Catheterization for the infant with BPD and concern for PAH

Jack Rome, MD
March 9, 2017
Disclosures

Conflicts of Interest - none

However:

1. I am an interventional cardiologist
2. I am not a pulmonary hypertension specialist
   (when we review the list of patients who need to be added on for cath each day, I don’t always jump at the opportunity to do the BPD pts for r/o PAH)
What determines when we bring the patient to catheterization?

**AHA/ATS Guideline**

**Pediatric Pulmonary Hypertension**

Guidelines From the American Heart Association and American Thoracic Society

- Steven H. Abman, MD, Co-Chair; Georg Hansmann, MD, PhD, FAHA, Co-Chair;
- Stephen L. Archer, MD, FAHA, Co-Chair; D. Dunbar Ivy, MD, FAHA; Ian Adatia, MD;
- Wendy K. Chung, MD, PhD; Brian D. Hanna, MD; Erika B. Rosenzweig, MD;
- J. Usha Raj, MD; David Cornell, MD; Kurt R. Stemmark, MD;
- Robin Steinborn, MD, FAHA; Bernard Thébaud, MD, PhD; Jeffrey R. Fineman, MD;
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- Michael Earing, MD; Robyn J. Barst, MD; Roberta L. Keller, MD; John P. Kinsella, MD;
- Mary Mullin, MD, PhD; Robin Deterding, MD; Thomas Kulik, MD;
- George Mallory, MD; Tilman Humpl, MD; David L. Wessel, MD; on behalf of the American Heart Association Council on Cardiopulmonary, Critical Care, Perioperative and Resuscitation; Council on Clinical Cardiology; Council on Cardiovascular Disease in the Young; Council on Cardiovascular Radiology and Intervention; Council on Cardiovascular Surgery and Anesthesia; and the American Thoracic Society

**ORIGINAL ARTICLE**

Executive summary. Expert consensus statement on the diagnosis and treatment of paediatric pulmonary hypertension. The European Paediatric Pulmonary Vascular Disease Network, endorsed by ISHLT and DGPK

Georg Hansmann, (Chair)¹ Christian Apitz, (Co-Chair)² Hashim Abdul-Khalik,³ Tero-Pekka Alastalo,⁴,⁵ Phillip Beerbaum,¹ Damien Bonnet,⁶ Karl-Otto Dubowy,⁷ Matthias Gorenflo,⁸ Alfred Hager,⁹ Anne Hilgendorff,¹⁰ Michael Kaestner,¹¹ Martin Koestenberger,¹¹ Juha W Koskenvuo,¹² Rainer Kozlik-Feldmann,¹² Titus Kuehne,¹³ Astrid E Lammers,¹⁴ Heiner Latus,¹⁵ Ina Michel-Behnke,¹⁶ Oliver Miera,¹⁷ Shahin Moledina,¹⁸ Vivek Muthurangu,¹⁹ Joseph Pattathu,²⁰ Dietmar Schranz,¹⁵ Gregor Warnecke,²⁰,²¹ Peter Zartner²²

Circulation. 2015;132:2037-2099

Cardiac catheterisation is indicated in all paediatric patients with pulmonary hypertension (PH) to confirm diagnosis, to evaluate the severity and when PH-specific drug therapy is considered.
Management of PH in BPD/nCLD

Screening Echocardiogram*
Consider drawing NT-proBNP

(-)

(+)

Oxygen saturation ≥ 93% (suspected PH^^), ≥ 95% (proven PH^^)
PH friendly ventilation strategies, consider diuretics

1 month
Clinical re-evaluation
Repeat Echo
Consider repeat NT-proBNP

Better
Worse
Borderline

Improved clinical status & ECHO
(Decreased NT-proBNP)

Worsened/unchanged clinical status & ECHO (TRjet>2.5m/sec)
(Increased NT-proBNP)

Improved/unchanged clinical status & ECHO
(Increased NT-proBNP)

Start sildenafil

1 month
Clinical re-evaluation
Repeat Echo
Repeat NT-proBNP

Better
Worse
Borderline

Improved clinical status & ECHO
(Decreased NT-proBNP)

Worsened/unchanged clinical status & ECHO (TRjet>2.5m/sec)
(Increased NT-proBNP)

Improved/unchanged clinical status & ECHO
(Increased NT-proBNP)

Start bosentan

If still suboptimal response after 4-6 weeks proceed to cardiac catheter study

Suggested screening criteria:
Context

"Primary Pulmonary Hypertension" with Vasoreactivity
Study: 2014-2017

Total of 161 procedures, 48 (30%) < 1y
Denominator: ~1300 procedures/yr
Indications for Catheterization in BPD
(should really leave to others)
• Evidence on echocardiography of PAH with concern for other “treatable” lesion
  • PDA, ASD, PVV stenosis
• Evidence of PAH with consideration for high risk medical therapy of pulmonary hypertension
• Plan for chronic pulmonary vasodilator rx.

