>
<td>RVOT proximal diameter (mm)</td>
<td>8</td>
<td>5</td>
<td>193</td>
<td>21</td>
<td>28</td>
</tr>
<tr>
<td>RVOT distal diameter (mm)</td>
<td>4</td>
<td>159</td>
<td>17</td>
<td>17</td>
<td>22</td>
</tr>
<tr>
<td>RA major dimension (mm)</td>
<td>10</td>
<td>8</td>
<td>267</td>
<td>34</td>
<td>44</td>
</tr>
<tr>
<td>RA minor dimension (mm)</td>
<td>10</td>
<td>8</td>
<td>715</td>
<td>26</td>
<td>35</td>
</tr>
<tr>
<td>RA end-systolic area (cm²)</td>
<td>10</td>
<td>8</td>
<td>283</td>
<td>10</td>
<td>14</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.*

RVOT measurements

RVOT proximal

RVOT distal
Clinical importance of RA size measurement

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>RA major dimension</td>
<td>cm</td>
<td>&gt;5.3</td>
</tr>
<tr>
<td>RA minor dimension</td>
<td>cm</td>
<td>&gt;4.4</td>
</tr>
<tr>
<td>RA end-systolic area</td>
<td>cm²</td>
<td>&gt;18</td>
</tr>
</tbody>
</table>

**Systolic function**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>TAPSE</td>
<td>cm</td>
<td>&lt;1.6</td>
</tr>
<tr>
<td>Pulsed Doppler peak velocity at the annulus</td>
<td>cm/s</td>
<td>&lt;10</td>
</tr>
<tr>
<td>Pulsed Doppler MPI</td>
<td>—</td>
<td>&gt;0.40</td>
</tr>
<tr>
<td>Tissue Doppler MPI</td>
<td>—</td>
<td>&gt;0.55</td>
</tr>
<tr>
<td>FAC (%)</td>
<td>%</td>
<td>&lt;35</td>
</tr>
</tbody>
</table>

**Diastolic function**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>E/A ratio</td>
<td>—</td>
<td>&lt;0.8 or &gt;2.1</td>
</tr>
<tr>
<td>E/E' ratio</td>
<td>—</td>
<td>&gt;6</td>
</tr>
<tr>
<td>Deceleration time</td>
<td>ms</td>
<td>&lt;120</td>
</tr>
</tbody>
</table>

**Fractional Area Change**

**FAC** – *Fractional Area Change* =

\[
\frac{(RVED \text{ area} - RVES \text{ area})}{(RVED \text{ area})} \times 100\%
\]

*Normal values: 35-59%*

*Kaul. S Am. Heart J. 1984*

*Trabeculation, tricuspid valve, chords should be included in the chamber*
Limitations of RV volume measurements using 2D echocardiography

The asymmetrical chamber is divided in slices having the same thickness; the volume of each slice = \textit{area} \times \textit{height}. The sum of slices gives the chamber volume.

- This is not feasible with echo: to calculate the volumes of slices, the chamber must be visualized in two orthogonal projection having a common long axis (do not exist for RV)

Gentzler et al., Circulation 1974
RA pressure estimation

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>
<tr>
<td>Secondary indices of elevated RA pressure</td>
<td></td>
<td></td>
<td>&lt;50%</td>
</tr>
<tr>
<td>Diastolic flow predominance in hepatic veins (systolic filling fraction &lt; 55%)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Ventricular interdependence

Excentricity index = \frac{\text{Long LV diameter}}{\text{Short LV diameter}}
Severe pulmonary hypertension

2-dimensional Echocardiography

EI

RA area
(MPI) Tei index - how to measure?

\[
\text{Tei index} = \frac{\text{ICT} + \text{IRT}}{\text{RVET}}
\]

Healthy normals:
- \(0.24 \pm 0.04\)
- \(0.28 \pm 0.04\)

