Introduction to Swan-Ganz catheterization

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Internship

Nurstoons

You were on call again?
Ya. Another night with only one hour of sleep.

Look on the bright side, compared to how much sleep the average person gets, you’ll be awake for the equivalent of three lifetimes.

Three lifetimes of internship!!

I guess that wasn’t very reassuring.

www.nursteen.com
THAT CONCLUDES MY TWO-HOUR PRESENTATION. ANY QUESTIONS?

DID YOU INTEND THE PRESENTATION TO BE INCOMPREHENSIBLE, OR DO YOU HAVE SOME SORT OF RARE "POWER-POINT" DISABILITY?

ARE THERE ANY QUESTIONS ABOUT THE CONTENT?

THERE WAS CONTENT?
Topics to be covered

• Should I even be using a PA catheter, and if so, in whom should I use them?
• How do I place a Swan-Ganz?
• What information do the numbers tell me?
• When can the numbers be misleading?
• What complications should I be aware of?
A Perspective

- 1930’s Wiggers and Katz advocate application of physiological principles toward management of cardiovascular disease
- 1940-1950’s Cardiac catheterization developed, applicable only in specialized labs
- 1960’s ICU developed, critical care emerges
- 1970 Balloon tipped “flow directed” catheter approach used for right heart catheterization
The Swan-Ganz Cathether
AKA Right Heart Catheter
AKA Pulmonary Artery Catheter

• 7.5 French (2.31 mm diameter)
• 110 cm Long
• Black rings at 10 cm intervals

 Ports
• Distal
• Right Atrial (30 cm from tip)
• Venous infusion (31 cm from tip)
• Thermister Bead (5 cm from tip)

http://www.rnceus.com/hemo/pacath.htm
Information to be gained

- Cardiac output (thermodilution)
- Central temperature
- RA, PA, PCWP pressures
- Blood gas
- *Pacing
- *Continuous cardiac output
Should I use a PA catheter?

• In summary, studies have never demonstrated mortality benefit from the use of Swan-Ganz catheters

• Swan-Ganz use continues mainly due to criticisms of studies and perceived benefit in selected patients
Why are PA catheters used in the critical care setting?

• Aid in differentiating mechanism of shock
  – Sepsis
  – Cardiogenic
  – Hypovolemic

• Monitor fluid status
  – CHF

• Diagnose Other Cardiac Abnormalities
  – Tamponade
  – Valvular Regurgitation
Who is an appropriate candidate for a PA catheter?

• In general, use in critically ill patients when stability of their condition cannot be assessed by clinical indicators
  – Persistent hypotension despite adequate fluid resuscitation
  – Pulmonary edema not responding to diuresis
  – Pulmonary edema with hypotension or pulmonary hypertension
  – Respiratory failure with high PEEP settings
He wanted to play doctor!

I was just prepping him for surgery!
How do I place a PA Catheter?

- Acquire central venous access with an 8.5F introducer
  - Right IJ and Left Subclavian are preferred sites
  - Right Subclavian can be used
  - Left IJ is difficult without fluor
- Test balloon (1–1.5cc air)
- Flush all ports
Placing a PA Catheter

- Attach transducer
- Place protective sleeve over catheter
- Insert tip of catheter into the introducer
- Advance 15 cm, then call for “Balloon up”
  - Always advance with balloon up, withdraw with balloon down
- Watch waveforms
- In general, catheter will advance 45-55 cm
The Cardiac Cycle

- Aorta
- Left ventricle
- LA (Left Atrium)
- LV (Left Ventricle)
- ECG (Electrocardiogram)

Pressures (mm Hg):
- 120
- 100
- 80
- 60
- 40
- 20
- 0

Events:
- Q
- R
- S
- T
- a
- c
- v
PAedp and PAOP \approx LVedp
CVP/RA Waveform

- a wave - occurs with atrial contraction
- c wave - occurs with closure of tricuspid valve
- v wave - due to blood filling the atrium when the tricuspid valve is closed
Right Atrial Waveform

- **a wave** - RA contraction
elevated in RV failure

- **c wave** - tricuspid closure

- **v wave** - passive filling of RA during ventricular systole = T wave on ECG
elevated in tricuspid regurgitation

- **x descent** - atrial diastole

- **y descent** - atrial emptying

http://www.staff.vu.edu.au/CriticalCare/Critical%20Care/lecture2_notes.htm
RV Waveform
Changes in Waveform as Catheter Is Advanced From the RV to the PA

Note difference in diastole
The PAOP Waveform

- Inflation of the balloon of the PAC stops measurement of the PA waveform.
- The waveform changes to a PAOP waveform with "a" and "v" waves.
- The mean PAOP value is close to the PA diastolic value.
Lung Zones

• Zone 1 – Upper lung
  – Essentially no capillary blood flow

• Zone 2 – Central lung
  – Alveolar pressure exceeds capillary pressure, wedging results in no flow

• *Zone 3 – Lower lung
  – PA and venous pressures exceed alveolar pressure; allows wedging
Correct PAC Position
Distal PAC Position
Measuring the PCWP

To measure the mean PAOP value:

- Locate the a wave near or after the QRS Complex
- Measure the top and bottom of the a wave values and average these values

Answer:

\[ 12 + 6/2 = 9 \]
PCWP and ventilation

Effects of Respiration on Waveforms

Spontaneous Ventilation

- Inspiration
- Exhalation

Mechanical Ventilation

- Inspiration
- Exhalation
Always measure at end expiration

Spontaneous breathing is UP
Mechanical breathing is DOWN
Interpretation of the numbers

