Current Management of Pulmonary Hypertension in Surgical Patients

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Heart Failure at the Shoe XI
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Disclosures

- No conflicts of interest
- No financial relationships
Learning Objectives

- At the conclusion of this activity the participants should understand the types of pulmonary hypertension.

- At the conclusion of this activity, the participants should have a familiarity management of perioperative pulmonary hypertension.

- At the conclusion of this activity, the participants should have an appreciation of the surgical treatments for pulmonary hypertension.
Overview

- Types of pulmonary hypertension (PH)
- Pharmacologic tools to manage PH
- Surgery and PH
  - PH due to surgery
  - Surgery for PH
- Future opportunities
Pulmonary Hypertension Classifications

- Group 1 – Pulmonary Artery Hypertension
- Group 2 – PH due to left heart disease
- Group 3 – PH due to lung disease or hypoxia
- Group 4 – Chronic thromboembolic pulmonary hypertension
- Group 5 – PH with unclear/multiple etiologies
Pulmonary Hypertension Classifications

- **4th World Symposium on PH in 2008 Dana Point, CA**
- Mean PAP $\geq$ 25 mmHg
- PCWP
  - $> 15$ mmHg $\rightarrow$ PH due to left heart
  - $\leq 15$ mmHg $\rightarrow$ Everything else

Simonneau et al. JACC 2009; 54:S43-54
Group 1: Pulmonary Artery Hypertension

- Idiopathic
- Inherited
- Drug or toxin induced
- Connective tissue disorder
- HIV
- Congenital heart disease
  - Atrial septal defects
  - Anomalous pulmonary venous return
  - Ventricular septal defects
  - Patient ductus arteriosus
  - Complex congenital anatomy
- Pulmonary veno-occlusive disease

Simonneau et al. JACC 2009; 54:S43-54
Group 2: PH due to left heart disease

- Systolic
- Diastolic
- Valvular
Group 3: PH due to lung disease or hypoxia

- COPD
- Interstitial lung disease
- Hypoventilation
- High altitude exposure
Group 4: Chronic thromboembolic pulmonary hypertension

- Central / proximal
- Distal / peripheral

Simonneau et al. JACC 2009; 54:S43-54
Group 5: Unclear / multifactorial

- Hematologic disorders
- Sarcoid
- Histiocytosis
- Lymphangioleiomyomatosis
- Metabolic disorders
# Predictors of Outcome (McLaughlin and McGoon)

<table>
<thead>
<tr>
<th>Better prognosis</th>
<th>Determinants of prognosis</th>
<th>Worse prognosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>No</td>
<td>Clinical evidence of RV failure</td>
<td>Yes</td>
</tr>
<tr>
<td>Slow</td>
<td>Rate of progression of symptoms</td>
<td>Rapid</td>
</tr>
<tr>
<td>No</td>
<td>Syncope</td>
<td>Yes</td>
</tr>
<tr>
<td>I, II</td>
<td>WHO-FC</td>
<td>IV</td>
</tr>
<tr>
<td>Longer (&gt;500 m)&lt;sup&gt;a&lt;/sup&gt;</td>
<td>6MWT</td>
<td>Shorter (&lt;300 m)</td>
</tr>
<tr>
<td>Peak $O_2$ consumption $&gt;$15 mL/min/kg</td>
<td>Cardio-pulmonary exercise testing</td>
<td>Peak $O_2$ consumption $&lt;$12 mL/min/kg</td>
</tr>
<tr>
<td>Normal or near-normal</td>
<td>BNP/NT-proBNP plasma levels</td>
<td>Very elevated and rising</td>
</tr>
<tr>
<td>No pericardial effusion TAPSE&lt;sup&gt;b&lt;/sup&gt; $&gt;$2.0 cm</td>
<td>Echocardiographic findings&lt;sup&gt;b&lt;/sup&gt;</td>
<td>Pericardial effusion TAPSE&lt;sup&gt;b&lt;/sup&gt; $&lt;$1.5 cm</td>
</tr>
<tr>
<td>RAP $&lt;$8 mmHg and CI $&gt;$2.5 L/min/m$^2$</td>
<td>Haemodynamics</td>
<td>RAP $&gt;$15 mmHg or CI $&lt;$2.0 L/min/m$^2$</td>
</tr>
</tbody>
</table>

<sup>a</sup> From Galie N et al. *E Heart J* 2009; 30:2493-537.

