Guyton at the bedside

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Hemodynamic monitoring: Guyton at the Bedside CC 2012
What did Arthur Guyton teach us?

• Paradigm shift:
  – Prior to Guyton, control of cardiac output was thought of in terms of HR, Stroke Volume, and contractility

• Little thought given to how blood gets back to the heart

• Credited Ernest Starling for realizing that:
  – *Filling of the heart is dependent upon venous return (VR)*
  – VR is dependent upon upstream pressure which Starling called “mean systemic pressure”
“When a change occurs in the hemodynamics of the circulatory system one cannot predict what will happen to the cardiac output unless he takes into consideration both the effect of this change on the ability of the heart to pump blood and also the tendency for blood to return to the heart from the blood vessels.”
Volume creates venous elastic recoil force

Determinants of flow

\[ Q = \frac{\text{Stressed Volume}}{Cv \times Rv} \]

- Increase the initial volume
- Greater flow
- Stressed volume
Heart has a "restorative" function. Volume stretches the veins and creates the "recoil" pressure that drives fluid back to the heart, creating the "recoil" function which refills the veins.

Heart has a "permissive" function. It lowers the outflow pressure and allows veins to empty.
The height of the water determines the outflow

MSFP
In contrast to your tub, the veins are the source of fluid in the circulation.
If there is no venous blood to return…..

… the heart has nothing to pump
Concept of Stressed and Unstressed Volume
Cardiac function

Return Function

Stressed volume
Unstressed volume

MSFP

Q

Pra

Rv
If cardiac function becomes limited a volume infusion will not increase cardiac output

= ‘wasted preload’ (excess volume)
Pra = MSFP

Q

Pra < MSFP

-1/Rv

MSFP
Lowering $P_{ra}$ further will not increase $Q$.

\[ VR_{\text{max}} = \frac{\text{MCFP}}{R_v} \]
Return Function

Cardiac Function

“Return limited”

“Cardiac limited”

“working CVP”
Increase in Cardiac Function Curve

- Higher Q for a given Pra
- ↓ Heart Rate
- ↑ Contractility
- ↓ Afterload
Increase Cardiac Function

Increase in gradient for venous return
Fall in cardiac output with rise in Pra

Decrease gradient for venous return
Increase in Volume

P

MSFP ↑

V

Q

Pra

MSFP

↑
Decrease in Volume

Fall in $Q$ with fall in $Pra$
Change in Capacitance
(can change by 10-15 ml /kg)
Change in Capacitance

Can recruit ~ 10 ml/kg of unstressed to stressed
Compare changes in Cardiac and Return functions

• Change in Cardiac Function
  – Changes in Q and Pra are in **opposite** directions

• Changes in Return Function
  – Changes in Q and Pra are in the **same** direction
CVP is not useful!

TRUE ....

If you do not know how to use it!
CVP does not indicate the magnitude of vascular volume. 

But why would you expect it to!? 

Marik, Baram, & Vahid Chest 2008
Reasons for low CVP

1. Normal cardiac function and blood volume

2. Depressed cardiac function but low blood volume

Give volume and inotrope

Q = 5 L/min
Pra = 0 mmHg

Q = 3 L/min
Pra = 0 mmHg
Low CVP (3)

Decrease in volume with normal cardiac function

Give volume

Q

Pra
1. Increased volume - normal cardiac function

2. Decrease cardiac function normal volume

3. Decrease RVR without change in cardiac function (?sepsis)
The CVP value by itself can make some diagnosis unlikely

- **LOW** CVP makes dx of cardiac tamponade, pulmonary embolism, RV failure unlikely causes of shock
  - But cannot rule out LV dysfunction
- High CVP means that fluids are unlikely to help (exceptions – high PEEP, chronic pulmonary hypertension

What is a high CVP?
Some Patients at all values of CVP fail to respond to fluids

Bafaqeeh & Magder JICM 2007
CVP by itself has limited value

• Major value is by looking at changes in relation to changes in perfusion
  – ie indicating position on the cardiac function curve.
• Trends are critical
CVP should not be considered alone

**CVP is best considered in relation to Q**

When given a value of CVP, the next question should be …

*what is the cardiac output or a surrogate?*

*or simply does the pt look normal!*
1 Assess the value of Pra (NOT the wedge).
2 Give sufficient fluid to raise Pra by ~2mmHg and observe Q.

