Hemodynamics: Cardiac and Vascular

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THE PERIPHERAL EVENT OF THE YEAR
## Disclosures

**Speaker’s Bureau:**
- None

**Honorarium:**
- None

**Consultant:**
- None

**Stockholder:**
- None

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- None
Hemodynamics: Cardiac and Vascular

Thank you to:
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www.cardiovillage.com
Objectives

• Define cardiac output and stroke volume
• Identify the determinants of cardiac output and stroke volume
• Discuss the hemodynamic monitoring system
• Identify normal and abnormal hemodynamic values
• Identify the components of normal atrial, ventricular, and arterial hemodynamic waveforms
• Demonstrate understanding of the relationship between the cardiovascular pathophysiology and hemodynamics
Normal 02 Saturations

- RV: 65% - 75%
- RA: 65% - 75%
- LA: 95% - 98%
- LV: 95% - 98%
- PA: 75%
- AO: 95% - 98%
- PCW: 99%
- SVC: 65% - 72%
- IVC: 68% - 75%
- RV: 65% - 75%
- LA: 95% - 98%
Normal Cardiac Pressures

AO 120/80/93
PA 15-30/8-12/14
LA 2-12
LV 120/0/4-12
RA 2-6
RV 15-30/0/2-6
PCWP 4-12
Roll over tracing to select a phase of the cardiac cycle.
Components of Hemodynamic Pressure Monitoring

- Invasive catheter
- High pressure tubing
- Manifold system
- Transducer
- Flush system
- Monitor
Wheatstone Bridge Circuit

Consists of 4 resistors arranged in a diamond orientation. An input DC voltage, or excitation voltage, is applied between the top and bottom of the diamond and the output voltage is measured across the middle. When the output voltage is zero, the bridge is said to be balanced.
LEVEL TRANSDUCER SYSTEM

- Re-level the transducer with any change in the patient’s position.
- Referencing the system 1 cm above the left atrium decreases the pressure by 0.73 mm Hg (1”~2mmHg).
- Referencing the system 1 cm below the left atrium increases the pressure by 0.73 mm Hg (1”~2mmHg).
Top of transducer that connects to the line to the patient

Open Air reference point that is to be at the phlebostatic axis. Turn stopcock up, tell monitor to zero, and when zero, turn it back to this position.

Transducer “meat” that includes the Wheatstone bridge

This is generally the direction we use the transducer because of the way the cable hangs, but it can be used in either orientation

Flush “exhaust” port, always turned “off” except to flush

This brand is 4.5 cms distance
UNDER DAMPED SYSTEM

after flushing transducer
Over Damped System

AO Pressure

Damped AO Pressure
Respiration effect

Inspiration: drops pressures, but, increases venous return.

Quiet
Passive expiration
Active inspiration
CARDIAC OUTPUT

HEART RATE

STROKE VOLUME

PRELOAD

CONTRACTILITY

AFTERLOAD

DIASTOLIC FILLING

FIBER STRETCH

CONTRACTILE FORCE

ARTERIAL PRESSURE

VENTRICULAR SIZE
Stroke Volume

• Stroke volume is the volume of blood ejected from the ventricle with each beat and is influenced by three factors:

• The amount of blood in the ventricles at the end of diastole just prior to systole (Preload)

• The amount of pressure that the ventricle has to pump against (Afterload)

• The degree of myocardial contractility
Stroke Volume

Preload- PCWP/LVEDP (4-12 mmHg) and CVP/RVEDP (2-6 mmHg)
Stretch, volume, pressure
Starlings law
Afterload- SVR and PVR
Contractility- Dp/Dt, EF%
Definition and effects of each on SV & CO
Vascular Resistance

Normal SVR:
900 and 1440 dynes/sec/cm$^{-5}$

Normal PVR:
20-120 dynes/sec/cm$^{-5}$

SVR = $\frac{A_{O\text{mean}} - R_{A\text{mean}}}{CO}$ $\times 80$

PVR = $\frac{P_{A\text{mean}} - P_{W\text{mean}}}{CO}$ $\times 80$
Cardiac Output

• Cardiac output = heart rate X stroke volume
• CO = 70 beats/min X 65 mls
• CO = 4550 mls or 4.55 liters/min
• Normal cardiac output ranges from 4-8 liters per minute.
• Variances in CO are caused by either changes in HR or SV
Cardiac Index (CI)

$CI = \frac{CO}{BSA}$

$CI = \frac{4.55}{2.0}$

$CI = 2.275 \text{ Liters/min/M}^2$
Normal Cardiac Pressures

RA mean=2-6
RV=15-30/0/2-6
PA=15-30/10-15
LA mean=2-12
LV=110-120/0/4-12
AO=110-120/60-80
3 Types of Waveforms

- Atrial
  - CVP, RA, LA, PCWP
  - Sine wave
- Ventricular
  - RV, LV
  - Rectangle up on end
- Arterial
  - AO, BA, RA, FA
  - Triangle
Atrial Waveforms
RA and LA Hemodynamics

- The atrial waveform portions:
  - “a” wave
  - “x” descent
  - “c” wave
  - “v” wave
  - “y” descent
Atrial Waveforms

- **a wave**
  - atrial contraction--PR interval—active vent filling (30%)

