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M2 Mini Review
August 2008
Normal Cardiac Cycle

Targeted to Bridge Mohrman & Heller per M1 and Lilly 4th ed. per M2
Yes -- it is the ~ same as last year -- it is a REVIEW

Louis G. D’Aleyc, Professor of Physiology
Normal Cardiac Cycle Outline 1

BEFORE LUNCH

1) Pressure Flow Circulation
2) Systole vs. Diastole
3) Cardiac Cycle Pressure Gradients
4) Heart Rate
    Normal
    Fast
    Slow
Origins & pathway through heart
Normal Cardiac Cycle Outline 2

AFTER LUNCH

1) Stroke Volume
   Preload
   Afterload
   Contractility

2) LV Pressure-Volume Loops

3) Measuring pressures
   CVP, RV,
   PAP, PCWP, LVEDP

4) Measuring Cardiac Output
Heart is a **Pressure** Pump but also pumps **FLOW** (volume/time)

Heart Rate \( \times \) Stroke volume = Cardiac Output

\[
HR \times SV = CO \\
\text{b/min} \times \text{mL/b} = \text{mL/min or L/min}
\]
# Requirements for Effective Cardiac Pumping

1. **Synchronized**
   - not arrhythmic

2. **Valves open fully**
   - not stenotic

3. **Valves don't leak**
   - not insufficient
   - or regurgitant

4. **Forceful**
   - not failing

5. **Must fill**
   - Not "dry"
Fig 1.2 Lilly
Fig. 3.14
Lilly p 61
Venous valves

Flow goes around the circulation by PUMPS & VALVES

Source Undetermined
Figure 4–1. Pressures, expressed in mm Hg, in the systemic and pulmonary circulations.
Pressure gradient from beginning to end of capillaries

- Pulmonary capillaries
  - Arterial end 12 mmHg
  - Venous end 8 mmHg

- Systemic capillaries
  - Arterial end 30 mmHg
  - Venous end 15 mmHg

4 mmHg                        15 mmHg

From Levitzky, Fig 4-1
Systole & Diastole

Text books vary in definitions but most the common use of the unmodified terms “systole” and “diastole” is:

**Systole** is the **period** from the closing of the atrio-ventricular valve (mitral) to the closing of the aortic valve (ventricular contraction).

**Diastole** is the **period** from the closing of the aortic valve to the closing of the atrio-ventricular valve (ventricular relaxation and filling).

EXTRA NOTE: Some more rigorous texts distinguish **ventricular systole** from **arterial systole**:

**Ventricular systole** is the period from the closing of the atrio-ventricular valve (mitral) until its opening.

**Arterial systole** is the period from the opening of the aortic valve until its closing.
MAP = $P_d + \frac{1}{3}P_p$

Pulse Pressure = (Systolic − Diastolic)
Fig. 2.1

- Aortic valve opens
- Aortic valve closes
- Arterial Pressure
- Atrio-ventricular (MV) valve opens
- Atrial waves

Source Undetermined
Diff = Stroke volume

Systolic Pressure

Diastolic Pressure
Not 125 mmHg

Figure 4-2 Cardiac cycle—right heart.
Heart is a Pressure Pump but also pumps FLOW (volume/time)

Heart Rate × Stroke volume = Cardiac Output

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

b/min × mL/b = mL/min or L/min
Origins of the Heart Beat

- **Automaticity:** the ability to initiate its own beat.
- **Rhythmicity:** regularity of pace-making activity.
- **Pacemaker:** the region of the heart that ordinarily generates impulses at the greatest frequency.
- **Sinoatrial (SA) node:** normal, main pacemaker.
- **Intrinsic rate:** \(~100\text{b/minute}\) for SA node  
  - vs. resting rate
- **Ectopic foci or pacemakers:** regions other than SA node that initiate beat.
Variations in the Heart Rate (fast)

- **Tachycardia**: heart rate greater than normal.
  - **Sinus tachycardia**: a heart rate greater than normal (> 100b/min) from SA node.
  - **Ectopic tachycardia**: a heart rate greater than normal originating from ectopic focus.
  - **Paroxysmal tachycardia**: a heart rate greater than normal originating from ectopic focus that begins and ends abruptly.
Variations in the Heart Rate (slow)

- **Bradycardia**: a heart rate less than normal.
  - **Sinus bradycardia**: a heart rate less than normal (< 60 beats/minute) from SA node.
  - **Idiojunctional Rhythm**: AV nodal rhythm when SA node fails. 40-60 b/minute
  - **Idioventricular Rhythm**: Ectopic ventricular rhythm when SA & AV nodes fails. 20-40 b/minute
Factors influencing heart rate