Ischi et al.; \(n = 150\) children
Pediatric Cardiol 2000

Eidem et al. \(n = 37\) adults.
Am J Cardiol 2001
Assessment of PAH severity

Prognostic value of echo measurements based on multivariable analysis

- Pericardial effusion
- RA size (RA area index)
- Exscentricity index
- TEI index

ESC guidelines 2009
Tricuspid annulus motion

TAPSE - Tricuspid Anular Plane Systolic Movement

<16 mm
RV mechanical dysfunction

Mmode
Prognostic value of TAPSE

TAPSE < 14 mm

- Predictor of death
- or
- Cardiac transplantation

...in PH secondary to post-ischemic dilated cardiomyopathy

Ghio S et al. Am J Cardiol 2000

TAPSE < 18 mm

- 1 mm of Decrease in TAPSE
- =
- Increase of 17% in Death Risk

...even in patients with PAH

Forfia PR et al. AJCCRM 2006
Measurement of RVSP

RVSP = 4 x TR2 + RA pressure
How to estimate pulmonary artery pressure?

Systolic PA pressure
\[ = 4 \times TR^2 + RAP \]
\[ 4 \times 42 + 20 \text{ mmHg} = 80 \text{ mmHg} \]

RAP = 20 mmHg

End diastolic PA pressure
\[ = 4 \times (PR \text{ end diastolic velocity})^2 + RAP = 4 \times 32 + 20 = 56 \text{ mmHg} \]
Tissue Velocity Imaging

Colour Doppler

Curved M-mode

Pulsed Doppler

[Diagram showing Colour Doppler images at different anatomical levels: apical, medial, basal. Each section has a line graph indicating velocity values with corresponding markers for s, e, and a waves.]

[Curved M-mode showing velocity measurements with s, e, and a markers indicated.]

[Images of Pulsed Doppler waveforms at different points, indicating velocity changes.]
Age -dependence of RV diastolic velocities

Age vs regional RV wall e/a velocities ratio

\[ y = -0.0408x + 2.8385 \]
\[ R^2 = 0.5812 \quad r = -0.76 \]

\[ y = -0.0366x + 2.5979 \]
\[ R^2 = 0.4316 \quad r = -0.69 \]

\[ y = -0.0304x + 2.3264 \]
\[ R^2 = 0.3854 \quad r = -0.65 \]

Myocardial acceleration during isovolumic contraction

In studies in patients with conditions affected by RV function, RV IVA may be used, and should be measured at the lateral tricuspid annulus. RV IVA is not recommended as a screening parameter for RV systolic function in the general echocardiography laboratory population.

Vogel M et al., Circulation. 2002;105:1693-1699.)
Limitations of regional velocity measurements

- Tethering
- Traction
- Fibers shortening
- Pressure overload
- Volume overload
- Tricuspid ring motion
- Overall heart motion
- Frank-Starling mechanism
Donal et al. Echocardiographic right ventricular strain analysis in CHF.
Eur J Echocardiography 2007
RV free wall strain in pulmonary arterial hypertension

Rv free wall – longitudinal strain

Basal segment  Medial segment  Apical segment
RV longitudinal strain for RV dyssynchrony measurements in PAH pts

Lopez-Candales et al, Cardiovascular Ultrasound 2009
Relation between strain parameters and global RV function measures

Lopez-Candales et al, Cardiovascular Ultrasound 2009
RV Strain, strain rate applications - limitations

- Different results obtained by Speckle tracking and Doppler techniques
- Non-homogenous distribution within RV free wall in comparison to LV distribution
- In pulmonary hypertension pts - the lowest strain values in outflow part of RV wall
- Rapid increase in afterload result in systolic strain rate increase and systolic strain reduction
- Reduction in systolic strain reflects decrease in RV stroke volume
Summary

• A gradual shift to more quantitative approaches for the assessment of RV size and function will help standardize assessment of the right ventricle across laboratories and allow clinicians to better incorporate assessment of the right heart into an echocardiographic evaluation.

• Improvements in 3D imaging will result in increased use and have the potential to help in the clinical assessment of RV size and function.