Hemodynamic Monitoring 2016
Avoiding Occult hypoperfusion
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Avoiding Occult Hypoperfusion

Science works within an established paradigm: a set of rules that govern the definition of terms, the collection of data and the boundaries of inquiry. But over time, anomalies appear inside the paradigm, data that can't be explained, questions that can't be answered using the tools of the existing model. As new methods and tools are introduced that explore outside the boundaries of the existing view, the old paradigm collapses.

Thomas Kuhn
The Structure of Scientific Revolutions
NO! Physical Assessment is often inaccurate, slow to change and difficult to interpret.

Temporal order of events
(each event can take minutes to hours)

1. Stroke volume falls
   - Heart rate compensates to keep cardiac output normal
     - Many reasons for heart rate to increase
2. Cardiac output falls
   - Heart rate compensation fails
   - Vasoconstriction (increase in SVR), BP remains unchanged
3. Increased oxygen extraction of hemoglobin
   - Peripheral initially (StO2)
   - Central later (ScvO2)
4. Blood pressure, urine output change

Are Physical Signs Early or Late Indicators of Clinical Status?

<table>
<thead>
<tr>
<th>Signs of Hypoperfusion</th>
<th>Which signs are similar with all three?</th>
</tr>
</thead>
<tbody>
<tr>
<td>LV dysfunction</td>
<td>BP</td>
</tr>
<tr>
<td>Hypovolemia</td>
<td>HR</td>
</tr>
<tr>
<td>Sepsis</td>
<td>LOC</td>
</tr>
<tr>
<td></td>
<td>Urine output</td>
</tr>
</tbody>
</table>

Which signs will fluid resuscitation change?
Level of consciousness?
Urine output?
References – Inaccuracies of Physical Assessment


Does CVP and PAOP tell us about blood volume and flow?

- CVP and PAOP should never be used in isolation
  - Inconsistent in revealing information about volume and flow
- Flow and pressure do not always correlate
  - Mark et al. Based on the results of our systematic review, we believe that CVP should no longer be routinely measured in the ICU, operating room, or emergency department.


<table>
<thead>
<tr>
<th>Trends...</th>
<th>Baseline</th>
<th>S/P 500 mls</th>
<th>LK</th>
<th>S/P 2000 mls</th>
</tr>
</thead>
<tbody>
<tr>
<td>SV</td>
<td>22</td>
<td>33</td>
<td>75</td>
<td>83</td>
</tr>
<tr>
<td>HR</td>
<td>113</td>
<td>99</td>
<td>6.5</td>
<td>3.2</td>
</tr>
<tr>
<td>CO</td>
<td>2.5</td>
<td>3.2</td>
<td>310</td>
<td>6.5</td>
</tr>
<tr>
<td>FTe</td>
<td>288</td>
<td>310</td>
<td>360</td>
<td>310</td>
</tr>
<tr>
<td>CVP</td>
<td>7</td>
<td>7</td>
<td>7</td>
<td>7</td>
</tr>
</tbody>
</table>

75

83

6.5

3.2

310

360

7

7

S/P 2500 mls
BP Measurement - Useful or Misleading?

- Is BP measured because it can be measured
- If BP increases, does blood flow increase?
- Blalock 1943, says: "It is well known by those interested in this subject that the blood volume and cardiac output are usually diminished in traumatic shock before the arterial blood pressure declines significantly"

Blalock A, (1943) Surgery 14: 487-508

Blood Pressure and Blood Flow

Do they equal each other?

BP = CO x SVR

- CO = Stroke volume x heart rate
  - decrease in SV causes increase in heart rate
  - decrease in CO causes increase in SVR

- Compensatory changes keep the BP close to normal initially in shock states
- BP does not change until late due to these compensatory responses
What is the Purpose of Blood Pressure?

The role of the biventricular cardiovascular system

<table>
<thead>
<tr>
<th>Systemic Values</th>
<th>Pulmonic Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>LV 110/10</td>
<td>RV 25/0-5</td>
</tr>
<tr>
<td>Aorta 120/80</td>
<td>PA 25/10</td>
</tr>
<tr>
<td>Capillaries 30-50</td>
<td>Capillaries 12-17</td>
</tr>
<tr>
<td>RA 0-5</td>
<td>LA 8-12</td>
</tr>
</tbody>
</table>

Moving toward Blood Flow Measurement

Stroke Volume as an End point

Stroke volume normal values

Stroke volume variation

Evidence (8 RCTs) of Using SV as Endpoint

SV Optimization for Fluid Administration

- Stop giving fluids
- Monitor SI as indicated
- Give 200 ml of colloid or 500 ml of crystalloid
- If SV/SI or FTc is low:
  - Is the heart pumping enough blood?
    - YES (SI increased < 10%)
    - NO (SI increased > 10%)
- If SV/SI decreased >10%:
  - Stop treatment
  - Monitor SI as indicated
  - Give preload reducer, afterload reducer or inotrope
- If SV/SI or PV is low:
  - Is the heart pumping enough blood?
    - YES (SI increased < 10%)
    - NO (SI increased > 10%)
- If SV/SI decreased >10%:

SV Optimization for Ht Failure

- SV as an End point
- SV normal values
- SV variation

Moving Toward Blood Flow Measurement
Determine success of fluid or inotropic therapy by
The response in stroke volume/index and \( \text{SvO}_2 \)

