3D Echocardiography in Right Ventricular Assessment: First Choice Imaging Modality?

Heleen B. van der Zwaan

EuroEcho Boedapest
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Characteristics of first choice imaging technique

Conclusions
Characteristics of first choice imaging technique

Conclusions
The right ventricle (RV): basics

- Complex geometry
- Thin-walled structure
- Many trabeculations
- Peristaltic contraction pattern from in- to outflow
(At risk for) RV dysfunction or failure

Importance RV function assessment

- Accurate quantification of RV volumes and EF → important, because it has diagnostic, prognostic, and therapeutic implications in everyday clinical practice.

- Clinical signs occur only when the right ventricle is already irreversibly and severely dilated.

→ Need for easy and reproducible imaging techniques to monitor function and to diagnose dysfunction early.
Properties of an ideal index of contractility

(1) Sensitive to changes in inotrophy
(2) Independent of load
(3) Independent of heart size and mass
(4) Easy and safe to apply
(5) Proven to be useful in the clinical setting

# Characteristic of indexes for ventricular function

<table>
<thead>
<tr>
<th>Index</th>
<th>Sensitive to Inotropic Changes</th>
<th>Dependence on Preload</th>
<th>Dependence on Afterload</th>
<th>Dependence on Heart Volume or Mass</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ejection fraction; fractional shortening</td>
<td>+++</td>
<td>+++</td>
<td>++++</td>
<td>++</td>
</tr>
<tr>
<td>End systolic volume or dimension</td>
<td>+</td>
<td>0</td>
<td>++++</td>
<td>++</td>
</tr>
</tbody>
</table>
| Afterload-corrected VCF              | +++                            | 0                     | 0                       | 0                                | +
| ESPVR                                | ++++                           | 0                     | 0                       | ++++                             | +
| End systolic stiffness               | ++++                           | 0                     | 0                       | 0                                | +
| Preload recruitable stroke work      | +++                            | 0                     | 0                       | ++                               | +
| dP/dt                                | ++++                           | ++                    | ++                      | ++                               | ++
- Characteristics of first choice imaging technique

- Conclusions
Assessment of RV function: 2D echo

Volumetric RV function assessment: 2D echo

→ No volumes and EF possible based on 2D echo

Pros and cons 2D echocardiography

- Non invasive, easy and safely applicable
- Widely available
- Large history in which proven to be very useful in clinical practice
- Good reproducibility

- No accurate estimation of RV volumes and EF

- (1) Sensitive to changes in inotrophy
- (2) Independent of load
- (3) Independent of heart size and mass
- (4) Easy and safe to apply
- (5) Proven to be useful in the clinical setting
Characteristics of first choice imaging technique

- 2D echo
- 3D echo
- Imaging RV
- CMR

Conclusions
Assessment of RV function: CMR
Assessment of RV function: CMR

End diastole

End systole
**Pros and cons CMR**

- **Non invasive technique**
- **Most accurate estimation of RV volumes and EF**
- **Reproducible technique**
- **Proven useful in clinical setting**

| 1. Sensitive to changes in inotrophy |
| 2. Independent of load |
| 3. Independent of heart size and mass |
| 4. Easy and safe to apply |
| 5. Proven to be useful in the clinical setting |

- **Limited availability**
- **High costs**
- **Time-consuming acquisition and analysis**

*Sugeng et al. JACC CV imaging 2010.*
*Bleeker et al. Heart 2006;92 Suppl 1:i19-26.*
Characteristics of first choice imaging technique

- 2D echo
- 3D echo
- Imaging RV
- CMR

Conclusions
Real-time 3D echo: transducers
Intra-thoracic position of the RV

The anterior wall and RV outflow tract are difficult to image using echocardiography!

Intra-thoracic position of the RV

Lateral (or modified) apical four chamber view

Real-time 3D echo: multiplane reconstruction
Real-time 3D echo: dataset analysis

TomTec RV analyse software
3D echo: feasibility

- 62 consecutive patients (27±10 years, 61% men)

<table>
<thead>
<tr>
<th>Diagnosis</th>
<th>Patients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tetralogy of Fallot</td>
<td>21</td>
</tr>
<tr>
<td>Pulmonary stenosis +/- VSD</td>
<td>5</td>
</tr>
<tr>
<td>Pulmonary atresia +/- VSD</td>
<td>3</td>
</tr>
<tr>
<td>Atrial correction for TGA</td>
<td>4</td>
</tr>
<tr>
<td>Arterial correction for TGA</td>
<td>3</td>
</tr>
<tr>
<td>Aortic valve stenosis/ insufficiency</td>
<td>10</td>
</tr>
<tr>
<td>Other</td>
<td>4</td>
</tr>
</tbody>
</table>

- Feasibility: \( \frac{51}{62} = 81\% \) well analyzable images

Bland-Altman comparison

<table>
<thead>
<tr>
<th>Metric</th>
<th>Mean</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>RV EDV (ml)</td>
<td>34</td>
<td>(-32 : 99)</td>
</tr>
<tr>
<td>RV ESV (ml)</td>
<td>11</td>
<td>(-43 : 66)</td>
</tr>
<tr>
<td>RV EF (%)</td>
<td>4</td>
<td>(-10 : 17)</td>
</tr>
</tbody>
</table>

