Advanced Hemodynamic Assessment: Tamponade, Valve Area, Shunt Calculations

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Things I Have Learned...

“Good Judgment Comes From Experience... Experience comes from bad judgment...”

“Always Tell the Truth and you’ll never have to remember anything”

“If you are nice, generally people are nice back!”
Things I Have’nt Figured Out Yet.....
Diagnostic Catheterization

• Declining
  – Earlier Surgery
  – Better Non-invasive Imaging Modalities

• Consequences
  – Decline in expertise
  – Calculations less routine in Interventional cases
  – Less patience

“Bad Data is worse than no Data”
Shunt Calculations

• What are we trying to achieve?
  • Does every patient undergoing defect closure require shunt calculation?

• What are the limitations of the techniques we use?
  • Assumed VO2

• When are these techniques not valid?
  • Thermodilution in patient with L-R shunt
What we hope ever
to do with ease we
may learn first to do
with diligence

Samuel Johnson

“Integrity without knowledge is weak and useless,
and knowledge without integrity is dangerous and
dreadful”
What Are we Trying to Achieve?

• Measure Relative Flows and Resistance

Pressure = Flow x Resistance

• Which of these parameters can we measure?

Pressure ✓
Flow ✓
Resistance
Example

- 12 year old girl with IPAH (No IC Shunts)
  
  - CO – Thermodilution = 3L/min/m2
  
  - Mean PCMP = 8mmHg, MAP = 41mmHg
  
  - ? Resistance
**Answer**

Pressure = Flow × Resistance

Resistance = Pressure/Flow

Resistance = 41-8 mmHg/3 L/min/m²

Resistance = 33 mmHg/3 L/min/m² = 11 mmHg/L/min/m²
Wood Unit

• Paul Wood

• Australian Cardiologist – Practiced in London

• Wood unit (u) = 1mmHg/L/min
  – Multiply x8 = Pascals
  – Multiply x80 = Dynes

• Indexed - .m2 (not/m2)
Wood Unit

- **Indexing Example:**
  - Child with BSA = 0.5m²
  - Pulmonary Blood Flow 2L/min
  - ΔP = 12mmHg

  - Absolute resistance = 12/2 = 6 Wood units
  - If corrected for by dividing by BSA = 12u/m²
  - However flow is corrected for BSA = 2/0.5 = 4l/min/m²
  - Resistance = 12/4 = 3u.m²
It Gets More Complicated....

• Most Patients – Intracardiac Shunts

• Measure Flow
  Fick Principle
  “Uptake of a substance by an organ = blood flow x A-V concentration difference of the substance”
  \[ VO_2 = Q \times AVO_2 \text{ Difference} \]
  \[ Q = \frac{VO_2}{AVO_2 \text{ Difference}} \]
Equations

Cardiac Index (L/min/m2) =
Oxygen Consumption (ml/min/m2)/
AV O2 Content Difference x 10

Oxygen Content = Hb x 1.36 x O2 Saturation

Qp = VO2/ (PVO2- PAO2) x 1.36xHbx10
Qs = VO2/(SaO2-MVO2) x 1.36xHbx10
VO2: Oxygen Consumption

- Influenced by a number of Variables:
  - Age
  - Sex
  - Height
  - HR

- Possible to measure directly:
  - Mass Spectrometry
  - Indirect Calorimetry

- Usually Assumed:
  - Lafarge
  - Miettinen
  - Lundell
  - Wesse

*Poor Levels of Agreement between measured and estimated VO2*

*Li et al. Crit Care Med. 2003;31:1235-40*
Example

• 41 y/o with ASD

• Mean PAP = 36, LAP = 8

• $Q_p = 3.3\text{L/min/m}^2$ (VO2 125mls/kg/min - assumed)
• $Q_s = 2.2\text{L/min/m}^2$

$$\frac{36 - 8}{3.3} = 8.5$$

Inoperable?
PH and Reversibility

• Acute Response Testing:
  – Decrease in mPAP of $\geq 10\text{mmHg}$ to absolute valve $<40\text{mmHg}$ without a decrease in CO

  – Varied Agents Used: Adenosine, NO, CCB, Prostacyclin

  – NO probably the most widely used in CHD practice

  – Develop a unit protocol and be consistent

  – Proforma helps!
Dissolved O2

• Dissolved O2 = 0.003 x pO2

• Important - calculating response to 100% O2

• \[ Q_p = \frac{V_O2}{[(P_{V_O2} \text{ Content}) + (0.003 \times PV \text{ pO2})] - [(P_{A_O2} \text{ Content}) + (0.003 \times PA \text{ pO2})]} \]
Case Example
37 y/o Female - PDA
Case Presentation

Rp = 15Wu

Rp = 11Wu
Measurements

A: 13.7 mm
B: 14.1 mm
C: 26.8 mm
D: 18.2 mm
A: 20.1 mm
PDA Occlusion in PH

137 Patients – 135 closure
Median follow-up: 5 Years
Post-trial Pp:Ps > 0.5 = PP-PAH

Treatment

Dual ERA

Trial - 742 Pts

Primary end point - time from the initiation of treatment to the first event related to pulmonary arterial hypertension.

10% CHD
Trial Occlusion
Hemodynamics
Post Device Release
Follow-up

PAP – Estimated 60% Systemic
Valve Area - Gorlin

Ao Valve area = to the flow through the aortic valve during ventricular systole/the systolic pressure gradient across the valve times a constant.

Valve Area (cm²) = \( \frac{\text{Cardiac Output (ml/min)}}{\text{Heart rate (beats/min)} \cdot \text{Systolic ejection period (s)} \cdot 44.3 \cdot \sqrt{\text{mean Gradient (mmHg)}}} \)

• May erroneously suggest stenosis if the CO is depressed
Example: An individual undergoes left and right heart cardiac catheterization as part of the evaluation of aortic stenosis. The following hemodynamic parameters were measured. With a heart rate of 80 beats/minute and a systolic ejection period of 0.33 seconds, the cardiac output was 5 liters/minute. During simultaneous measurement of pressures in the left ventricle and aorta (with the use of one catheter in the left ventricle and a second in the ascending aorta), the mean systolic pressure gradient was measured at 50 mmHg. What is the valve area as measured by the Gorlin equation?

Answer:

\[
\text{Aortic Valve Area} = \frac{5000 \text{ ml}}{80 \text{ beats/min} \cdot 0.33 \text{s} \cdot 44.3 \cdot \sqrt{50 \text{ mmHg}}} \approx 0.6 \text{ cm}^2
\]
Hakki Equation

• Simplification of Gorlin: In most cases

\[ HR \times SEP \times 44.3 = 1000 \]

Aortic Valve area (cm²) \( \approx \frac{\text{Cardiac Output (litre min⁻¹)}}{\sqrt{\text{mean Gradient (mmHg)}}} \)

Example: An individual undergoes left and right cardiac catheterization for the evaluation of aortic stenosis. Measurements include an aortic pressure of 120/60, LV pressure of 170/15, cardiac output of 3.5 liters/minute. What is the aortic valve area?

Answer: The peak gradient between the LV and aorta is 50 mmHg. This gives

\[ \text{Aortic valve area} \approx \frac{3.5}{\sqrt{50}} \approx 0.5 \text{ cm}^2 \]
Tamponade

• Not an indication for Diagnostic Catheterization

• May occur during catheterization
  – Increased Filling Pressures (Loss of y descent)
  – Increased HR
  – Respiratory Variation on Arterial Waveform
  – Hypotension

• Confirm with Echocardiogram
MARCH 3–5, 2016 | DUBAI, UAE

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