Type of fluid is not of importance if given fast enough.
Change in CVP of even 1 mmHg should be sufficient to test the Starling response.

\[ \text{Slope} = 500 \text{ ml/min/mmHg} \]
BP = Cardiac Output x SVR
BP = Cardiac Output x SVR

First Question to ask:

*Is the cardiac output decreased*

Or

*Is the cardiac output normal or increased*
BP = Cardiac Output x SVR

Cardiac Function
- Heart Rate
- Stroke Volume
- Afterload
- Contractility
- Preload

Return Function
- Stressed volume
- Compliance
- Resistance
- Pra
Volume responsiveness does not mean volume need

Your CVP sitting in this lecture is likely < 0 mmHg

You do not need a saline bolus!
Initial Right Atrial Pressure

mmHg

No Insp Fall

+ve Insp Fall

0

4

8

12

16

20
Approach:

1. Assess adequacy of inspiratory effort from wedge
2. Evaluate the change in Pra

Eg of no fall in Pra with inspiratory effort

Magder et al JCCM 1992
Magder et al JCCM 1992
Fluids after cardiac surgery: A pilot study of the use of colloids versus crystalloids*

Sheldon Magder, MD; Brian J. Potter, MD; Benoit De Varennes, MD; Steve Doucette, Msc; Dean Fergusson, PhD; for the Canadian Critical Care Trials Group

Crit Care Med 2010 Vol. 38, No. 11
Fluid Protocol

CI < 4 and CVP ≤ 12 ?

Protocol Fluid Bolus

Check CI and CVP

CVP incr. ≥ 2 and CI incr. < 0.3

CVP incr. < 2 and CI incr. ≥ 0.3

CVP incr. > 2 and CI incr. ≥ 0.3

CI < 2.2 or MAP < Target or SBP < Target or CVP < 3 or Urine < 20 cc/hr

CI < 2.2 or MAP < Target or SBP < Target or CVP < 3 or Urine < 20 cc/hr

Total Protocol Fluid > 1L/24hr?

Yes

Inadequate challenge

Review fluid criteria

No

Cardiac response ok

Yes

Catecholamine Protocol

No

Observe or wean

Pt not volume responsive

Saline

Yes

No

CI < 2.2 or MAP < Target or SBP < Target or CVP < 3 or Urine < 20 cc/hr

Pt not volume responsive
## Primary Outcome

Catecholamines between 8:00 and 9:00 AM

<table>
<thead>
<tr>
<th></th>
<th>HES 119</th>
<th>Crystalloid 118</th>
<th>YES</th>
<th>13</th>
<th>34</th>
<th>10.9%</th>
<th>28.8%</th>
<th>0.38 (0.21, 0.68)</th>
<th>p = 0.001</th>
</tr>
</thead>
</table>


Serum Creatinine over time

Day 0

S Creat (mmol/l)

0 20 40 60 80 100 120 140

Saline
HES

Day 0 1 2 3 4 5 Last
Part = Q \times SVR\quad (+K)

Heart
- Heart Rate
- Afterload
- Contractility
- Preload

Circuit
- Stressed volume
- Compliance
- Resistance
- Pra

Dobutamine
Milrinone

Volume
NE

Sepsis
Drugs
Spinal

NE
Circulatory Model

Heart

Rv

unstressed volume

MSFP
Concept of arterial pressure driving the flow around the circuit
Question 1

The term mean systemic pressure was first used by:
1. Ernest Starling
2. Mathew Levy
3. Arthur Guyton
4. Sol Permutt
• Patient comes back from aorto-coronary bypass surgery. The initial hemodynamics are:
  – Q = 2.2 l/min/m², Pra = 8 mmHg, Pw = 6 mmHg, Part = 110/70 mmHg

• One hour later
  – Q = 1.8 l/min/m², Pra = 12 mmHg, Pw = 8 mmHg, Part = 80/60 mmHg

1. Give fluids
2. Give norepinephrine
3. Give dobutamine
4. Give dopamine
• Post operative cardiac surgery
• Initial blood pressure is 80 mmHg
What do you want to know next?
1. CVP
2. LV size
3. LV ejection fraction
4. Cardiac output

• CI = 3.2 l/min/m², Pw= 12 mmHg, Pra= 10 mmHg,
Results from the previous patient indicate:
CI = 3.2 l/min/m²,  Pw= 12 mmHg,  Pra= 10 mmHg

What would you do next (remember BP =80)
1. Give a fluid bolus
2. Give dobutamine
3. Give Norepinepherine
4. Just observe