Cardiac Catheterization is Unnecessary in the Evaluation of Patients with Pulmonary Hypertension:
CON

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Diagnostic Evaluation:
Right Heart Cardiac Catheterization ‘Gold Standard’

• Establish diagnosis
• Ascertain etiology
• Evaluate vasoreactivity
• Establish severity & prognosis
• Guide treatment

Pulmonary Arterial Hypertension

- Sustained elevation of mean pulmonary arterial pressure to > 25 mm Hg, with a mean pulmonary capillary and left atrial pressure < 15 mm Hg at rest
  - Pulmonary Vascular resistance > 3 Units X m²


Echo Doppler Estimate of PA pressure
Limitations of Doppler Estimate of PA Systolic Pressure

- Requires a good acoustic window
- Requires a good and properly aligned Doppler signal
- Tricuspid regurgitation has to be present
- Can be affected by incorrect assumption of right atrial pressure

Pulmonary Vein Stenosis IN BPD
Pulmonary Vein Stenosis

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What Is the Cause of Pulmonary Hypertension?

**Pulmonary Hypertension: Types**

- **Post-Capillary PH**
  - (PCWP>15 mmHg; PVR nl)
  - Atrial Myxoma
  - Cor Triatriatum
  - MV Disease

- **Pre-capillary PH (PAH)**
  - PCWP<15 mmHg
  - PVR > 3 Wu

- **Respiratory Diseases**
  - PE
  - PV compression
  - PVOD

- **Myocardial Disease**
  - Dilated CMP (ischemic/non-ischemic)
  - Hypertrophic CMP
  - Restrictive/infiltrative CMP
  - Obesity and others

- **Systemic HTN AoV Disease**

- **Infections**

**BPD and PAH**

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Treatment Overview

Incomplete response

Yes

No

Responder

Calcium Channel Blocker

Incomplete response

Incomplete response

Incomplete response

Incomplete response

Conventional treatment

Acute vasodilator response

Bosentan oral
Sildenafil oral
Tadalafil oral
Iloprost inhaled
Treprostinil SC
Treprostinil inhaled

Non Responder

Right heart failure

Responder

Calcium Channel Blocker

Incomplete response

Incomplete response

Incomplete response

Incomplete response

Combination of drugs

IV prostanoids
(Epoprostenol, Treprostinil)

Atrial septostomy

Transplantation

Pulmonary Vascular Reactivity Testing

• Acute response - Classic
  - Decrease in mPAP of at least 20%
  - with the PVR decreasing 20%
  - with no change or an increase in cardiac output

• Acute response - Revised
  - Decrease in mPAP of at least 10 mmHg
  - with the mPAP decreasing ≤ 40 mmHg
  - with a normal or high cardiac output
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Hemodynamics—NIH Registry

Hemodynamic Predictors of Survival in Patients With PPH: A National Prospective Registry

<table>
<thead>
<tr>
<th>Variable</th>
<th>Odds Ratio (95% CIs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Right atrial pressure (mean)</td>
<td>1.99 (1.47 – 2.69)</td>
</tr>
<tr>
<td>Pulmonary arterial pressure (mean)</td>
<td>1.16 (1.05 – 1.28)</td>
</tr>
<tr>
<td>Cardiac index</td>
<td>0.62 (0.46 – 0.82)</td>
</tr>
</tbody>
</table>


PAH Determinants of Risk

<table>
<thead>
<tr>
<th>Determinants of Risk</th>
<th>Lower Risk</th>
<th>Higher Risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clinical evidence of RV failure</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Progression</td>
<td>Gradual</td>
<td>Rapid</td>
</tr>
<tr>
<td>WHO class</td>
<td>II, III</td>
<td>IV</td>
</tr>
<tr>
<td>6MW distance</td>
<td>Longer (&gt;400 m)</td>
<td>Shorter (&lt;300 m)</td>
</tr>
<tr>
<td>BNP</td>
<td>Minimally elevated</td>
<td>Very elevated</td>
</tr>
<tr>
<td>Echocardiographic findings</td>
<td>Minimal RV dysfunction</td>
<td>Pericardial effusion, significant RV dysfunction</td>
</tr>
<tr>
<td>Hemodynamics</td>
<td>Normal/near normal RAP and CI</td>
<td>High RAP, low RAP</td>
</tr>
</tbody>
</table>

