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Cardiac Hydraulics

M1 – Cardiovascular/Respiratory Sequence

Louis D’Alecy, Ph.D.
Wednesday 10/29/08, 11:00
Cardiac Hydraulics
30 slides, 50 min.

1. Contractility
2. Control of Stroke Volume
3. Ventricular function
4. Estimation of Preload
5. Measurement of stroke volume
Terms Related to Cardiac Performance

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.
Complex interactions so we will treat each separately with others held constant.
Increased Contractility = Positive Inotropic Effect

Increased peak isometric tension at each resting length.

Increased Contractility = Positive Inotropic Effect

Increased shortening

AFTERLOADED CONTRACTION

peak isometric tension

more shortening

with NE

without NE

resting tension

muscle tension, g

muscle length

Afterload & preload ~ CONSTANT

2.10 MH

Increased Contractility = Positive Inotropic Effect

Increased stroke volume

Beta adrenergic stimulation: increased force (faster and more) and faster relaxation.
β (Beta) adrenergic effects

- Positive inotropic (strength) effect
- Positive lusitropic (rate of relaxation) effect
- Positive chronotropic (heart rate) effect
- Positive dromotropic (conduction velocity) effect
- Decreased duration (both AP and contraction)

Acetylcholine (cholinergic) has small negative inotropic effect.
Cellular mechanism of positive inotropy and lusitropy

Lusitropy = Increased rate of relaxation by Ca++
Controllers of stroke volume

- End-diastolic ventricular volume
  - Activity of sympathetic nerves to heart
  - Plasma epinephrine

Cardiac muscle
- Stroke volume
Ventricular function curve

- **Stroke volume (ml)**
- **Ventricular end-diastolic volume (ml)**

- Normal resting value
SV or Tension or LVP or CO

LVEDV or LVEDP or Length or Preload
HR effect
**limited by filling vol

↓Afterload
↑Contractility
↑Heart Rate

↑Afterload
↓Contractility
↓Heart Rate

**limited by fiber overlap
M & H 3 -7 Summary of Determinants of CO

CARDIAC PARASYMPATHETIC NERVE ACTIVITY LEVEL

negative chronotropic

HEART RATE

positive chronotropic

CARDIAC SYMPATHETIC NERVE ACTIVITY LEVEL

contractility (positive inotropic)

CARDIAC OUTPUT

ARTERIAL PRESSURE

FILLING PRESSURE

STROKE VOLUME

preload

afterload

(Frank-Starling law)

But how do we determine “preload”?
Swan-Ganz Catheter

- Distal Port for PCWP
- Balloon Deflated
- Balloon Inflated
- Thermistor for Cardiac Output
A pulmonary artery catheter wedges a pulmonary branch and forms a "column of blood" between the catheter tip and LA (left atrium). The distal port is used for PCWP (pulmonary capillary wedge pressure) measurement.
FIGURE 2-3. Frank-Starling curve describing cardiac function. The normal (N) relationships are in the shaded area.

- LVEDP or LV Preload or PCWP
- No More Frank-Starling Left!!
PCWP is used as an index of LV EDP PRELOAD
Lilly Box 3.1

Pressure Changes as Catheter Moves
Through Right Heart

Lilly, L. Pathophysiology of Heart Disease. Lippincott, 2007. 4th ed. Figure 3.1
Dicrotic notch

Pulmonary Artery

Right ventricle

Pressure (mm Hg)

Time

Lilly, L. Pathophysiology of Heart Disease. Lippincott, 2007. 4th ed. Figure 3.1
Pressure wave difference between PA and RV

PA vs. RV
- has notch
- > diastole
- dn vs. up
Pressure Changes as Catheter Moves

Through Right Heart to PA & PCWP
Pressure Changes as Catheter Moves Through Right Heart
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
How do we determine??
Swan-Ganz Catheter

- Distal Port for PCWP
- Balloon Deflated
- Balloon Inflated
- Thermistor for Cardiac Output
Heart Rate X Stroke Volume = Cardiac Output

Measure
Cardiac Output by Thermal Dilution

Calculate SV

HR X SV = CO
b/min X mL/b = mL/min
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<th></th>
<th>RANGE</th>
<th>TYPICAL</th>
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<tr>
<td><strong>1 Right Atrium</strong></td>
<td>-1 to +7</td>
<td>+3</td>
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<tr>
<td><strong>2 Rt. Ventricle</strong></td>
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<tr>
<td>Systolic</td>
<td>15 to 30</td>
<td>24</td>
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<tr>
<td>Diastolic</td>
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<td>4</td>
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<td><strong>3 Pulmonary Artery (PAP)</strong></td>
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<tr>
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<td>24</td>
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<tr>
<td>Diastolic</td>
<td>8 to 15</td>
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<tr>
<td>Mean</td>
<td>10 to 20</td>
<td>15</td>
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<tr>
<td><strong>4 Pulmonary Capillary Wedge Pressure</strong></td>
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<tr>
<td></td>
<td>8 to 12</td>
<td>10</td>
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<tr>
<td><strong>5 Left Ventricle</strong></td>
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</tr>
<tr>
<td>Systolic</td>
<td>90 to 140</td>
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<td>Diastolic</td>
<td>5 to 12</td>
<td>9</td>
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<td><strong>6 Aorta (Systemic Art.)</strong></td>
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<td>Diastolic</td>
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<td>Mean</td>
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Slide 20: Source Undetermined; D’Alecy
Slide 21: Bartlett, Critical Care Physiology. Figure 2-3
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