Acute Right Heart Failure in the ICU

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Disclosures

Research Grants
Actelion
Bayer
Genzyme
Gilead
National Institutes of Health
Novartis
Pfizer
United Therapeutics
Acute Right Heart Syndrome

- Increase in RV afterload (or impedance) precipitating RV failure
- RV dilates, contractile function deteriorates
- Right atrial and RV end diastolic pressures rise (> 8 mm Hg)
- Cardiac output and systemic blood pressure fall
Acute Right Heart Syndrome in ICU: Precipitating events

- Acute or acute on chronic pulmonary embolism
- Acute lung injury/ARDS/sepsis
- Heart, Lung, Liver Transplantation
- LV Failure, LV assist device
- Cardiac Surgery (valve replacement)
- Lung Resection
- Deteriorating Chronic Pulmonary Arterial Hypertension
ARHS in ALI/ARDS

- Of 502 pts in FACCT (Fluid and Catheter Trial) of ARDSnet, 73% had trans-pulmonary gradient (mPAP-PAW) > 12 mm Hg
  - Bull T et al, AJRCCM 2010

- Decrease in ARDS-related cor pulmonale from 60% in 1985 to 20% in 2001 associated with use of low VT
  - Vieillard-Baron A et al, CCM 2001
Right Heart Intolerant

Afterload (mean pressure)

CO

RV

LV

40

150

Afterload (mean pressure)
Right Heart Intolerant

Positive Inotrope

CO

RV

LV

40

150

Afterload (mean pressure)
Cardiac Echo in Acute Rt Heart Syndrome

Apical four-chamber

Parasternal short axis

Vieillard-Baron et al, AJRCCM 2002; 166:1310
Cardiac Echo in Acute Rt Heart Syndrome

Apical four-chamber

Parasternal short axis

Vieillard-Baron et al, AJRCCM 2002; 166:1310
PA catheter helpful in diagnosis, assessing response to therapy
Principles of ARHS Management

- Reverse
- Precipitating Event

RV Failure
Principles of ARHS Management

Reverse Precipitating Event

RV Failure

Control Contributing Factors: Acidemia, anemia, infection, arrhythmias
Principles of ARHS Management

RV Failure

Reverse Precipitating Event

Control Contributing Factors:
- Acidemia, anemia, infection, arrhythmias

Oxygenation, Lung Protection
Principles of ARHS Management

Reverse Precipitating Event

Maintain Perfusion Pressure
mPAP > mSBP = +

Control Contributing Factors:
Acidemia, anemia, infection, arrhythmias

Oxygenation, Lung Protection

RV Failure
Principles of ARHS Management

Reverse Precipitating Event

Maintain Perfusion Pressure
mPAP > mSBP = +

Optimize Fluid Volume

Control Contributing Factors:
Acidemia, anemia, infection, arrhythmias

Oxygenation, Lung Protection

RV Failure
Principles of ARHS Management

RV Failure

Maintain Perfusion Pressure
mPAP > mSBP = +

Optimize Fluid Volume

Inotropy

Reverse Precipitating Event

Contributing Factors:
Acidemia, anemia, infection, arrhythmias

Control

Oxygenation, Lung Protection
Principles of ARHS Management

**RV Failure**

- **Reverse Precipitating Event**
- **Maintain Perfusion Pressure**
  \[ mPAP > mSBP = + \]
- **Optimize Fluid Volume**
- **Inotropy**
- **Pulmonary Vasodilators**
- **Control Contributing Factors:**
  - Acidemia, anemia, infection, arrhythmias
- **Oxygenation,**
  **Lung Protection**
Controlling predisposing factors

Optimize fluid balance
- Ventricular interdependence
- Cautious fluid administration – bolus and observe response
- Dilated IVC on echo, unlikely to respond
- Consider cautious diuresis
- Massive fluid overload, consider CVVH
Controlling predisposing factors

Optimize fluid balance
- Ventricular interdependence
- Cautious fluid administration – bolus and observe response
- Dilated IVC on echo
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Pressors in Acute Right Heart Syndrome

- Norepinephrine, Dopamine, Epi
  - To treat systemic hypotension (no clear winner)
  - To maintain RV coronary perfusion without pulmonary vasoconstriction or impaired myocardial performance
  - Effects on renal perfusion may favor norepi (in dog model of pulmonary embolism)
Inotropes

- Dobutamine (catechol), milrinone (PDE3I)
  - Systemic vasodilators; dobut tachy, mil ↓ BP, often need pressors
  - Mild pulmonary vasodilators
  - May be used in combination with more potent pulmonary vasodilators (like inhaled NO or PGI2) to increase CO and further lower PA pressure
  - No clear winner

Bradford et al, J Cardiovasc Pharmacol 2000; 36:146
Newer Inotrope

• Levosimendan (not available in US - can be given orally)
  – Ca++ sensitizer, K+ channel opener, no increase in myocardial O2 consumption
  – In dogs with partial PA ligation, increases RV inotropy, decreases RV afterload (better pulmonary vasodilator than dobutamine)
  – Some favorable case reports for PH after surgery

Kerbaal et al, Crit Care Medicine 2006; 34:2814
Goals of Pulmonary Vasodilation in Right Heart Failure
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- Decrease PVR and impedance to reduce RV afterload
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- Avoid systemic hypotension and maintain coronary perfusion (↓ PVR/SVR)
Goals of Pulmonary Vasodilation in Right Heart Failure

- Decrease PVR and impedance to reduce RV afterload
- Increase RV stroke volume and cardiac output
- Avoid systemic hypotension and maintain coronary perfusion ($\downarrow$ PVR/SVR)
- Avoid hypoxemia (from worsened ventilation/perfusion relationships)
Systemic Vasodilators
Systemic Vasodilators