<sup>b</sup>
Pharmacologic Tools to Treat PH

- Treat underlying condition if possible
- Multimodal approach
- Oxygen
- Exercise
- Anticoagulation
- Digoxin
Milrinone

- IV phosphodiesterase inhibitor
- Inotropic effect
- Pulmonary and some systemic vasodilatory effect

- 0-0.75 mcg/kg/min
- Bolus load 50 mcg/kg over 20 min
Nitrates

- Inhaled Nitric Oxide 1-40 ppm
  - Pulmonary vasodilator
  - Rebound PH if weaned rapidly
  - Expensive

- Nitroglycerine 0-5 mcg/kg/min
  - Systemic BP effects

- Nitroprusside 0-5 mcg/kg/min
  - Systemic BP effects
Diuretics

- Decrease volume overload
- Decrease hepatic congestion
- Decrease peripheral edema

- Balance potassium wasting and sparing

- Avoid renal malperfusion
  - Low intravascular volume
  - Low CO/CI
Oral Phosphodiesterase Inhibitors

- Prolong nitric oxide effect
- Sildenafil (Viagra)
  - 20-80 mg TID
- Vardenafil (Levitra)
- Tadalafil (Cialis)

- Increase 6 minute walk and lower PVR and PAP
- May have systemic hypotension
Prostanoids

- Short half life
- Some degree of hypoxia
- Pulmonary vasodilator

- Epoprostenol (Flolan)
  - IV titrate to 6-10mg/kg/min with need for dose escalation
  - Inhaled 1.5 mg diluted to 15 mcg/mL nebulized
    - 0, ¼, ½, and full strength

- Treprostinil (Remodulin)
  - IV
  - Subcutaneous
Calcium Channel Blockers

- Amlodipine
- Nifedipine
- Diltiazem

- Controversial
Endothelin Receptor Antagonist

- Bosetan (Tracleer) – Non selective
- Ambrisentan (Letaris) – Type A selective
Pulmonary Hypertension and Non-Cardiac Surgery

- 145 patients from Mayo Clinic, Rochester, MN
- Mean PAP 44 ± 15 mmHg and PCWP 15 ± 8 mmHg
- Independent predictors of 30 day mortality
  - Pulmonary embolism
  - NYHA functional class ≥ II
  - Intermediate / high risk surgery
  - Anesthesia > 3 hours

Ramakrishna G et al. JACC 2005; 45:1691-9
Pulmonary Hypertension and Cardiac Surgery

- PH due to surgery
- Surgery for PH
Pulmonary Hypertension and Surgery

- What is the acuity of the PH?
- Was there PH prior to surgery?
- Is the PH worse?
- What was done in the operating theater?
- What else may account for the PH?
Perioperative PH That Is New or Worse

- What was done in the OR?
Perioperative PH That Is New or Worse

- What was done in the OR?

- Is there an intracardiac shunt (ASD/VSD)?
  - New?
  - Old?
Perioperative PH That Is New or Worse

- What was done in the OR?
- Is there an intracardiac shunt (ASD/VSD)?
  - New?
  - Old?
- Inadequate myocardial protection / graft failure?
Perioperative PH That Is New or Worse

- What was done in the OR?
- Is there an intracardiac shunt (ASD/VSD)?
  - New?
  - Old?
- Inadequate myocardial protection / graft failure?
- Is it a function of the repair?
  - Mitral stenosis?
  - Competent tricuspid valve with unappreciated high trans-pulmonary gradient?
  - Ventricular assist device?
  - Post heart transplant?
Identify Patients At Higher Risk

- Low ejection fraction
- Previous myocardial infarction
- Redo cardiac surgery
- Pulmonary hypertension
- Renal dysfunction
- Urgent operations
- Cardiac surgery other than CABG
Pulmonary Hypertension and MR

