IMAGING THE RIGHT VENTRICLE: What the Heart Failure Clinician Needs to Know

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Disclosures

- No relevant disclosures
Objectives

• Describe the advantages and pitfalls of non-invasive imaging for the diagnosis of pulmonary hypertension

• Describe currently available imaging tools for assessing right heart size and function in heart failure patients

• Identify emerging non-invasive techniques to assess right heart disease
Right Ventricle – Imaging Challenges

- Asymmetric geometry
- RV physiology
  - Load dependent
  - Compliant
  - Interventricular interactions
- No consensus ‘best’ metric for size and functional assessment
- Clinically and prognostically very important

Imaging Modalities Available

Echo  Cardiac MRI  CT  Nuclear
Echo Evaluation of Pulmonary Hypertension

1) Estimation of pulmonary artery systolic pressure
2) Assess secondary (morphologic and functional) right heart changes associated with PH
Pulmonary Artery Systolic Pressure Estimation

- Estimated RV systolic pressure (modified Bernoulli equation)
  \[ 4 \text{ (TR peak velocity)}^2 + \text{estimated RA pressure} \]

- RVSP ≈ PASP (no outflow obstruction)
- CVP ≈ RAP

### Estimated RAP

<table>
<thead>
<tr>
<th>Estimated RAP</th>
<th>IVC diameter</th>
<th>IVC collapsibility with forced inspiration</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 mmHg</td>
<td>≤ 2.1 cm</td>
<td>&gt;50%</td>
</tr>
<tr>
<td>8 mmHg</td>
<td>≤ 2.1 cm</td>
<td>&lt;50%</td>
</tr>
<tr>
<td></td>
<td>OR</td>
<td></td>
</tr>
<tr>
<td></td>
<td>&gt;2.1 cm</td>
<td>&gt;50%</td>
</tr>
<tr>
<td>15+ mmHg</td>
<td>&gt;2.1 cm</td>
<td>&lt;50%</td>
</tr>
</tbody>
</table>

- Continuous-wave Doppler of tricuspid valve regurgitation
- 2D or M-mode imaging of inferior vena cava

Rudski et al. JASE 2010;23:685
Pitfalls of PASP Estimation by Echo

- TR jet – adequate signal and proper alignment of Doppler angle

- Proper peak velocity measurement

- Severe TR causes rapid equalization of RV-RA pressure gradient – **underestimates** PASP

- Age, BMI and gender dependent
  Lack consensus cut-offs for grading severity

1) McQuillan et al. Circ 2001;104:2797, 2) Rudski et al. JASE 2010;23:685, 3) Courtesy of Dr. Sorin Piscaru, Mayo Clinic
Secondary PH Imaging Findings

- RV enlargement and/or systolic dysfnc
- Interventricular septal flattening
- RA enlargement
- Functional tricuspid regurgitation
- Low cardiac output
- Pericardial effusion

‘Notched’ RVOT Doppler flow profile in PH
Type of PH

Two patients with severely elevated PASP

Post-capillary PH

Pre-capillary PH
Post-Capillary PH

- Left heart evaluation
  - Chamber size
  - Wall thickness
  - Systolic function
  - Diastolic function
  - Valvular function

- Mixed etiology PH
Right Heart Size

RV Dimensions – Imaging window and transducer angle dependent

Rudski et al. JASE 2010;23:685
RV Systolic Function - TAPSE and RV S’

Tricuspid annular peak systolic excursion – AbN <17 mm

• Fast, Reproducible, Prognostic
• Surrogate for RV longitudinal function based upon TV annular movement
• Caveats and pitfalls
  • Translational motion, angle dependent, regional dysfunction, post-pericardiotomy

RV annular peak vel (S’) AbN <9 cm/sec

RV Systolic Function - FAC and RIMP

Fractional Area Change – AbN <35%

- Reproducible, Prognostic
- Monoplane assessment

RV Index of Myocardial Performance – AbN >0.45

- Prognostic
- Less reproducible
- Less reliable with ↑ RAP

Rudski et al. JASE 2010;23:685
RV Strain – Speckle-tracking Echo

Strain (deformation) = change in dimension over time

RV Fibre Orientation

RV Diastolic Function

- Echo parameters and cut-off values for defining abnormal RV diastolic function have been published.