Contraindication for Cath
• Patient in who predicted mortality is high regardless of what one does or does not do.
The patient’s level of consciousness during cardiac catheterisation should be consistent in subsequent invasive assessments.

The preferred mode to perform cardiac catheterisation in a patient PH/PHPHD who is spontaneously breathing, either awake or moderately sedated.

Vasoreactivity testing should be performed using nitric oxide as vasodilator.

Vasoreactivity testing with the initial combination of nitric oxide and oxygen is reasonable and shortens the AVT study.

That would go well
BPD/PAH Anesthetic Considerations*

• Residual pulmonary parenchymal disease
• Echo evidence of RV hypertension/RV dysfunction
• Electrolyte indications of compensated chronic respiratory acidosis
• Acquired large airway disease (stenosis, malacia, or combination)

* James Steven, MD Director of Cardiac Anesthesia
CHOP Anesthesia approach

- Sedative premedication: light if significant residual pulmonary disease or severe PAH
- Intravenous induction with ketamine safest
- Controlled ventilation: target top-normal pH (often requires permissive hypercapnia in chronic respiratory acidosis)
- Minimal supplemental oxygen at baseline, but may require some
- Avoid respiratory depressant intravenous medications
- ICU surveillance post-cath if PVR significantly elevated and/or RV dysfunction
Interpretation trade-offs

• Light sedation/spontaneous respiration:
  • Most likely some respiratory depression that could adversely affect data
  • More difficult to rescue from “spells” or “crises”

• Controlled ventilation and volatile anesthetic:
  • Uncertainty about target ventilation goals might affect data
  • Residual anesthetic effect more easily eliminated
  • Less likely to have crises and easier to rescue if they do
Conduct of catheterization: Access

- Venous access
  - the right femoral vein
    - (think about for long-term access patients)
- Arterial
- In small infants femoral artery access has 20-50% incidence of femoral artery thrombosis
  - individualize: may not be needed (if existing atrial hole, peripheral arterial line)
Hemodynamic Assessment: Baseline

- Initial blood gas to achieve appropriate baseline
  - “normalize” ventilation and oxygenation

- Oximetry and blood gas determinations
  - routine sampling through right heart for shunt detection
    - Most commonly asd/pfo and/or PDA
  - evaluation of baseline oxygenation
    - If ASD/pfo left atrial, if desaturated, pvv sampling
    - In intact atrial septum, arterial

- Pressure measurement
  - RA, RV, each PA and PCWp and pullback through the right heart.
    - If elevated PCWp, and no atrial hole, retrograde catheterization

- Flow measurement
  - Shunt present- Fick (VO2 comment)
  - Shunt Absent - TD (note, 5F TD catheter inadequate for pressure measurement)
Hemodynamic Assessment: Pulmonary Vasoreactivity Testing

• Our standard: 100% FiO2 + 40PPM NO, 5 min re-equilibration

• Oximetry/Flow determination:
  • If shunt lesion repeat appropriate oximetry (ABG for dissolved O2 at any site where saturation > ~94%).
  • If no shunt, TD output

• Arterial saturation and ABG, if low and there is an atrial hole, assess left atrial sat and ABG

• Pressures: repeat systemic and pulmonary arterial and venous pressures
7 M male ex 27 wk with chronic lung disease
ASD, s/p PDA ligation Echo – diagnosed PAH, treated with sildenafil

<table>
<thead>
<tr>
<th>PH</th>
<th>PCO2</th>
<th>PO2</th>
<th>HCO3</th>
</tr>
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<tbody>
<tr>
<td>7.45</td>
<td>44.1</td>
<td>117.1</td>
<td>29.9</td>
</tr>
<tr>
<td>7.53</td>
<td>35.8</td>
<td>485.2</td>
<td>28.9</td>
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**Dive Table**

