Right Heart Catheterization

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Right Heart Catheterization

- Pressure measurements
- Oxygen saturation measurements
  - Cardiac output, Vascular resistance
  - Shunt calculation
  - Hemodynamic assessment of left and right heart (i.e. filling pressures)
- Angiography
  - Pulmonary angiography
  - RV Angiography
- Endomyocardial biopsy
<table>
<thead>
<tr>
<th>Recommendations</th>
<th>Class</th>
<th>Level</th>
<th>Ref.</th>
</tr>
</thead>
<tbody>
<tr>
<td>RHC is recommended to confirm the diagnosis of pulmonary arterial hypertension (group 1) and to support treatment decisions</td>
<td>I</td>
<td>C</td>
<td></td>
</tr>
<tr>
<td>In patients with PH, it is recommended to perform RHC in expert centres (see section 12) as it is technically demanding and may be associated with serious complications</td>
<td>I</td>
<td>B</td>
<td>69</td>
</tr>
<tr>
<td>RHC should be considered in pulmonary arterial hypertension (group 1) to assess the treatment effect of drugs (Table 16)</td>
<td>IIa</td>
<td>C</td>
<td></td>
</tr>
<tr>
<td>RHC is recommended in patients with congenital cardiac shunts to support decisions on correction (Table 24)</td>
<td>I</td>
<td>C</td>
<td></td>
</tr>
<tr>
<td>RHC is recommended in patients with PH due to left heart disease (group 2) or lung disease (group 3) if organ transplantation is considered</td>
<td>I</td>
<td>C</td>
<td></td>
</tr>
<tr>
<td>When measurement of PAWP is unreliable, left heart catheterization should be considered to measure LVEDP</td>
<td>IIa</td>
<td>C</td>
<td></td>
</tr>
<tr>
<td>RHC may be considered in patients with suspected PH and left heart disease or lung disease to assist in the differential diagnosis and support treatment decisions</td>
<td>IIb</td>
<td>C</td>
<td></td>
</tr>
<tr>
<td>RHC is indicated in patients with CTEPH (group 4) to confirm the diagnosis and support treatment decisions</td>
<td>I</td>
<td>C</td>
<td></td>
</tr>
</tbody>
</table>

Right Heart Catheterization

Recommendations ESC Guidelines 2016

Eur Heart J 2016;37:67-119
Right Heart Catheterization Recommendations ESC Guidelines 2016

- Confirmation of diagnosis
- In IPAH to assess treatment effect of drugs
- In patients with congenital shunt
- In patients with PHTN due to left heart disease
- In patients with PHTN and lung disease
- In CTEPH patients

- RHC is recommended to perform in expert centres

Eur Heart J 2016;37:67-119
Complications of Right Heart Catheterization

**Vascular access complications**
- Vasovagal reaction
- Arterial puncture
- Arteriovenous fistula
- Bleeding from insertion site
- Nerv injury
- Air embolism
- Pneumothorax, hemothorax (subclavian, internal jugular vein approach)

**Related to catheter insertion**
- Arrhythmias (supraventricular tachycardia, ventricular premature beats, VT, VF)
- Right bundle branch block or complete heart block
- Injury to chordae in right ventricle
- Tricuspid regurgitation
- Dislodgement of pacemaker leads
- PA rupture/right ventricular perforation

**Related to catheter residence**
- PA rupture
- Pulmonary infarction
- Thrombosis
- Infection/endocarditis/thrombophlebitis
- Balloon rupture / embolization

Eberli FR in Cardiac Catheterization .. Mukerjee D et al Informa Health Care 2010
Right Heart Catheterization

Window into the left heart

Eberli FR in Cardiac Catheterization .. Mukerjee D et al Informa Health Care 2010
RHC: Prerequisites for Correct Pressure Measurements