- **x decent**
  - atrial relaxation

- **c wave**
  - AV valve closure--after QRS

- **v wave**
  - atrial filling--T wave

- **y decent**
  - Atrial emptying--passive ventricular filling (70%)
Atrial - A V, mean
Measure RA
13:06:48
60 BPM
Unconfirmed
Phase: PHASE 1

RA

a wave 10
V wave 8

50 mm/s

50 mm/s
PCWP Hemodynamics

- The PCWP or PAW is a reflection of the LA hemodynamics
PCWP
CVP/RA and PCWP/LA

**Increased A wave**
- Stenotic AV valves
- Non compliant stiff ventricle
- Inc. resistance to ventricular filling
- Constrictive pericarditis
- Hypervolemia

**No A wave**
- Atrial fibrillation
CVP/RA and PCWP/LA

Increased V wave
- Regurgitant AV valves
- VSD with L-R shunt
- Constrictive pericarditis
- Cardiac tamponade
- Hypervolemia
Ventricular Waveforms

- **Systole**
  - Isovolumetric contraction
  - Rapid ejection
  - Slow ejection
- **Diastole**
  - Isovolumetric relaxation
  - Passive/rapid filling
  - Atrial kick
  - End diastolic pressure
    - (R wave of EKG)
Ventricular Waveforms (S/D/EDP)
Arterial Waveforms

• Systole
  • After QRS

• Dicrotic notch
  • Semi-lunar valve closure

• Diastole
  • Runoff to the periphery

• Invasive vs: Non-Invasive monitoring
AO

PA
Alterations in Arterial Pressure

- **Elevated Pressure**
  - Arteriosclerosis
  - Renal Failure
  - Aortic regurgitation
  - Hypervolemia

- **Reduced Pressure**
  - Low cardiac output
  - Aortic stenosis
  - Dysrhythmias
  - Vasodilator therapy
  - Decreased LV function
  - Mitral stenosis
  - Cardiac tamponade
  - Dilated cardiomyopathy

- **Abnormal Pressure Reduction**
  - Vascular stenosis
Venous Return

Skeletal muscle pump-muscles press against thin-walled veins
Alterations in CVP

- Elevations in CVP
  - Increased blood volume
  - Right ventricular failure
  - Tricuspid or pulmonic value disease
  - Pulmonary hypertension/COPD

- Cardiac tamponade
- Positive pressure ventilation
- Vasoactive drugs venoconstriction
- Chronic left heart failure
Alterations in CVP

- Reductions in CVP
  - Decreased blood volume
  - Damped waveforms
  - Beta adrenergic stimulation (causing venodilatation)
Pulmonary Artery Pressure Monitoring

- Normal 15-30/10-15, mean 10-18 mmHg
- Increased in anything that increases PVR, pulmonary volume or LV failure
  - LV MI, aortic/mitral valve diz, HTN, tamponade, hypervolemia
  - Increased PVR/lung disease (COPD)
  - Increased pulmonary blood flow, shunt
- Decreased in decreased right heart cardiac output, hypovolemia, damped waveform
PCWP Monitoring

- Normally PCWP=PAd=LA=LVEDP (preload)
- Does not equilibrate with
  - Mitral stenosis, stiff LV, cor-triatrimum, PE, Left atrial myxoma, pulmonary venous obstruction, catheter in nondependent zone of the lung
PCWP Monitoring

- Normal PCWP 4-12 mmHg
- Increased in anything that causes LV failure
  - LV MI, aortic/mitral valve diz, HTN, cardiac tamponade, hypervolemia
  - NOT with increased PVR or lung disease
- Decreased in hypovolemia, damped waveform
PA/PCWP Monitoring

- Lung disease - increased PA, normal PCWP
- Left heart disease - increased PA and PCWP
Identify Catheter Location on Pullback

- LV-AO
- PAW-PA
- PA-RV
- RV-RA

Know the normal pullback sequence through cardiac chambers
Identify Normal and Abnormal Pressures

These are the only 4 numbers you need to remember: 4mmHg, 10mmHg, 25mmHg, & 130 mmHg

<table>
<thead>
<tr>
<th>Right Heart</th>
<th>Pressures in mm Hg</th>
<th>Left Heart</th>
<th>Pressure in mm Hg</th>
</tr>
</thead>
<tbody>
<tr>
<td>PAW =</td>
<td>12,12,10 (a,v,m)</td>
<td>LA =</td>
<td>12,12,10 (a,v,m)</td>
</tr>
<tr>
<td>PA =</td>
<td>25/10, 15 (S/D, m)</td>
<td>AO =</td>
<td>130/80, 100 (s/d, m)</td>
</tr>
<tr>
<td>RV =</td>
<td>25/0, 4 (s/bd, ed)</td>
<td>LV =</td>
<td>130/0, 8 (s/bd, ed)</td>
</tr>
<tr>
<td>RA =</td>
<td>5,5,4 (a,v,m)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

These are the only 4 numbers you need to remember: 4mmHg, 10mmHg, 25mmHg, & 130 mmHg
Right atrium
Normal pressure: 2-6 mm Hg

Right ventricle
Normal pressure: 20-30 mm Hg

Pulmonary artery
Normal pressure: 6-13 mm Hg
Mean pressures: 10-20 mm Hg

Pulmonary capillary wedge pressure
Normal: 4-12 mm Hg
LV to AO Pullback
The End For Now

• But there is much more to come!!!!!!
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