$SvO_2$ – often overlooked

- Measure of tissue oxygenation
- Less than 60% reflects poor oxygenation
  - Low Cardiac Index
    - Hypovolemia, LV failure
  - Low Hgb
    - Bleeding
  - Low $SaO_2$
    - Pulmonary Dysfunction
- High $SvO_2$ (>80%) seen in sepsis, cirrhosis, AV shunt
- Normal $SvO2$ with low CI reflects adequate tissue oxygenation
Stroke Volume/Index

• Fall in stroke volume maintain a normal CO/CI if heart rate increases
  – Cardiac Causes
    • CHF
    • MI
    • Tamponade
    • PE
  – Hypovolemia
CVP
Useful for Right Sided Assessment

• Reflection of RV filling pressure
• Low CVP
  – Hypovolemia (Bleeding, third spacing)
• High CVP
  – RV failure
  – Pulmonary hypertension
  – PE
  – Tamponade
  – Constrictive pericarditis
PCWP
The number everyone wants

• Reflects Left Ventricular filling pressure
• Low PCWP (<10-12)
  – Hypovolemic (Bleeding, third spacing)
  – RV failure
  – PE
• High PCWP (>18)
  – LV failure
  – Hypertension
  – Constrictive pericarditis
A high SVR decreases CO by the same mechanism that makes a small straw difficult to blow through.

Afterload reducers decrease SVR, represented by this larger drinking straw, which increases CO.

In other words, increasing the size of the straw enables me to blow more forcefully, now I can shoot a spitball clear across the room.

I see she's teaching hemodynamics again.
SVR and PVR

- Useful to assess afterload
- Low SVR (<960 dynes x sec x cm⁻⁵)
  - Sepsis
- High SVR (>1500 dynes x sec x cm⁻⁵)
  - LV failure
  - Hypovolemia
- High PVR (>250 dynes x sec x cm⁻⁵)
  - PE
  - Pulmonary Hypertension
Cardiac Output/Index

- Thermodilution technique
- High CI (>4.2 L/min/m²)
  - Sepsis
- Low CI (<2.4)
  - LV/RV failure
  - Hypovolemic shock
  - PE
  - Tamponade
Tips with the numbers

• In absence of Swan, a CVP and mixed venous $O_2$ sat ($SvO_2$) can be very useful
• PAEDP should be the same as PCWP
  – Except when tachycardic or PVR is elevated
• Normal $SvO_2$ in the face of low CI may warrant just close followup
• Use clinical situation to guide therapies!
Common Clinical Patterns
Shock

- Cardiogenic Shock
  - PCWP elevated, CI low, SVR elevated

- Hypovolemic Shock
  - PCWP low, CI low, SVR elevated

- Septic shock (early)
  - CI elevated, SVR low, PVR elevated
Common Clinical Patterns

• RV failure
  – CVP elevated, CVP ≥ PCWP, CI low
• Tricuspid Regurgitation
  – CVP elevated, RVEDP elevated
• Acute Mitral Regurgitation
  – Elevated PCWP, prominent v waves
• Acute Ventricular Septal Defect
  – Oxygen step-up from RA to RV, RV to PA
Common Clinical Patterns
Pulmonary

• Acute Pulmonary Embolism
  – CO low, PA high, PVR high, PCWP normal

• Chronic Pulmonary Hypertension (precapillary)
  – CVP high, RV Systolic high, PA high, PVR high, PCWP normal
• Cardiac Tamponade
  – CVP = PCWP (“Equalization of Pressures”)
  – PCWP/CVP elevated, CI low

• Constrictive/Restrictive Pericarditis
  – CVP elevated, PCWP elevated
  – Diastolic pressures equal
When can the numbers be misleading?

• Tricuspid Stenosis
  – Elevates CVP

• Tricuspid Regurgitation
  – Elevates CVP
  – Lowers CO/CI
When can the numbers be misleading?

• Mitral Regurgitation
  – Elevated LA and PCWP pressures
  – Accentuated $v$ waves similar to PA systolic
    • $V$ wave occurs during T wave, simultaneous EKG may be helpful

• Mitral Stenosis
  – PCWP will be artificially elevated

• Mechanical Ventilation
  – Measure PCWP at end-expiration
When can the numbers be misleading?

• “Overwedging” – occurs when tip is distal to optimal position, high PCWP
  – Can occur with tip migration
  – Resistance noted with inflation of balloon
  – Pull back catheter in $\frac{1}{2}$-1 cm increments
Difficulties

• Catheter wedges in RV papillary muscles
  – No difference in ‘wedged’ and unwedged tracings

• Catheter ‘fails to wedge’
  – Mitral regurgitation?
  – Loop in RV?
  – Try refloating Swan
Difficulty – Coiled Catheter
Complications of Insertion

• Arterial Puncture
  – Use anatomic landmarks, proper technique
• Pneumothorax/Hemothorax
  – Dx by chest xray, treat with chest tube
• Air Embolism
  – Acute respiratory distress, cyanosis
  – Mill Wheel murmur
  – Left lateral decubitus, 100% FiO₂
Ventricular Arrhythmia

- Most are transient during insertion
- Keep balloon inflated, keep advancing!
- If sustained, deflate balloon and remove catheter
- Defibrillate if VF/Pulseless VT
Heart Block

• Do not place PA catheter in a patient with Left Bundle Branch Block unless you have backup pacing!

• Insertion can cause transient RBBB which would become complete heart block
Catheter loops and knots

• Avoid advancing catheter against resistance or if waveforms are not as expected
  – At 30 cm should see RV
• Do not allow loops to remain in RV
• If knot develops, use fluoroscopy for guidance
Complications during use

• Pulmonary Artery Rupture
• Pulmonary Infarction
  – High pressure wedging
  – Keep inflation duration < 15 seconds
• Infection
• Ventricular Arrythmias
• Remove PA catheter when information is no longer useful!
References

- [http://www.pacep.org](http://www.pacep.org)