- Calcium Channel Blockers
  - Tolazoline
- α antagonists
- Smooth muscle relaxers
  - Hydralazine, nitroprusside

- Not very useful, potent systemic vasodilators, CCBs negatively inotropic, increase shunt, may be dangerous
Prostacyclin (PGI$_2$)

- Potent vasodilator, ↓ platelet aggregation
- Probably not inotrope (Naeje, Chest 07)
- Strong evidence for efficacy in Class IV PAH (↑ functional status, survival)
- Given as continuous IV infusion starting at 2 - 4 ng/kg/min, ↑ as tolerated
- Systemic vasodilator, may worsen hypoxemia
- Inhaled, is more specific pulmonary vasodilator

( Kieler-Nielsen et al, J Heart Lung Txplnt ’93)
Inhaled Vasodilators may
Inhaled Vasodilators may
Inhaled PGI$_2$ for ARHS (off label)

126 pts -78 s/p card surg, 43 s/p lung Txplant, 5 s/p resection mPA > 30, P/F < 150, or CVP >16 mm Hg, CI < 2.2

De Wet et al, J Thorac Cardiovasc Surg 2004; 127: 1061
Inhaled PGI$_2$ for ARHS (off label)

126 pts. 78 s/p card surg. 43 s/p lung Txplant

Cont miniHeart neb 30-50 μg/min or CVP >16 mm Hg, CI < 2.2

De Wet et al, J Thorac Cardiovasc Surg 2004; 127: 1061
Inhaled PGI₂ for ARHS (off label)

126 pts: 78 s/p card surg, 43 s/p lung Txplant

Cont miniHeart neb 30-50 μg/min

or CVP > 16 mm Hg, CI < 2.2

<table>
<thead>
<tr>
<th></th>
<th>Before PGI₂</th>
<th>After 4-6h PGI₂</th>
</tr>
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<tbody>
<tr>
<td>MAP (mm Hg)</td>
<td>77</td>
<td>78</td>
</tr>
<tr>
<td>MPAP (mm Hg)</td>
<td>35</td>
<td>24*</td>
</tr>
<tr>
<td>MPAP/MAP</td>
<td>0.47</td>
<td>0.32*</td>
</tr>
<tr>
<td>CO (L/min)</td>
<td>4.6</td>
<td>5.3*</td>
</tr>
<tr>
<td>P/F ratio</td>
<td>256</td>
<td>281</td>
</tr>
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De Wet et al, J Thorac Cardiovasc Surg 2004; 127: 1061
# Inhaled Iloprost (1/2 life 20 min)

22 pts after endarterectomy with “residual” PH following surgery given 25 mcg inhalation

<table>
<thead>
<tr>
<th></th>
<th>iloprost (11)</th>
<th>saline (11)</th>
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<tbody>
<tr>
<td>Pre (dsc\textsuperscript{m-5})</td>
<td>503</td>
<td>413</td>
</tr>
<tr>
<td>30 min</td>
<td>328</td>
<td>404*</td>
</tr>
<tr>
<td>90 min</td>
<td>352</td>
<td>415*</td>
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Kramm et al, Eur J Cardiothor Surg, 2005
Inhaled NO in Acute Right Heart Syndrome

- Potent vasodilator - stimulates soluble guanylate cyclase in vascular smooth muscle, ↑intracellular cGMP
- Usually improves O₂ - by enhancing blood flow to ventilated areas
- Virtually no systemic side effects; immediately inactivated by hemoglobin (forms methemoglobin)
- Given by titration in concentrations of 5-40 ppm (little gain > 20 ppm)
NO for Acute Right Heart

26 pts with mPA > 30 mm Hg, RV dilatation by Echo

>20% ↑ CO, ↓ PVR  Resp  Nonres

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<tbody>
<tr>
<td>n</td>
<td>14</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>mPAP</td>
<td>40</td>
<td>39</td>
<td></td>
</tr>
<tr>
<td>CO (L/min)</td>
<td>5.2</td>
<td>5.9</td>
<td></td>
</tr>
<tr>
<td>PVR</td>
<td>512</td>
<td>361</td>
<td></td>
</tr>
<tr>
<td>% on pressors</td>
<td>57</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>Mortality (%)</td>
<td>70</td>
<td>50</td>
<td></td>
</tr>
</tbody>
</table>

Bhorade et al, AJRCM, 1999 150:571.
Caveats re Use of iNO for ARHS

- Withdrawal problems very common (2/3)
  - Drop SBP, O2 sats, increase PVR
  - ? Related to suppression of endogenous eNOS
- Methemoglobin and NO₂ may accumulate
- Very expensive! Up to $3000/day in US!
iNO (20 ppm) vs inhaled epoprostenol (50 ng/kg/min)

Change PVR (%)
Phosphodiesterase 5 inhibitors

- Potent acute pulmonary vasodilators by slowing metabolism of cGMP
- Potentiate the effect of iNO or prostacyclin, reduce rebound
- Also systemic vasodilators so must be used with great caution in hypotensive patients; prelim evidence suggests more selectivity by inhaled route
Sildenafil as Rescue Therapy

- Added in 20 pts failing IV epoprostenol monotherapy
- Improved NYHA class
- Fewer sx of Rt heart failure
- Smaller RV end diast diam by echo
- 2 deaths after 2 years
  - Ruiz M et al, J Heart Lung Txplant 2006
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If ↓ SPB, start at low dose (10-12.5 mg tid)
Summary: Rt Heart Failure in ICU

- High morbidity, mortality
- Important to characterize, identify and correct reversible factors preoperatively
- Cardiac echo and PA catheter helpful
- Key to maintain perfusion, optimize fluid volume, avoid hypoxemia
- Prostacyclins are potent vasodilators,