<table>
<thead>
<tr>
<th>Stroke Volume</th>
<th>End-Diastolic Volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \Delta \text{SV} &lt; 10% )</td>
<td>( \Delta \text{EDV} &lt; 10% )</td>
</tr>
<tr>
<td>( \Delta \text{SV} &gt; 10% )</td>
<td>( \Delta \text{EDV} &gt; 10% )</td>
</tr>
<tr>
<td>( \Delta \text{SV} = 0% )</td>
<td>( \Delta \text{EDV} = 0% )</td>
</tr>
</tbody>
</table>

Treatment Guidelines

Methods of Measuring SV

<table>
<thead>
<tr>
<th>Uses</th>
<th>Ease of use</th>
<th>Accuracy</th>
<th>Professional Reimbursement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Doppler - USCOM</td>
<td>Anywhere</td>
<td>Good</td>
<td>Good</td>
</tr>
<tr>
<td>Doppler (EDM)</td>
<td>OR, ICU</td>
<td>Excellent</td>
<td>Excellent</td>
</tr>
<tr>
<td>ECON</td>
<td>OR, ICU</td>
<td>Good</td>
<td>Fair</td>
</tr>
<tr>
<td>Bioimpedance</td>
<td>Anywhere</td>
<td>Good</td>
<td>Fair</td>
</tr>
<tr>
<td>Pulse contour (FloTrac, LiDCo, PICCO)</td>
<td>OR, ICU</td>
<td>Difficult</td>
<td>Fair</td>
</tr>
<tr>
<td>NICO</td>
<td>OR, ICU</td>
<td>Difficult</td>
<td>Fair</td>
</tr>
<tr>
<td>PAC</td>
<td>OR, ICU</td>
<td>Difficult</td>
<td>Good</td>
</tr>
<tr>
<td>Bioreactance</td>
<td>OR, ICU</td>
<td>Good</td>
<td>Good</td>
</tr>
</tbody>
</table>

Non invasive CO/SV measurement
• All methods have strengths and limitations
• Many acute and critical care patients can have these techniques used
• All can be used within limitations
• Use oxygenation end points to validate information regarding blood flow

Which Technique is Best?

Arguable – but the one with the most evidence is clear – esophageal Doppler
Which has the most potential application?
Non invasive Doppler

U.S. & U.K. Support at the Federal Level
No Matter What Technology is Used:
Stroke Volume Optimization is the Key

Interpreting Stroke Volume

Overview
Normal Ranges

- SV: How much blood is pumped with each beat
  Normal: 50-120 ml/beat
- SI: How much referenced against body size
  Normal: 25-50 ml/m²
- SD: The distance that blood flows in a specific time period (This is the most accurate).
  Normal: > 10; Hypovolemia: <10

*Normals are just reference points. The real test is whether or not they change if fluid is given.

Esophageal Doppler Variables

Esophageal Doppler Variables

Normal Ranges

- FTc: Flow Time corrected
  The time of systolic flow corrected to heart rate.
  330 - 360 milliseconds
- PV: Peak Velocity
  The velocity of the blood measured at the peak of systole.
  20 yrs: 90 - 120 cm/sec
  50 yrs: 60 - 90 cm/sec
  70 yrs: 50 - 80 cm/sec

NOTE: Normal Ranges should not be confused with a Physiological Target.

After induction, FTc of 323 ms, (low) indicated possible hypovolemia.

- SV of 77 ml was reasonable; however, HR of 60 gives a cardiac index (CI) of 2.3 l/m²/m².
- 200ml of colloid was given.
- SV increased >10%, suggesting more colloids be given to optimize the intravascular volume.
After 2nd bolus, SV increased by 14 ml (19%) and FTc also increased.

CI increased from 2.3 to 2.7 l/min/m²

Indicated more fluid could be given to optimize SV.

More colloid given in accordance with the SV optimization algorithm until SV increases were less than 10%.

Who is being harmed by our current practices?

We must have a sense of urgency

Seeking a Direct Measure of Tissue Oxygenation

- Blood draw
- Lab or bedside analysis
- Normal lactate – 1-2 mmol
- pH – normal 7.35-7.45
- If lactate > 4 mmol and pH is less than 7.30, consider tissue hypoxia
- CAUTION: Lactate can increase for reasons other than hypoxia

- Reflects perfusion status where oxygen is delivered to tissue
- If SLO₂ is < 75% or dropping, consider inadequate tissue perfusion
- Potentially earliest indicator of a threat to tissue oxygenation
- CAUTION: May not be the same as ScvO₂ or SvO₂
Lactate as Indicator of Hypoxia

Chemical energy (high-energy electrons)

Glycolysis

Glucose → Pyruvic acid

Chemical Energy

Krebs cycle

Electron transport chain and oxidative phosphorylation

Mitochondrion

ATP synthesis

Lactate

N = 529
< 2 (N=219) 2-4 (N=177) > 4 (N = 104)

SBP > 90
158/219 (72%) 116/177 (65%) 64/104 (62%)

SBP < 90
61/219 (28%) 61/177 (34%) 40/104 (38%)

Lactate Levels and SBP

No Ventilation CPR

ABC's or CAB's
The relationship between hemodynamics and oxygenation

The role of mixed venous oxyhemoglobin (SvO2)

Microvascular Blood Flow Is Impaired with normal or elevated macro hemodynamics (SV, CO)

StO2 Monitoring
Near Infra-Red Spectrometry (NIRS)
Summary

- Hemodynamic monitoring should focus on stroke volume optimization
- Most patients can have hemodynamic monitoring
- Tissue oxygenation should be combined with macro hemodynamic measurements
- The application of hemodynamic monitoring is greater than ever