**Effector Pathways**

+ or - **CHRONOTROPIC**

1. **↑ Plasma epinephrine**
   - **↑ Activity of sympathetic nerves to heart** (Tonic)
   - **↓ Activity of parasympathetic nerves to heart** (Tonic)

2. **↑ Heart rate**

**Reflexes**
- Drugs
- Temp.
Phase 4 = relatively more $\text{Na}^+$ going in and less $\text{K}^+$ going out thus +++

Fig. 1.15

Membrane potential (mV)

-40

-80

Time

Ca$^{++}$ influx

K$^+$ efflux

Pacemaker (Na$^+$)
SA Nodal Cell

Sympathetic

Vagal

Threshold

Maximal Hyperpolarization

mV

Time

24
Markedly Different conduction velocities
Source Undetermined
Normal Cardiac Cycle Outline 2

AFTER LUNCH

1) Stroke Volume
   - Preload
   - Afterload
   - Contractility
2) LV Pressure-Volume Loop
3) Measuring pressures: CVP, RV, PAP, PCWP, LVEDP
4) Measuring Cardiac Output
Fig 9.2

Contractility

Preload

Afterload

Heart rate

Stroke volume

CARDIAC OUTPUT

Source Undetermined
Lilly Table 9.1 Definitions

**Preload** - The ventricular wall tension at the end of diastole.

**Afterload** -- The ventricular wall tension during contraction; the resistance that must be overcome for the ventricle to eject its contents. Approximated by systolic ventricular or arterial pressure.

**Contractility** -- Property of heart muscle that accounts for changes in strength of contraction independent of preload and afterload.
Left ventricle pressure-volume loop

Counter Clockwise

Pressure (mm Hg)

Volume (ml)

Stroke volume

Fig. 9.4
Pressure increases as radius decreases.

Ejection Fraction = 70/130 = 54%

COUNTER CLOCKWISE ROTATION

LV end-diastolic Volume

**** LVEDV ****

PRELOAD

3.3 MH

Source Undetermined
Matching Question
Know all the answers !!!!

- a
- a to b
- b
- c
- d
- e
- b to c
- c to d

- Stroke volume
- Isovolumetric contraction
- Ventricular filling
- 1st heart sound
- 2nd heart sound
- Systolic arterial pressure
- Diastolic arterial pressure
- Left ventricular end-diastolic P&V
- Opening of atria-ventricular valve
LV Pressure-Volume Loop

- End-systolic pressure volume relationship (ESPVR).
- Slope of ESPVR ~ contractility
- Contractility ~ inotropic state
- Preload = stretch on ventricle @ end of diastole (~ EDP or EDV)
- Afterload = tension during contraction
  - (~ arterial pressure ~ MAP or diastolic AP)
“Isolated” increased afterload decreases stroke volume

(Preload)
Increased contractility increases stroke volume

~ held constant Afterload

~ held constant Preload
Increased preload increases stroke volume

- ESV ~ held constant
- Contractility
- Afterload ~ held constant

(Preload)
What should we be thinking about? Measuring?

- What are the differences in the interpretation of CVP and PCWP?
- What are the clinical concerns?
- What makes each go up and down? Physiologically and pathophysiologically?

CVP = central venous pressure
PCWP = pulmonary capillary wedge pressure
Swan-Ganz Catheter

Balloon Deflated

Distal Port for PCWP & PAP
RV - Sys, Dia CVP

Thermistor for Cardiac Output

Balloon Inflated

Pulmonary Artery Catheter (PAC)

Source Undetermined
Swan-Ganz Catheter

Edwards.com

Catheter X-Section
Insertion vein varies but: 50-60% Jugular, 30-40% Subclavian, 20-30% Arm or Leg

Fig. 3.14

PCWP
Pulmonary artery catheter

Catheter tip occludes branch of pulmonary artery

Shaded area represents “column of blood” between catheter tip and LA

A pulmonary vein

Pulmonary capillaries

PA

LA

Lilly Fig. 3.15

P 64
Pressure Changes as Catheter Moves Through Right Heart to PA to PCWP
Pulmonary Artery vs. RV
1) has notch
2) > diastole
3) down vs. up
Pressure Changes as Catheter Moves Through Right Heart to PA & PCWP
Swan-Ganz Catheter Pressure Recording

Right Ventricle               Pulmonary Artery     Pul. Cap Wedge

Pulmonary branch

Open end to measure PCWP

Balloon

wedged
LV EDV

LV EDP (Preload)