<table>
<thead>
<tr>
<th></th>
<th>21% FiO2</th>
<th>100% FiO2 + 40 ppm iNO</th>
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<tbody>
<tr>
<td>MV sat</td>
<td>68%</td>
<td>75%</td>
</tr>
<tr>
<td>LA sat</td>
<td>98%</td>
<td>100%</td>
</tr>
<tr>
<td>RA</td>
<td>10/10 (8)</td>
<td></td>
</tr>
<tr>
<td>RV</td>
<td>55/10</td>
<td></td>
</tr>
<tr>
<td>LPA</td>
<td>47/20 (31)</td>
<td>36/17 (25)</td>
</tr>
<tr>
<td>LPCW</td>
<td>10/10 (9)</td>
<td></td>
</tr>
<tr>
<td>LA</td>
<td>9/11 (9)</td>
<td>10/10 (8)</td>
</tr>
<tr>
<td>Qp</td>
<td>7.5 L/min/m2</td>
<td>7.1 L/min/m2</td>
</tr>
<tr>
<td>Qs</td>
<td>3.2 L/min/m2</td>
<td>2.9 L/min/m2</td>
</tr>
<tr>
<td>PVRi</td>
<td>2.9 iWU</td>
<td>2.5 iWU</td>
</tr>
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</table>
4-month-old former 23 weeks gestation, severe BPD, persistent PDA, and PAH. Hospitalized at an another institution and transferred to ours at 3M. Intubated on 20 ppm iNO. PDA patent despite several courses indomethicin.
Percutaneous Closure of Patent Ductus Arteriosus in Small Infants With Significant Lung Disease May Offer Faster Recovery of Respiratory Function When Compared to Surgical Ligation


<table>
<thead>
<tr>
<th>TABLE III. Comparison of Treatment Groups</th>
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<thead>
<tr>
<th></th>
<th>Percutaneous cases (n = 8)</th>
<th>Surgical controls (n = 8)</th>
<th>P</th>
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<tbody>
<tr>
<td>Gestational age (weeks)</td>
<td>29.8 (24–38)</td>
<td>29 (23–37)</td>
<td></td>
</tr>
<tr>
<td>Birth weight (kg)</td>
<td>1425 (520–2965)</td>
<td>1549 (482–3040)</td>
<td></td>
</tr>
<tr>
<td>Weight at procedure (kg)</td>
<td>2.8 (2.2–3.9)</td>
<td>2.75 (2.3–4.2)</td>
<td></td>
</tr>
<tr>
<td>Age at Procedure (months)</td>
<td>3.7 (1–5.3)</td>
<td>1.4 (0.2–4.2)</td>
<td>0.07</td>
</tr>
<tr>
<td>Complete PDA occlusion</td>
<td>8 (100%)</td>
<td>8 (100%)</td>
<td>NS</td>
</tr>
<tr>
<td>Peri-procedural complication</td>
<td>7</td>
<td>7</td>
<td>NS</td>
</tr>
<tr>
<td>Baseline RSS</td>
<td>440 (130–1436)</td>
<td>262 (144–606)</td>
<td>0.09</td>
</tr>
<tr>
<td>Time to return to baseline RSS (hr)</td>
<td>17 (0–113)</td>
<td>53 (13–219)</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Procedural mortality</td>
<td>0</td>
<td>0</td>
<td>NS</td>
</tr>
<tr>
<td>Late mortality</td>
<td>2</td>
<td>3</td>
<td>NS</td>
</tr>
</tbody>
</table>

Data presented as median (range) or count (percentage of total).
h, hours; kg, kilogram; NS, not significant; PDA, patent ductus arteriosus; RSS, respiratory severity score.
2-month-old male with alveolar capillary dysplasia, pulmonary hypertension, readmitted with increased work of breathing and increased oxygen requirement. Shortly after admission, had a code event in the PICU consistent with a pulmonary hypertensive crisis.
6 month old former 24wks premature infant, chronic lung disease, surgical NEC, chronic respiratory failure, and PAH. Previously on iNO. Currently mechanically ventilated on 35-40% FiO2. His two most recent echocardiograms have demonstrated evidence of RV hypertension.
Subsequently underwent a sutureless repair for pvv stenosis
**Pulmonary vein stenosis of ex-premature infants with pulmonary hypertension and bronchopulmonary dysplasia, epidemiology, and survival from a multicenter cohort**


**TABLE 1** Associations with the diagnosis of pulmonary vein stenosis in all subjects during their course on the neonatal intensive care unit (NICU) irrespective of whether the diagnosis was made pre or post NICU discharge

