The Hemodynamics of PH

Interpreting the numbers

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Outline

- The pulmonary vasculature
- Non-invasive assessment of hemodynamics
  - Echocardiography
- Invasive assessment
  - PA catheterization:
    - The mechanics
    - What numbers are we looking for?
    - What do the numbers mean?
The Pulmonary Vasculature

- The elegance of the pulmonary vascular bed
- High capacitance low resistance system
- 4x increase flow with small change in pressure
- Vasodilatation and recruitment.
Pathogenesis of Pulmonary Arterial Hypertension

1. Risk Factors and Associated Conditions
   - Collagen Vascular Disease
   - Congenital Heart Disease
   - Portal Hypertension
   - HIV Infection
   - Drugs and Toxins
   - Pregnancy
   - HHV-8

2. Vascular Injury
   - Endothelial Dysfunction
     - ↓ Nitric Oxide Synthase
     - ↓ Prostacyclin Production
     - ↑ Thromboxane Production
     - ↑ Endothelin 1 Production
   - Vascular Smooth Muscle Dysfunction
     - Impaired Voltage-Gated Potassium Channel (Kv1,3)

3. Disease Progression
   - Loss of Response to Short-Acting Vasodilator Trial
     - Smooth Muscle Hypertrophy
     - Adventitial and Intimal Proliferation
     - In situ Thrombosis
     - Plexiform Lesion
     - Advanced Vascular Lesion

NORMAL
REVERSIBLE DISEASE
IRREVERSIBLE DISEASE

JAMA 2000;284:3164
The Pathology of PPH/IPAH
The Plexiform Lesion
Pulmonary Arterial Hypertension Defined

- PA mean > 25 mmHg at rest of > 30 mmHg with exercise

and

- PCWP < 15 mmHg

- Pulmonary venous hypertension
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Echocardiography

- Best screening tool for Pulmonary Hypertension
  - Accurate and precise estimation in most patients.
  - Information on RV, RA and LV size and function
  - Information on valvular and pericardial disease.
Echocardiography

- PA systolic pressure = RVSP in the absence of pulmonary outflow obstruction

- RVSP estimated from TR jet velocity
  - As PASP $\uparrow$ the TR jet velocity $\uparrow$

- Simplified Bernoulli equation
  - RVSP = $4v^2 + RAP$
Echocardiography

Pulmonary Hypertension

Normal PA pressure
Tricuspid regurgitation
Estimation of RVSP

Simplified Bernoulli equation: \( P = 4V^2 \)
Echocardiogram

Disadvantages:

- Can be fooled:
  - Air trapping (COPD/Emphysema)
  - Expansion of thoracic cage
  - Alterations of position of heart

- No estimation of LVEDP (PCWP) or CO/CI
  - Important in selection of therapy

- Not useful for vasodilator challenges
  - Important in selection of therapy
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Right Heart Catheterization
Pulmonary Artery Catheter

- Swan-Ganz
- Direct measurement of cardio/pulmonary hemodynamics
- Assessment of Cardiac output and Cardiac Index
- Assessment of LVEDP via PCWP
- Vasodilator challenge
PA catheter
Right Heart Catheterization
Pressure measurement
What do we want to know?

- The true pressures?
  - RA, RV, PA, PCWP
- How much blood is exiting the heart?
  - Cardiac output, Cardiac Index
- What is the resistance?
  - PVR
- SVO2
- Shunt?
- Vasoreactive?
Hemodynamics: The Numbers

- **RA:** 0-6 mmHg
- **RV:** 30/0-6 mmHg
- **PA:** 30/6-12 mmHg  Pa mean 15-20 mmHg
- **PCWP:** 5-15 mmHg
Hemodynamics: The Numbers

- **Cardiac Output**: 4-6.5 L/min
  - Thermodilution
  - Fick Calculation

- **Pulmonary Vascular Resistance**
  - 0.7-0.95 WU
  - PVR = (mPA-PCWP)/CO

- **SVO2**: 70%
Pulmonary Capillary Wedge Pressure
PCWP

PA cath → Pulmonary Artery → Pulmonary Vein → Left Atrium

LA
Classification of PH

- Pulmonary Arterial Hypertension (PAH)

RV → PA → Pulmonary Capillary → PV → LV
Classification of PH

Pulmonary Venous Hypertension (PVH)
Classification of PH

PAH medications

RV
PA
Pulmonary Capillary
PV
LV
Concerning findings

- Elevation in PCWP
- Elevation in RA pressure
- Decrease in CO/CI
- Elevation of PCWP with vasodilator
  - Pulmonary Veno-occlusive Disease (PVOD)

PVH: Limits rx for PAH

Consider intravenous therapy
Pulmonary Veno-occlusive disease

PAH medications

RV
PA
Pulmonary Capillary
PV
LV
Vasoreactivity

- Why do we care?

- Acute “response” to vasodilator provides prognostic and treatment information

Calcium Channel Blocker
Yes or No?
Vasoreactivity: The Mechanics

- Patient brought to cath lab and measure baseline hemodynamics: RA, PA, PCWP, CO
- Acute administration of pulmonary vasodilator:
  - Adenosine
  - Prostacyclin
  - Nitric Oxide
- Repeat hemodynamic measurement
Vasoreactivity

**Old Definition**

- > 20% decrease in mPA and PVR

- Initially 20% pts were thought to be vasoresponse
Effect of High-Dose CCBs on Survival in IPAH According to Response Status

Vasoreactivity

Simonneau et al Circ 2005:1111 3105-3111
Vasoreactivity

Simonneau et al Circ 2005:1111 3105-3111
Vasoreactivity

The new definition
“Long term response to calcium channel blockers in IPAH”

- Decrease of mPA to below 40 mmHg
- Decrease of mPA by at least 10 mmHg
- No decrease in CO

Simonneau et al Circ 2005:1111 3105-3111
Vasoreactivity

- If Vasoreactive start CCB
  - Close follow up necessary
  - 3 month evaluation

- If acutely unresponsive and normal PCWP:
  select other PAH specific therapy
New Directions

- Utility of exercise hemodynamics in screening

- Other Imaging Studies: Cardiac MRI

- Continuous monitoring of hemodynamics

McGoon et al
Summary

- The elegance pulmonary vasculature
- Echocardiography
- Importance of invasive measurements
  - Confirmation of pressure elevation
  - PAH vs. PVH
  - Prognosis
  - Intra-cardiac shunts
  - Vasoreactivity
Summary

- Flight to Washington D.C. $425
- One night Crystal City Hyatt : $130
- Membership in PHCR: $135

- Understanding the Hemodynamics of PH

- Priceless $$$$$