LAP

Pulmonary Venous P

Pul Cap P

Pulmonary Capillary Wedge Pressure

PCWP is used as an index of LV EDP PRELOAD
Ventricular function curve

↑ Preload  →  ↑ SV

“Preload”

Stroke volume (ml)

Ventricular end-diastolic volume (ml)
Fig. 9.3
How do we determine??
Heart is a Pressure Pump but also pumps volume/time

Heart Rate \times \text{Stroke volume} = \text{Cardiac Output}

Measure\n\text{Cardiac Output} \ \text{by Thermal Dilution}

Calculate \ \text{SV}\n
\text{HR} \times \text{SV} = \text{CO}\n
\text{b/min} \times \text{mL/b} = \text{mL/min}
Swan-Ganz Catheter

Balloon Deflated

Balloon Inflated

Distal Port for PCWP

Thermistor for Cardiac Output

DEFLATE BALLOON FOR CARDIAC OUTPUT
CO by Swan - Ganz

Thermistor @ 4 cm
Thermal Filament
Balloon
PA Distal Lumen
VIP Port @ 30 cm
Proximal Injectate Port @ 26 cm
Conclusions: PAC-guided therapy did not improve survival or organ function but was associated with more complications than CVC-guided therapy. These results, when considered with those of previous studies, suggest that the PAC should not be routinely used for the management if acute lung injury. (Clinical Trials.gov num, NCT00281268.)
Pulmonary artery catheter use is associated with reduced mortality in severely injured patients: A National Trauma Data Bank analysis of 53,312 patients*

Randall S. Friese, MD; Shahid Shafi, MD; Larry M. Gentilello, MD

Conclusions: Trauma patients managed with a PAC are more severely injured and have a higher mortality. However, severely injured patients (Injury Severity Score, 25–75) who arrive in severe shock, and older patients, have an associated survival benefit when managed with a PAC. This is the first study to demonstrate a benefit of PAC use in trauma patients. (Crit Care Med 2006; 34:1597–1601)
Severity of illness and risk of death associated with pulmonary artery catheter use*

by

Dean R. Chittock et al

Crit Care Med 2004 Vol. 32, No.4
PDF on web site
thanks for your interest,
i have no problem with you using it as a PDF on the web page..attached is the PDF...in answer to the safety...there are two large trials ongoing ....one in the US from NIH and the other in UK...they should answer the outstanding questions for us...ps... there is nothing inherently wrong with the catheter...just with the users!
Conclusions: PAC-guided therapy did not improve survival or organ function but was associated with more complications than CVC-guided therapy. These results, when considered with those of previous studies, suggest that the PAC should not be routinely used for the management if acute lung injury.

(Clinical Trials.gov num, NCT00281268.)
<table>
<thead>
<tr>
<th>Cardiovascular System</th>
<th>Central Pressures (mmHg)</th>
<th>RANGE</th>
<th>TYPICAL</th>
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<tbody>
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<td><strong>Central Pressures (mmHg)</strong></td>
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<tr>
<td>1  Right Atrium</td>
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<td>-1 to +7</td>
<td>+3</td>
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<tr>
<td>2  Rt. Ventricle Systolic</td>
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<td>15 to 30</td>
<td>24</td>
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<tr>
<td>2  Rt. Ventricle Diastolic</td>
<td></td>
<td>0 to 8</td>
<td>4</td>
</tr>
<tr>
<td>2  Pulmonary Artery (PAP)</td>
<td></td>
<td>15 to 30</td>
<td>24</td>
</tr>
<tr>
<td>2  Pulmonary Artery (PAP)</td>
<td></td>
<td>8 to 15</td>
<td>9</td>
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<tr>
<td>2  Pulmonary Artery (PAP)</td>
<td></td>
<td>10 to 20</td>
<td>15</td>
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<tr>
<td>3  Pulmonary Capillary</td>
<td></td>
<td>8 to 12</td>
<td>10</td>
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<td>4  Pulmonary Capillary</td>
<td></td>
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<tr>
<td>5  Left Ventricle Systolic</td>
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<td>90 to 140</td>
<td>130</td>
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<tr>
<td>5  Left Ventricle Diastolic</td>
<td></td>
<td>5 to 12</td>
<td>9</td>
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<tr>
<td>6  Aorta (Systemic Art.)</td>
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<td>90 to 140</td>
<td>125</td>
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<td>60 to 90</td>
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Matching Question
Know all the answers !!!!

- Stroke volume
- Isovolumetric contraction
- Ventricular filling
- 1st heart sound
- 2nd heart sound
- Systolic arterial pressure
- Diastolic arterial pressure
- Left ventricular end-diastolic P&V
- Opening of atria ventricular valve

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