- Proper catheter
  - Large lumen, correct stiffness
  - Appropriate frequency response
- High quality pressure transducer
- Transducer positioned at the level of the left atrium
  - Halfway between the sternum and the bed surface
Right Heart Catheterization
Swan-Ganz-Catheter
A) Resolution of a Normal Ventricular Pressure Tracing into its first 10 Harmonics by Fourier Analysis

B) Effect of Frequency Response

Measurement of LV Pressure by Swan Ganz Catheter Advanced Through ASD into LA and LV

Underdamping of soft Swan Ganz Catheter
## Hemodynamic Definition of Pulmonary Hypertension

<table>
<thead>
<tr>
<th>Definition</th>
<th>Characteristics&lt;sup&gt;a&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>PH</td>
<td>PAPm ≥25 mmHg</td>
</tr>
<tr>
<td>Pre-capillary PH</td>
<td>PAPm ≥25 mmHg, PAWP ≤15 mmHg</td>
</tr>
<tr>
<td>Post-capillary PH</td>
<td>PAPm ≥25 mmHg, PAWP &gt;15 mmHg</td>
</tr>
<tr>
<td>Isolated post-capillary PH (Ipc-PH)</td>
<td>DPG &lt;7 mmHg and/or PVR ≤3 WU&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>Combined post-capillary and pre-capillary PH</td>
<td>DPG ≥7 mmHg and/or PVR &gt;3 WU&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

<sup>a</sup> Hemodynamic parameters used to define PH are typically measured at catheterization, including PAPm (mean pulmonary artery pressure), PAWP (pulmonary arterial wedge pressure), PVR (pulmonary vascular resistance), and DPG (pulmonary capillary wedge pressure).
Diastolic Pressure Gradient (dPAP-PCWP) 
Transpulmonary Gradient (mPAP-PCWP)

DPG: normal 1-5 mmHg, pathological >7 mmHg
TPG: normal 5-10 mmHg; pathological >12 mmHg
RHC: Prerequisites for Correct Pressure Measurements

• Measurement taking physiologic conditions into consideration
  • Inspiration/exspiration (transmission of intrathoracic pressures)
  • Supine position (obese person!)
  • Adrenergic state
  • Fluid status
Respiratory Changes of PCWP COPD Patient

Sharkey: A guide to interpretation... Lippincott 1997, page 36
Underestimation of LVEDP by Mean PCWP

<table>
<thead>
<tr>
<th>CONDITION</th>
<th>DISCREPANCY</th>
<th>CAUSE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decreased LV compliance</td>
<td>Mean LAP &lt; LVEPD</td>
<td>Mean LAP &lt; LVEPD</td>
</tr>
<tr>
<td>Aortic valve regurgitation</td>
<td>LAP a wave &lt; LVEDP</td>
<td>Mitral valve closure prior to end-diastole</td>
</tr>
<tr>
<td>Pulmonic valve regurgitation</td>
<td>PADP &lt; LVEDP</td>
<td>Bidirectional runoff for pulmonary artery flow</td>
</tr>
<tr>
<td>Right bundle branch block</td>
<td>PADP &lt; LVEDP</td>
<td>Delayed pulmonic valve opening</td>
</tr>
<tr>
<td>Decreased pulmonary vascular bed</td>
<td>PAWP &lt; LVEDP</td>
<td>Obstruction of pulmonary blood flow</td>
</tr>
</tbody>
</table>
Overestimation of LVEDP by mean PCWP

