FUNDAMENTALS OF HEMODYNAMICS, VASOACTIVE DRUGS AND IABP IN THE FAILING HEART
CINDY BITHER, MSN, ANP, ANP, AACC, CHFN
CHIEF NP, ADV HF PROGRAM
MEDSTAR WASHINGTON HOSPITAL CENTER

CONFLICTS OF INTEREST
• NONE

OUTLINE
• THE NORMAL CARDIAC CYCLE
• NORMAL PRESSURES
• PULMONARY ARTERY SATURATIONS
• WHAT MAKES UP CARDIAC OUTPUT
• TERMS TO BE FAMILIAR WITH
• WHAT WILL ALTER CARDIAC OUTPUT
### THE CARDIAC CYCLE

![Cardiac Cycle Diagram]

### PA CATHETER
**OFTEN CALLED SWAN-GANZ**

![PA Catheter Diagram]

### NORMAL FILLING PRESSURES

<table>
<thead>
<tr>
<th>Pre-Capillary</th>
<th>Post-Capillary</th>
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<tbody>
<tr>
<td>Right Atrium</td>
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<tr>
<td>PCWP</td>
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<td>0-5</td>
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<td>Right Ventricle</td>
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<tr>
<td>Tricuspid</td>
<td>Pulmonary</td>
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<td>Valve</td>
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LUNGS
- Pre-Capillary: 0-5
- Post-Capillary: 15-30
- Right Atrium: 6-12
- Right Ventricle: 100-120
- Pulmonary Valve: 15-30
- Tricuspid Valve: 0-5
- Systemic BP: 90-110
HOW CAN WE MAKE A QUICK DETERMINATION?

• THE ABSENCE OF NORMAL DELIVERY AND OXYGEN UPTAKE LEADS TO AEROBIC METABOLISM OR DEVELOPING LACTIC ACIDOSIS
  • HAVE YOU CHECKED YOUR PATIENT LACTATE LEVEL RECENTLY?

PULMONARY ARTERY SATURATION

• SVV2 = OXYGEN DELIVERY AND OXYGEN CONSUMPTION (AMOUNT OF OXYGEN USED AT THE TISSUE LEVEL).
  • NORMAL 60-80%
  • SO WHAT CAN CHANGE IT:
    • DECREASE IN DELIVERY ABILITY
      • ANEMIA
      • LOW CARDIAC OUTPUT
    • THE NEED FOR INCREASED OXYGEN USE BY TISSUES
      • SEPSIS
      • INCREASED MUSCULAR NEED

HOW DO WE ACTUALLY MEASURE THEM?

• WHERE DO WE DRAW THE BLOOD FOR THE MOST ACCURACY?
  • THE TIP OF THE PA CATHETER, THIS IS WHERE THE BLOOD IS THE MOST MIXED FROM THROUGHOUT THE BODY
  • CAN WE USE OTHER SOURCES?
    • YES, YOU CAN OFTEN USE A PICC LINE. IT WON'T BE A COMPLETE MIX BUT IF IT IS NEAR THE RA OR IN THE RA, YOU CAN USE IT AS AN ESTIMATE (SVC ABG)
VISUAL OF A PA SAT

NORMAL FILLING PRESSURES

CARDIAC OUTPUT

CARDIAC OUTPUT IS THE VOLUME OF BLOOD PUMPED PER MINUTE, MEASURED BY THE FOLLOWING EQUATION:

\[ \text{CO} = \text{SV} \times \text{HR} \]

- \text{CO} IS CARDIAC OUTPUT EXPRESSED IN L/MIN (NORMAL ~5)
- \text{CI} IS THE OUTPUT INDEXED TO BODY SIZE
- \text{SV} IS STROKE VOLUME EJECTED PER BEAT
- \text{HR} IS THE NUMBER OF BEATS PER MINUTE
STROKE VOLUME (SV)

- Determined by three factors: preload, afterload, and contractility.
  - Preload: the volume of blood that the ventricle has available to pump. Sometimes thought of as the CVP.
  - Contractility: the force that the muscle can create at its given length.
  - Afterload is the arterial pressure or resistance against which the muscle will contract.
- These factors establish the volume of blood pumped with each heart beat.

CARDIAC VOCABULARY

- Chronotropy: rate at which the heart contracts.
  - Important when looking at cardiac output.
  - Does the body require the heart to beat faster because the stroke volume is so low? Consider this with sinus tachycardia in the HF patient.