- Reproducibility and clinical utility less well established compared with LV

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Abnormality Threshold</th>
</tr>
</thead>
<tbody>
<tr>
<td>E-wave decel time (msec)</td>
<td>&lt;119, &gt;242</td>
</tr>
<tr>
<td>E/A</td>
<td>&lt;0.8, &gt;2.0</td>
</tr>
<tr>
<td>e’ (cm/sec)</td>
<td>&lt;7.8</td>
</tr>
<tr>
<td>E/e’</td>
<td>&gt;6.0</td>
</tr>
</tbody>
</table>
Cardiac MRI

- Imaging standard for quantification of RV volumes and EF
- Fibrosis imaging using LGE
- Flow data using phase-contrast imaging
- Incremental value to echo
  - Technically difficult or discordant echo data
  - Need to quantify RV volumes and EF
  - Uncertainty regarding diagnosis, i.e. ARVC
- Limitations
  - Availability, cost

1) Shehata et al. AJR 2011;196:87, 2) Valsangiacomo et al. EHJ 2012;33:949, 3) Courtesy of Dr. Yoko Mikami, Calgary AB
Emerging Techniques – 3D Echo

- Validated against cardiac MRI
- Limitations
  - Dependent on image quality
  - Off-line analysis, less availability

EDV 127 mL
ESV 82 mL
SV 45 mL
EF 35%

1) Sugeng et al. JACC CV Imaging 2010;3:10, 2) Lang et al. JASE 2015;28:1
Emerging Techniques – 3D Strain

1) Courtesy of Dr. Alessandro Satriano, Calgary AB, 2) Smith et al. JACC 2014;64:41, 2
Emerging Techniques – V-A Coupling

- Non-invasive surrogate for invasive pressure-volume analysis to assess RV-PA coupling
- Has been reported as: TAPSE/PASP
- Prognostic of outcome in HFrEF, HFpEF and PAH
- Can assess at rest and with exercise

Summary - RV Imaging in Heart Failure

- Unique RV geometry and physiology create challenges for imaging evaluation and serial assessment.
- Echo is the most routinely used non-invasive tool to assess pulmonary artery pressure and right heart structural and functional changes for different types of PH and right heart disease.
  - Multiple parameters involved in quantitative assessment.
  - Subjective assessment remains an important component.
- CMR is the imaging standard for RV volume and EF quantification, in addition to tissue characterization and flow quantification.
- Emerging techniques include: 3D volumetric and strain imaging, V-A coupling analysis analysis at rest and with exercise.
Thank you

- Questions or comments?
- nmfine@ucalgary.ca
### PH Guidelines – Echo Assessment

<table>
<thead>
<tr>
<th>Peak tricuspid regurgitation velocity (m/s)</th>
<th>Presence of other echo ‘PH signs’\textsuperscript{a}</th>
<th>Echocardiographic probability of pulmonary hypertension</th>
</tr>
</thead>
<tbody>
<tr>
<td>\leq 2.8 or not measurable</td>
<td>No</td>
<td>Low</td>
</tr>
<tr>
<td>\leq 2.8 or not measurable</td>
<td>Yes</td>
<td>Intermediate</td>
</tr>
<tr>
<td>2.9–3.4</td>
<td>No</td>
<td>High</td>
</tr>
<tr>
<td>2.9–3.4</td>
<td>Yes</td>
<td>High</td>
</tr>
<tr>
<td>&gt;3.4</td>
<td>Not required</td>
<td>High</td>
</tr>
</tbody>
</table>

**A: The ventricles\textsuperscript{a}**

- Right ventricle/left ventricle basal diameter ratio \(>1.0\)
- Right ventricular outflow Doppler acceleration time <105 msec and/or midsystolic notching
- Flattening of the interventricular septum (left ventricular eccentricity index \(>1.1\) in systole and/or diastole)
- Early diastolic pulmonary regurgitation velocity \(>2.2\) m/sec

**B: Pulmonary artery\textsuperscript{a}**

- Inferior cava diameter \(>21\) mm with decreased inspiratory collapse \((<50\%\) with a sniff or \(<20\%\) with quiet inspiration)
- Right atrial area (end-systole) \(>18\) cm\(^2\)

**C: Inferior vena cava and right atrium\textsuperscript{a}**

- PA diameter \(>25\) mm.

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\textsuperscript{a} Galie et al. EHJ 2016;37:67
Echo Hemodynamic Right Heart Assessment

- Diastolic PAP = 4 (end PR vel)² + RAP
- Mean PAP = (0.61 x RVSP) + 1.95
- PVR = 10 x (pk TR vel/RVOT TVI) + 0.16

‘Notched’ RVOT Doppler flow profile in PH