## Predictors of Outcome on Epoprostenol

<table>
<thead>
<tr>
<th>Variables</th>
<th>Hazard Ratio (95% CI)</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age &gt;44 yrs</td>
<td>1.17 (0.71-1.94)</td>
<td>0.535</td>
</tr>
<tr>
<td>Gender (female/male)</td>
<td>0.95 (0.53-1.71)</td>
<td>0.877</td>
</tr>
<tr>
<td>Anorexigenic (yes/no)</td>
<td>0.95 (0.55-1.65)</td>
<td>0.853</td>
</tr>
<tr>
<td>Raynaud’s phenomenon (presence/absence)</td>
<td>1.38 (0.72-2.65)</td>
<td>0.334</td>
</tr>
<tr>
<td>History of syncope (yes/no)</td>
<td>0.75 (0.44-1.35)</td>
<td>0.226</td>
</tr>
<tr>
<td>History of right-sided heart failure (yes/no)</td>
<td>2.19 (1.31-3.64)</td>
<td>0.003</td>
</tr>
<tr>
<td>NYHA FC IV vs III</td>
<td>2.24 (1.34-3.73)</td>
<td>0.002</td>
</tr>
<tr>
<td>Six-minute walk distance ≤250 m</td>
<td>2.20 (1.31-3.69)</td>
<td>0.003</td>
</tr>
</tbody>
</table>

### Baseline hemodynamics

| mRAP ≥12 mm Hg  | 2.74 (1.58-4.75) | 0.0003 |
| mPAP <55 mm Hg | 1.72 (1.04-2.86) | 0.036 |
| mPAP ≥55 mm Hg | 0.87 (0.51-1.55) | 0.323 |
| PAOP ≥300 mm Hg | 0.96 (0.56-1.59) | 0.879 |
| TPR ≥35 U/m²   | 0.65 (0.39-1.09) | 0.102 |
| mSAP <93 mm Hg | 1.24 (0.71-2.10) | 0.449 |
| Mean R wave    | 0.76 (0.43-1.34) | 0.349 |
| Heart rate     | 1.46 (0.83-2.55) | 0.734 |
| Svo2 ≤55%      | 1.54 (0.93-2.56) | 0.096 |

### NYHA FC III/IV vs I/II

| 8.75 (4.58-16.7) | <0.0001 |

### Six-minute walk distance <380 m

| 2.62 (1.45-4.74) | 0.001 |

### Increase in distance walked <112 m from baseline

| 1.09 (0.61-1.96) | 0.759 |

### Dose of epoprostenol achieved <14 ng/kg/min

| 0.60 (0.33-1.08) | 0.086 |

### mRAP >10 mm Hg

| 3.57 (1.65-7.71) | 0.001 |

### mPAP <59 mm Hg

| 1.94 (1.06-3.55) | 0.032 |

### Decrease in mPAP ≥10% relative to baseline

| 1.25 (0.69-2.27) | 0.462 |

### CI ≤2.4 L/min/m²

| 1.45 (0.79-2.66) | 0.231 |

### Increase in CI <0.5 L/min/m² relative to baseline

| 2.35 (1.33-4.53) | 0.010 |

### TPR <255 Um²

| 1.53 (0.82-2.85) | 0.185 |

### Decrease in TPR ≥30% relative to baseline

| 1.90 (1.02-3.54) | 0.041 |

### Svo2 ≤62%

| 2.54 (1.41-4.59) | 0.002 |

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## Diagnostic Evaluation: Right Heart Cardiac Catheterization

‘Gold Standard’

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Guide Treatment:

- Epoprostenol dosing
- Timing of listing for lung transplantation
- Timing for addition or change of therapy
- Performance of atrial septostomy