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<tr>
<th>CONDITION</th>
<th>DISCREPANCY</th>
<th>CAUSE</th>
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</thead>
<tbody>
<tr>
<td>PEEP</td>
<td>Mean PAWP &gt; mean LAP</td>
<td>Increased intrathoracic pressure</td>
</tr>
<tr>
<td>Pulmonary HTN</td>
<td>PADP &gt; mean PAWP</td>
<td>Increased PVR</td>
</tr>
<tr>
<td>Pulmonary veno-occlusive disease</td>
<td>Mean PAWP &gt; mean LAP</td>
<td>Obstruction to flow in large pulmonary veins</td>
</tr>
<tr>
<td>Mitral stenosis</td>
<td>Mean LAP &gt; LVEDP</td>
<td>Obstruction to flow across mitral valve</td>
</tr>
<tr>
<td>Mitral regurgitation</td>
<td>Mean LAP &gt; LVEDP</td>
<td>v wave raises mean PCWP</td>
</tr>
<tr>
<td>Tachycardia</td>
<td>PADP &gt; mean LAP &gt; LVEDP</td>
<td>Short diastole can create pulmonary vascular and mitral valve gradients</td>
</tr>
<tr>
<td>VSD</td>
<td>Mean LAP &gt; LVEDP</td>
<td>v wave raises mean PCWP</td>
</tr>
</tbody>
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Echocardiographic signs suggesting PHTN

<table>
<thead>
<tr>
<th>A: The ventricles(^a)</th>
<th>B: Pulmonary artery(^a)</th>
<th>C: Inferior vena cava and right atrium(^a)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Right ventricle/ left ventricle basal diameter ratio &gt; 1.0</td>
<td>Right ventricular outflow Doppler acceleration time &lt; 105 msec and/or midsystolic notching</td>
<td>Inferior cava diameter &gt; 21 mm with decreased inspiratory collapse (≤ 50% with a sniff or ≤ 20% with quiet inspiration)</td>
</tr>
<tr>
<td>Flatting of the interventricular septum (left ventricular eccentricity index &gt; 1.1 in systole and/or diastole)</td>
<td>Early diastolic pulmonary regurgitation velocity &gt; 2.2 m/sec</td>
<td>Right atrial area (end-systole) &gt; 18 cm(^2)</td>
</tr>
<tr>
<td>PA diameter &gt; 25 mm.</td>
<td></td>
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</tbody>
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## Echocardiographic Probability of PHTN in Patients with Suspected PHTN

<table>
<thead>
<tr>
<th>Peak tricuspid regurgitation velocity (m/s)</th>
<th>Presence of other echo ‘PH signs’ (^a)</th>
<th>Echocardiographic probability of pulmonary hypertension</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤2.8 or not measurable</td>
<td>No</td>
<td>Low</td>
</tr>
<tr>
<td>≤2.8 or not measurable</td>
<td>Yes</td>
<td>Intermediate</td>
</tr>
<tr>
<td>2.9–3.4</td>
<td>No</td>
<td></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></td>
</tr>
</tbody>
</table>

\(^a\) Presence of specific echo findings diagnostic of pulmonary hypertension.
How precise is estimation of PA pressure by tricuspid regurgitation velocity?

Tricuspid regurgitation velocity measured by CW-Doppler

Max Velocity = 4 m/sec.; RVP = 4.v^2 = 4.4.4.= 64 mmHg
Estimation of systolic PAP by Tricuspid Regurgitation Velocity (TRV)

- Systolic PAP = TRV + 10 mmHg
- Systolic PAP = TRV + RAP estimated on clinical grounds
- Systolic PAP = TRV + RAP estimated by cava index

- It is recommended to use continuous wave Doppler measurement of peak TRV (and not estimated systolic PAP) as the main variable for assigning the probability of PHTN
Comparison of Invasive vs Non-invasive Pressure Measurements of Tricuspid Regurgitation Velocity

Unadjusted

Measured RA pressure subtracted

Echocardiographic Assessment of Pulmonary Hypertension in Patients with Advanced Lung Disease


374 Pat with advanced lung disease evaluated for lung transplant
RHC and Doppler within 72h
52% overestimation (>10 mmHg difference), 48% erroneously diagnosed as having PHTN
Estimation of PA Pressure
Tricuspid Regurgitation Velocity

Chan et al. JACC 1987;9:549-554
Tricuspid Regurgitation Velocity Problems:

