Assessing right ventricular function with cardiac resonance imaging

Anton Vonk Noordegraaf
VU University Medical Center
Amsterdam
The Netherlands
Disclosures

• **Speakers fees:**
  GSK, Actelion, Pfizer, Bayer, Lilly

• **Advisory Board**
  Actelion, Pfizer, Bayer
Assessment of RV volume and function by means of MRI

- Mass
- Ventricular end diastolic volume
- Ventricular end systolic volume
- Systolic function measures
- Diastolic function measures
- Stroke volume
Flow measurements

- Stroke volume
- Distensibility
- Shunt
The prognostic value of MRI RV parameters in iPAH

64 patients

Baseline measurements
Catheterization
Cardiac MRI
6 MWT

54 survivors
10 deaths

1 year follow-up measurements
Catheterization
Cardiac MRI
6 MWT

45 survivors
9 deaths
19 deaths

Demographic variables
- Total number: 64
- Age (years): 43 ± 13
- Female/male: 47 (73%)/17 (27%)

Functional status
- NYHA functional class II, III, IV: 7 (11%), 44 (69%), 13 (20%)

Distance of 6MWT (m)
- 335 ± 125

Dyspnoea score (Borg index)
- 5 ± 2

Medication use
- Intravenous prostacyclin: 30 (47%)
- Endothelin receptor antagonists: 25 (39%)
- Sildenafil: 4 (6%)
- Calcium antagonists: 5 (8%)

Haemodynamic measurements
- Mean PAP (mmHg): 56 ± 13
- Mean right atrial pressure (mmHg): 10 ± 5
- PVRI (dyne s/cm²/m²): 588 ± 295

Prognostic value of MRI in 64 iPAH patients measured at baseline

(A) survival (%)

- SVI > 25 mL/m²
- SVI ≤ 25 mL/m²

P = 0.009

(B) survival (%)

- RV mass index < 59 g/m²
- RV mass index ≥ 59 g/m²

P = 0.059

(C) survival (%)

- RVEDVI < 84 mL/m²
- RVEDVI ≥ 84 mL/m²

P = 0.011

(D) survival (%)

- LVEDVI > 40 mL/m²
- LVEDVI ≤ 40 mL/m²

P = 0.016

Univariate analysis of the change over 1 year

A failing right ventricle dilates and reduces stroke volume

- Stroke volume \( \downarrow \)
- End diastolic pressure \( \uparrow \)
- End diastolic volume \( \uparrow \)

Humbert M Circulation. 2010
Benze RL, Circulation 2010
Right ventricular function assessed by MRI

• Reflects prognosis
Is the right ventricular function just a reflection of right ventricular afterload?
## Study population

<table>
<thead>
<tr>
<th>Follow-up population</th>
<th>N = 76</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Age, years</strong></td>
<td>50 ± 14</td>
</tr>
<tr>
<td><strong>Female, n</strong></td>
<td>63</td>
</tr>
<tr>
<td><strong>Diagnosis, n</strong></td>
<td></td>
</tr>
<tr>
<td>Idiopathic PAH</td>
<td>54</td>
</tr>
<tr>
<td>Familial PAH</td>
<td>5</td>
</tr>
<tr>
<td>Associated PAH</td>
<td></td>
</tr>
<tr>
<td>Connective tissue disease</td>
<td>11</td>
</tr>
<tr>
<td>Other</td>
<td>6</td>
</tr>
<tr>
<td><strong>NYHA, II / III / IV</strong></td>
<td>37 / 34 / 5</td>
</tr>
</tbody>
</table>

M. Veerdonk et al, JACC (in press)
### Changes with follow-up

**N = 76**

<table>
<thead>
<tr>
<th>Catheterization</th>
<th>Baseline</th>
<th>Follow-up</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>mPAP</strong>, mmHg</td>
<td>50 ± 16</td>
<td>47 ± 16</td>
</tr>
<tr>
<td><strong>PVR</strong>, dyne·s·cm⁻⁵</td>
<td>772 ± 384</td>
<td>660 ± 378*</td>
</tr>
<tr>
<td><strong>Cardiac index</strong>, L·min⁻¹·m⁻²</td>
<td>2.7 ± 0.7</td>
<td>3.1 ± 1.2†</td>
</tr>
<tr>
<td><strong>6 MWT</strong>, m</td>
<td>421 ± 117</td>
<td>425 ± 138</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>MRI</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>RVEDV</strong>, mL</td>
<td>127 ± 36</td>
<td>133 ± 45</td>
</tr>
<tr>
<td><strong>RVEF</strong>, %</td>
<td>35 ± 10</td>
<td>36 ± 13</td>
</tr>
<tr>
<td><strong>SV</strong>, mL</td>
<td>49 ± 14</td>
<td>51 ± 16</td>
</tr>
</tbody>
</table>