3D echo: time consumption

* P < 0.001

RV function in pulmonary hypertension

RV function in pulmonary hypertension

RV function assessment after a half marathon

RV function in pulmonary hypertension

Reproducibility: 3D echo vs CMR

<table>
<thead>
<tr>
<th>Metric</th>
<th>3DE, mean bias (SD)</th>
<th>CMR, mean bias (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>EDV (mL)</td>
<td>−6.9 (17.6)</td>
<td>−0.4 (16)</td>
</tr>
<tr>
<td>EF (%)</td>
<td>1.3 (6.3)</td>
<td>−1.3 (5.4)</td>
</tr>
</tbody>
</table>
Identification of RV dysfunction

<table>
<thead>
<tr>
<th>CMR</th>
<th>Healthy controls*</th>
</tr>
</thead>
<tbody>
<tr>
<td>EDV&lt;sub&gt;ind&lt;/sub&gt;</td>
<td>86 ± 21</td>
</tr>
<tr>
<td>ESV&lt;sub&gt;ind&lt;/sub&gt;</td>
<td>35 ± 11</td>
</tr>
<tr>
<td>SV&lt;sub&gt;ind&lt;/sub&gt;</td>
<td>51 ± 12</td>
</tr>
<tr>
<td>EF</td>
<td>60 ± 6</td>
</tr>
</tbody>
</table>

* Mean ± SD

→ RV dysfunction:

- Ejection fraction < 48%;
- EDV<sub>ind</sub> > 129 ml;
- ESV<sub>ind</sub> > 58 ml.

2D versus 3D: ROC curves

Receiver operating characteristic curves

EF by 3D echo
Fractional area change
TAPSE

AUC
0.89
0.78
0.72
## 2D versus 3D: reproducibility (n=37)

<table>
<thead>
<tr>
<th>Variation coefficients</th>
<th>Inter-observer</th>
<th>Intra-observer</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>2D echo</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PSAX RVOT 1</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>PSAX RVOT 2</td>
<td>13</td>
<td>15</td>
</tr>
<tr>
<td>AP4C inlet</td>
<td>12</td>
<td>5</td>
</tr>
<tr>
<td>AP4C longe-axis</td>
<td>9</td>
<td>3</td>
</tr>
<tr>
<td>Area ED</td>
<td>11</td>
<td>5</td>
</tr>
<tr>
<td>Area ES</td>
<td>11</td>
<td>11</td>
</tr>
<tr>
<td>FAC</td>
<td>19</td>
<td>13</td>
</tr>
<tr>
<td><strong>M-mode</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TAPSE</td>
<td>6</td>
<td>5</td>
</tr>
<tr>
<td><strong>Real-time 3D echo</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EDV</td>
<td>10</td>
<td>6</td>
</tr>
<tr>
<td>ESV</td>
<td>13</td>
<td>11</td>
</tr>
<tr>
<td><strong>EF</strong></td>
<td>12</td>
<td>6</td>
</tr>
</tbody>
</table>
### Test-retest reproducibility

<table>
<thead>
<tr>
<th></th>
<th>Sonographer 1</th>
<th>Sonographer 2</th>
<th>Sonographer 1</th>
<th>Absolute mean difference</th>
<th>CoV</th>
<th>Absolute mean difference</th>
<th>CoV</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>EDV</strong></td>
<td>15 ± 13</td>
<td>12 ± 12</td>
<td>12 ± 12</td>
<td>7</td>
<td>7</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td><strong>ESV</strong></td>
<td>12 ± 12</td>
<td>7 ± 6</td>
<td>7 ± 6</td>
<td>7</td>
<td>7</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td><strong>SV</strong></td>
<td>13 ± 10</td>
<td>12 ± 10</td>
<td>12 ± 10</td>
<td>11</td>
<td>11</td>
<td>11</td>
<td>11</td>
</tr>
<tr>
<td><strong>EF</strong></td>
<td>5 ± 4</td>
<td>4 ± 3</td>
<td>4 ± 3</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>8</td>
</tr>
</tbody>
</table>

3D echocardiography using contrast

<table>
<thead>
<tr>
<th></th>
<th>Without contrast</th>
<th>With contrast</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Invisible</td>
<td>201 (26%)</td>
<td>166 (22%)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Barely visible</td>
<td>140 (18%)</td>
<td>120 (16%)</td>
<td></td>
</tr>
<tr>
<td>Visible</td>
<td>145 (19%)</td>
<td>143 (19%)</td>
<td></td>
</tr>
<tr>
<td>Optimal</td>
<td>279 (36%)</td>
<td>336 (44%)</td>
<td></td>
</tr>
</tbody>
</table>
3D transesophageal echocardiography

3D transesophageal echocardiography

Pros and cons 3D echocardiography

- Non invasive, easy and safely applicable
- Useful in clinical setting to rule out RV dysfunction
- Accurate estimation of RV volumes and EF


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(1) Sensitive to changes in inotrophy
(2) Independent of load
(3) Independent of heart size and mass
(4) Easy and safe to apply
(5) Proven to be useful in the clinical setting

- Not all patients are eligible to undergo echocardiography (feasibility 3D echo ± 80%)
- Learning curve use 3D echo
Conclusions

- Evidence is accumulating that 3D echocardiography is feasible, accurate, and a practical approach to assess RV size and function
- In case of important clinical decisions or suboptimal image quality: choose for additional imaging by CMR