- 13-28% of patients have no TR
- CW Doppler does not indicate the origin of the gradient
- Correct alignment with TR jet not always possible
- SEE 0.89 in best study, less in others.
- Estimated pressure of 50 mmHg 95% confidence limits are 34-66 mmHg.
Goals of Invasive Assessment

- Confirm non-invasive estimation of pulmonary pressures
- Measurement of pressures and saturations in all heart chambers
- Find etiology of PHTN
- Test vasoreactivity, if indicated
- Plan therapy
- Assess prognosis
Adverse Prognostic Indicators in Primary Pulmonary Hypertension

Haemodynamic

- Pulmonary arterial oxygen saturation < 63%
  - >63%: 55% survival at 3 years
  - < 63%: 17% survival at 3 years

- Cardiac index < 2.1 l/min/m²
  - < 2.1: 17 months median survival

- Right atrial pressure > 10 mmHg
  - < 10 mmHg: 4 years mean survival
  - > 20 mmHg: 1 month mean survival

- Lack of pulmonary vasodilator response to acute challenge
Vasoreactivity Testing
ESC Guidelines

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<td>Vasoreactivity testing is indicated only in expert centres</td>
<td>I</td>
<td>C</td>
<td>69</td>
</tr>
<tr>
<td>Vasoreactivity testing is recommended in patients with IPAH, HPAH and PAH</td>
<td>I</td>
<td>C</td>
<td>84,85</td>
</tr>
<tr>
<td>associated with drugs use to detect patients who can be treated with high</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>doses of a CCB</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A positive response to vasoreactivity testing is defined as a reduction of</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>mean PAP ≥10 mmHg to reach an absolute value of mean PAP ≤40 mmHg with an</td>
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<td></td>
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<tr>
<td>increased or unchanged cardiac output</td>
<td></td>
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Vasoreactivity Testing
ESC Guidelines

A positive response to vasoreactivity testing is defined as a reduction of mean PAP $\geq$ 10 mmHg to reach an absolute value of mean PAP $\leq$ 40 mmHg with an increased or unchanged cardiac output.
### Vasoreactivity Tested with iv Prostaglandin E1

<table>
<thead>
<tr>
<th></th>
<th>HF min⁻¹</th>
<th>AOM mmHg</th>
<th>RA mmHg</th>
<th>MAP mmHg</th>
<th>PCWP mmHg</th>
<th>TPG mmHg</th>
<th>HZV L/min</th>
<th>PVR Dyn·s⁻¹·cm⁻⁵</th>
<th>SVR Dyn·s⁻¹·cm⁻⁵</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Baseline</strong></td>
<td>56</td>
<td>83</td>
<td>3</td>
<td>58</td>
<td>2</td>
<td>56</td>
<td>3.5</td>
<td>1280</td>
<td>1828</td>
</tr>
<tr>
<td><strong>150ng/kg/min</strong></td>
<td>75</td>
<td>75</td>
<td>4</td>
<td>62</td>
<td>2</td>
<td>60</td>
<td>4.9</td>
<td>979</td>
<td>1154</td>
</tr>
</tbody>
</table>

**No increase in stroke volume**

Baseline: 3500: 56 = 62.5 ml SV ; 150 ng/kg/min PGE₁ 4900:79 = 65.3ml SV

Decrease in PVR secondary to increased cardiac output. No decrease in pulmonary artery pressure or transpulmonary gradient. Increase in RA pressure indicating underlying RV dysfunction.

C.A. 30.4.1960
Right Heart Catheterization

Important diagnostic tool

In pulmonary hypertension:

– Echocardiography precedes RHC for assessing probability of PHTN and morphologic description of RV/LV
– RHC confirms the diagnosis through hemodynamic measurements
– RHC is necessary for vasoreactivity testing, if indicated
– RHC is an important and helpful complementary to imaging modalities in the diagnosis and treatment of PHTN patients.