- Inotropy: strength at which the heart contracts.

CARDIAC VOCABULARY

- Preload: preload is the muscle length prior to contractility, and it is dependent on diastole (or end diastolic volume...EDV).
  - Ventricle fills during this time.
  - The most important determining factor for preload is venous return (in other words your JVP or CVP). Think of it in terms of volume but don't forget the ability of the heart to eject it!
CARDIAC VOCABULARY

- **AFTERLOAD**: Afterload is the tension (or the arterial pressure) against which the ventricle must contract. (SVR)
- If arterial pressure increases, afterload also increases.
- Increased vasoconstriction also increases afterload.
- Afterload for the left ventricle is determined by aortic pressure (systemic blood pressure and systemic vascular resistance or SVR ~800-1200).
- Afterload for the right ventricle is determined by pulmonary artery pressure. (Hence the term pulmonary hypertension!)

USING VALUES WISELY

- Is a thermodilution output always accurate?
  - Tricuspid regurgitation
- Is a wedge pressure really the “gold standard”?
  - What about pulmonary arterial disease
  - So how do we measure it?

INTERPRETING

- Mr. Jones has the following findings:
  - CVP = 10
  - RV = 30/10
  - PA = 54/22 Amean 33
  - PCWP = 35
  - SVR = 1698
  - PA saturation = 60%
  - Fick CO/CI = 5.5/2.2
- What are your thoughts?
THINKING THIS THROUGH

• WHAT DOES IT SHOW?
  • PT IS WET
  • WHAT IS THE GUT FEELING ABOUT HOW DIFFICULT THIS WILL BE TO FIX?
  • WHY?
  • WHAT DOES THE SVR MEAN?
  • WHAT USUALLY HAPPENS TO THE PA SAT WITH DIURESIS?
  • WHAT "BOX" WOULD THEY BE IN?

INTERPRETING

• CVP = 10
• RA = 30/10
• PA = 54/22
• PCWP = 35
• SVR = 1900
• PA SATURATION = 40%
• FICK CO/CI = 2.9/1.3

WHAT DOES THIS MEAN?

• HOW DO YOU THINK THIS PERSON SHOULD BE TREATED?
• WHAT DO THEY NEED?
  • INCREASED INOTROPY
  • DECREASED SVR
  • DECREASED PRELOAD
**INTERPRETING**

- RA = 20
- PA = 62/30
- PCWP = 40
- PA SAT = 55%

**PULMONARY HYPERTENSION**

- MEAN PA PRESSURE ≥25 MMHG AT REST, IN THE SETTING OF A PCWP OF 15 MMHG

- PVR (CALCULATED IN WOOD UNITS)
  - (TRANS PULMONARY GRADIENT) MEAN PA - PCWP
  - IF >3 WOOD UNITS = PAH

**NORMAL FILLING PRESSURES**

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<td>Systems BP</td>
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WHAT DOES THIS MEAN?

• YOU ARE CALLED TO CONSULT ON THIS PATIENT WITH A NEW DIAGNOSIS OF PAH
• CAN YOU DEFINITELY SAY THIS?
• WHAT DO YOU NEED FIRST…
  • NORMALIZED PCWP

INTERPRETING

• RA = 20
• PA = 75/30
• PCWP = 20
• PA SAT = 60%

• TO QUALIFY FOR PAH YOUR PCWP MUST BE NORMAL
  • IS THIS PCWP NORMAL?

WHY MIGHT THE PCWP NEVER BE NORMAL?

• WHAT IS THE CAUSE OF THE PAH?
  • INTRINSIC LUNG DAMAGE OR PRESSURES CAN FALSELY ELEVATE A PCWP.
• HOW DO WE GET A DIRECT MEASUREMENT?
  • LVEDP = LEFT VENTRICULAR END DIASTOLIC PRESSURE
  • WHEN IS THIS USUALLY MEASURED?
HOW TO GET THE DIRECT MEASUREMENT

HEMODYNAMIC DIFFERENCES IN LEFT HEART FAILURE AND RIGHT HEART FAILURE

- RIGHT HEART FAILURE (PAH) - PRECAPILLARY
  - NORMAL LV FUNCTION AND PRESSURES
  - ISOLATED RV FAILURE AND ELEVATED PRESSURES

- LEFT HEART FAILURE (PVH) - POST CAPILLARY
  - ELEVATED PRESSURES
  - LOW CARDIAC OUTPUT/INDEX
  - LOW PA SATS

QUESTIONS?