<table>
<thead>
<tr>
<th>Parameter</th>
<th>YES, n (%)</th>
<th>NO, n (%)</th>
<th>Missing data, n (%)</th>
<th>P-value (Chi-squared test)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Antenatal steroids</td>
<td>17 (44%)</td>
<td>11 (28%)</td>
<td>11(28%)</td>
<td>0.26</td>
</tr>
<tr>
<td>Umbilical vein catheter</td>
<td>16 (41%)</td>
<td>9 (23%)</td>
<td>14 (36%)</td>
<td>0.16</td>
</tr>
<tr>
<td>Respiratory support</td>
<td>34 (87%)</td>
<td>1 (3%)</td>
<td>4 (10%)</td>
<td>*P &lt; 0.01</td>
</tr>
<tr>
<td>Invasive ventilation</td>
<td>26 (67%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BiPAP/CPAP</td>
<td>20 (51%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HFNC/LFNC</td>
<td>22 (56%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Home oxygen</td>
<td>20 (51%)</td>
<td>11 (28%)</td>
<td>8 (21%)</td>
<td>0.11</td>
</tr>
<tr>
<td>Persistent pulmonary hypertension of the newborn</td>
<td>5 (13%)</td>
<td>29 (74%)</td>
<td>5 (13%)</td>
<td>*P &lt; 0.01</td>
</tr>
<tr>
<td>Bronchopulmonary dysplasia</td>
<td>29 (74%)</td>
<td>4 (10%)</td>
<td>6 (15%)</td>
<td>*P &lt; 0.01</td>
</tr>
<tr>
<td>Patent ductus arteriosus</td>
<td>28 (72 %)</td>
<td>6 (15 %)</td>
<td>5 (13%)</td>
<td>*P &lt; 0.01</td>
</tr>
<tr>
<td>Necrotising enterocolitis</td>
<td>9 (23%)</td>
<td>25 (64%)</td>
<td>5 (13%)</td>
<td>*P &lt; 0.01</td>
</tr>
<tr>
<td>Retinopathy of prematurity</td>
<td>18 (78%)</td>
<td>5 (22%)</td>
<td>0 (%)</td>
<td>*P &lt; 0.01</td>
</tr>
<tr>
<td>Intraventricular hemorrhage</td>
<td>10 (26%)</td>
<td>24 (62%)</td>
<td>5 (13%)</td>
<td>*P &lt; 0.01</td>
</tr>
<tr>
<td>Sepsis*</td>
<td>13 (33%)</td>
<td>21 (54%)</td>
<td>5 (13%)</td>
<td>0.171</td>
</tr>
</tbody>
</table>
- 406 caths in 144 pts
- 11 systemic embolic events (10 strokes)
  - Clinical stroke in 8% of pts
  - 25% of procedures associated with some complication

So when you approach your interventional cardiologist requesting catheterization for a patient with BPD, PAH, and PVV stenosis, you might understand why s/he doesn’t jump for joy…
Predictors of Catastrophic Adverse Outcomes in Children with Pulmonary Hypertension Undergoing Cardiac Catheterization: A Multi-Institutional Analysis From The Pediatric Health Information Systems Database

O’Byrne et al. JACC 66:1261-1269, 2015

- 6,339 procedures from 38/43 centers contributing data to the PHIS database
- The observed risk of composite outcome was 3.5% (death or ECMO within 1 day of procedure)

<table>
<thead>
<tr>
<th>Outcomes % (n)</th>
<th></th>
</tr>
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<tbody>
<tr>
<td>Composite outcome within 1 day</td>
<td>3.5% (222)</td>
</tr>
<tr>
<td>Death within 1 day</td>
<td>0.3% (17)</td>
</tr>
<tr>
<td>ECMO within 1 day</td>
<td>3.3% (206)</td>
</tr>
<tr>
<td>Composite outcome on day of catheterization</td>
<td>1.0% (61)</td>
</tr>
<tr>
<td>Death on day of catheterization</td>
<td>0.1% (9)</td>
</tr>
<tr>
<td>ECMO on day of catheterization</td>
<td>0.8% (52)</td>
</tr>
</tbody>
</table>
Conclusions

• Rather than list conclusions, would rather just note that there are many unknowns in this very high risk population regarding
  – Who should undergo catheterization
  – When they should
  – What the conduct of the procedure should be
  – What the role of interventions should be