- 171 patients
  - 55% MV repair
  - 30% CABG
  - 17% TV De Vega Annuloplasty

- Preoperative PAS > 65 mmHg
  - Highest sensitivity and specificity

- Ischemic MR with CABG increases mortality risk

Perioperative PH - Evaluation

- Pulmonary artery catheter
  - RA, PAS, PAD, PCWP, CO/CI

- Echocardiogram

- Arterial and mixed venous blood gases
ICU Management

- Milrinone
- Pulmonary vasodilators
- Inhaled NO and Epoprostenol
- Inotrope
- Careful fluid management
- Avoid high PEEP - compress alveolar capillaries and elevate PVR
- Avoid hypercapnea – increases PVR
- Anticoagulation in pulmonary endarterectomy
Inhaled NO and Sildenafil

- Nitric oxide (10 ppm)
  - Decreased PAP 10% and PVRI 21%
  - No hypoxia

- Sildenafil (100 mg)
  - Decrease MAP 19%, PAP 22%, PVRI 32% and P/F ratio 14%

- Combination had a further decrease in MAP and PAP
Pulmonary Hypertension and Cardiac Surgery

- PH due to surgery
- Surgery for PH
CTEPH

- Ventilation perfusion scan
  - Can exclude CTEPH with 90-100% sensitivity and 94-100% specificity

- Contrast CT pulmonary angiogram

- Echocardiogram

- Traditional pulmonary angiography

- Best results at a multi-disciplinary program

CTEPH

- Pulmonary artery endarterectomy
- Low mortality 2.2-5.2% at dedicated center
- Efficacious for segmental disease as well
- PVR drop from ~ 800 dynes/sec/cm$^{-5}$ to ~200
- Mean PAP decrease from ~45 mmHg to ~27 mmHg

Circulatory Arrest or Antegrade Perfusion for Pulmonary Endarterectomy

- Randomized study of 74 pts from Cambridge, UK
- No difference in adverse events
- No difference in cognitive function or evaluation
- 9 patients crossed over to DHCA
- DHCA allowed for better visualization

Vuylsteke A et al. Lancet 2011; 378:1379-87
Lung Transplant Indications - PAH

- Persistent NYHA Class III or IV on maximal medical therapy
- Low (350 m) or declining 6-minute walk test
- Failing therapy with intravenous epoprostenol, or equivalent.
- Cardiac index of <2 L/min/m²
- Right atrial pressure >15 mm Hg
Lung Transplant for PAH

- Of 316 patients at University of Toronto
  - 19% unable to be listed
  - 12% refused
  - 21% too early in disease process
  - 15% died during evaluation
  - 14% were listed
    - Of those
      - 79% were transplanted
      - 18% died on the waiting list

*de Perrot et al. J Thorac Cardiovasc Surg 2012; 143: 910-8*
ADULT LUNG TRANSPLANTATION
Kaplan-Meier Survival By Diagnosis (Transplants: January 1990 – June 2009)

Survival comparisons
All comparisons with Alpha-1 and CF are statistically significant at < 0.01
COPD vs. IPF: p < 0.001

Survival (%)

Years

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14

ISHLT 2011
ADULT LUNG TRANSPLANTATION

Kaplan-Meier Survival By Diagnosis Conditional on Survival to 1 Year
(Transplants: January 1990 – June 2009)

Survival comparisons
All comparisons are statistically significant at 0.05 except Alpha-1 vs. Sarcoidosis, CF vs. IPAH and COPD vs. IPF

ISHLT
Surgery for Pulmonary Hypertension

- Interventional Lung Assist for Pulmonary Hypertension
- Novalung

Surgery for Pulmonary Hypertension

- Novalung – University of Toronto

*de Perrot et al. J Heart Lung Transplant 2011;30:997-1002*
Summary

- Pulmonary hypertension increases risk of surgery
Summary

- Pulmonary hypertension increases risk of surgery

- PH due to CTEPH, congenital heart disease, and lung disease amenable to surgical treatment at appropriate centers
Summary

- Pulmonary hypertension increases risk of surgery
- PH due to CTEPH, congenital heart disease, and lung disease amenable to surgical treatment at appropriate centers
- Multimodal pharmacologic and ICU management is key
Remember...

Be a Buckeye for Life
Support Organ and Tissue Donation