* *p* < 0.001; † *p* < 0.05

M. Veerdonk et al, JACC (in press)
Poor relation between changes in PVR and changes in RVEF

M. Veerdonk et al, JACC (in press)
Similar changes in PVR

Relative change in PVR:
survivors $-12\%$, non-survivors $-11\%$
$p = 0.86$

Relative change in RVEF:
survivors $+10\%$, non-survivors $-21\%$
$p < 0.01$
Patients with decreased PVR (red dots) will be included in the next analysis
Patients with decreased PVR (n=52)

Both groups showed similar decrease in PVR

- PVR: -287 ± 220
- PVR: -250 ± 172
Right ventricular function assessed by MRI

- Reflects prognosis

- Can deteriorate despite a reduction in pulmonary vascular resistance
Can we simplify 3 D to 2 D?

End diastole

End-systole

What is the relevance of the transversal shortening?
Transverse Shortening

Transverse movements of the right ventricle

Changes in RV geometrical shortening over time

- 42 PAH patients diagnosed between 2003 and 2005
- All patients underwent baseline and follow up MRI and RHC after 1 year.
- Definitions:
  - Non-survivors: survival between 1 - 5 years
  - Survivors: survival of >5 years (served as comparison)

## MRI parameters

<table>
<thead>
<tr>
<th></th>
<th>Survivors</th>
<th></th>
<th>Non Survivors</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Baseline</td>
<td>Follow-up</td>
<td>Baseline</td>
<td>Follow-up</td>
</tr>
<tr>
<td><strong>RVEDV</strong></td>
<td>74 ± 21</td>
<td>71 ± 21</td>
<td>80 ± 31</td>
<td>94 ± 39*</td>
</tr>
<tr>
<td><strong>RVEF</strong></td>
<td>35 ± 11</td>
<td>33 ± 12</td>
<td>28 ± 9</td>
<td>19 ± 7*</td>
</tr>
<tr>
<td><strong>SVI</strong></td>
<td>28 ± 9</td>
<td>27 ± 10</td>
<td>24 ± 7</td>
<td>19 ± 7*</td>
</tr>
<tr>
<td><strong>LVEDVI</strong></td>
<td>43 ± 12</td>
<td>44 ± 15</td>
<td>39 ± 13</td>
<td>32 ± 11*</td>
</tr>
</tbody>
</table>

Mauritz GJ et al, Chest (in press)
Mauritz GJ et al, Chest (in press)
Follow up in non-survivors: free wall and septum separate

Mauritz GJ et al, Chest (in press)
Right ventricular function by MRI

- Reflects prognosis
- Can deteriorate despite a reduction in pulmonary vascular resistance
- Changes in transversal shortening reflects better worsening of right ventricular function than longitudinal changes
Advances in RV imaging
Delayed contrast enhancement of the myocardium

McCann GP et al. AJR 2007;188:349-55
Strain analysis

Shehata ML et al., AJR 2011; 196: 87-94
Reduced myocardial perfusion reserve contributes to RV dysfunction in PAH

MRI

One-Stop Shop for the Comprehensive Assessment of Pulmonary Arterial Hypertension?

A
Pulmonary Arteries (PA)
- Structure (angiography)
- Function (perfusion)

Left: MRI pulmonary angiogram using a gadolinium injection from a peripheral vein. Note the lack of branching and obliteration of vessels (explaining the "pruning" seen in CXR). Right: An MRI protocol studying lung perfusion. Areas of decreased perfusion (a) in blue compared to an area of high perfusion (b) is brown as in the perfusion in the descending aorta. A scale corresponding to lung perfusion is shown on the right. *Courtesy of Richard Thompson, University of Alberta.

B
Right ventricle (RV)
- Structure (mass, volume)
- Function (systolic/diastolic)
- Perfusion

Standard protocols trace RV epicardial and endocardial surface to estimate RV mass (left) and stacked images to measure volumes in systole and diastole (right). These can be performed in the same setting with the studies in A and C.

C
PA-RV
Molecular Imaging:
- Stem cells, viruses tracking
- In vivo apoptosis imaging

Left: Linking annexin-V to superparamagnetic iron oxide particles allows for localization and quantification of apoptosis with in vivo imaging. (taken from ref 18 with permission)
Right: T2 relaxation shows the lowest T2 in the region of iron-labeled mesenchymal stem cells injection, in the myocardium. The color map corresponds to T2* values indicated on the scale. (taken from ref 17 with permission)

Right ventricular function assessment by MRI

- Reflects prognosis
- Can deteriorate despite a reduction in pulmonary vascular resistance
- Changes in transversal shortening reflects worsening of right ventricular function
- Holds a promise for the future
Acknowledgements

• Tim Marcus
• Yuen Ying Wong
• Frances de Man
• Bart Boerrighter
• Gert Jan Mauritz
• Taco Kind
• Pia Trip
• Gerrina Ruiter

• Anco Boonstra
• Harm Jan Bogaard
• Pieter Postmus