New Directions in Non Invasive Monitoring

Mike McEvoy, PhD, RN, CCRN, NRP
Professor Emeritus – Critical Care Medicine, Albany Medical College
Chair Resuscitation Committee - Albany Medical Center, New York
EMS Coordinator – Saratoga County (NY)
EMS Editor – Fire Engineering magazine

Class Code: 665

Goals for this talk:

• Complications of hemodynamic monitoring
• Non invasive tissue perfusion monitoring devices
• Algorithms that interpret patient monitoring data – is this the future?

Goal of patient monitoring

• Assess tissue perfusion
  – Oxygenation and distribution (flow)
• Others?
  – Respirations
  – Hydration
  – Labs:
    – Poisons
    – Perfusion markers
    – Hemoglobin
Are physical findings enough?

- HR
- LOC
- BP
- UO

Apparently not...

- 50% of physical assessments wrong
- Therapeutic interventions altered with invasive assessment 34 - 56% of the time:
  - 1980 Del Guercio
  - 1984 Eisenberg
  - 1991 Steinberg
  - 1994 Minoz
  - 2002 Jacka

Why do we measure BP?

- Because we can.
Purpose of blood pressure

Biventricular CV System

<table>
<thead>
<tr>
<th>L (systemic)</th>
<th>R (pulmonic)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LV 110/10</td>
<td>RV 25/0-5</td>
</tr>
<tr>
<td>AO 120/80</td>
<td>PA 25/10</td>
</tr>
<tr>
<td>capillary 30-50</td>
<td>capillary 12-17</td>
</tr>
<tr>
<td>RA 0-5</td>
<td>LA 8-12</td>
</tr>
</tbody>
</table>
Arterial Pressure Monitoring

Direct

Indirect

Pressure

Flow

Flow measurements

- Pulses
- Cuff
- NIBP
- Doppler

All sense pulsatile flow
Flow Measurements
Not Accurate:
• Low blood flow states
• High SVR states
Cohn JM. JAMA 1967;199:972

If BP increases, does flow increase?
• Think of levophed...
NOPE

What is “normal”? 

Blood Pressure:
• Bland, Shoemaker
  J Surg Obst 1978 -
  – 74% of survivors achieved normal values
  – 76% of NON-SURVIVORS achieved normal vital signs
Currently: BP ≠ perfusion
Connors et al 1996 JAMA

The effectiveness of right heart catheterization in the initial care of critically ill patients. SUPPORT Investigators

5734 adult ICU patients 1989-1994, 5 ICUs at 15 tertiary med centers

PA cath = ↑ 30 day mortality, ↑ ICU LOS, ↑ costs of care

Harvey et al: PAC-Man 2005

Lancet - Game Over?

1014 patients at 65 UK institutions: NO DIFFERENCE between PA cath versus no PA cath

Assessment of the clinical effectiveness of pulmonary artery catheters in management of patients in intensive care (PAC-Man): a randomised controlled trial

Cochrane R & R: 2006

(Review and Reappraisal)

“The PAC is a monitoring tool; if it is used to direct therapy and there is no improvement in outcome, then the therapy does not help.”

A reappraisal for the use of pulmonary artery catheter (PAC)
**Bye Bye PA catheter**

- 65% decrease in use between 1993 – 2004 (US)
- Consistent across diagnoses
- Not due to changes in coding practices
- Due to evidence lacking mortality reduction?

Wiener R. JAMA 2007;298:423-29

---

**Critical Information**

- Oxygenation
- Perfusion

---

**Evaluating Perfusion**

- Tools we have
**Lactate (Lactic Acid)**

- Hypoperfusion severity index
- NL < 2, concerned when > 4
- > 15 often fatal
- More helpful as trend

**POC Lactate Testing**

- Developed for athletes & climbers
- Not FDA approved
- Currently under investigation in EMS and Fire service

**SvO₂ and ScvO₂**

- Reflects O₂ reserve & extraction
- Oximetry value of venous blood
  - ↓ Hct, CO, SaO₂
  - ↑ VO₂
- The lower the level, the worse...
- < 40% typically fatal (SvO₂)
**Capnography**

- CO₂ clearance reflects perfusion!
- Available for intubated and non-intubated patients
- Development in progress: IPI

**End-tidal CO₂ (EtCO₂)**

**Normal a-A gradient**
- 2-5mmHg difference between the EtCO₂ and PaCO₂ in a patient with healthy lungs
- Wider differences found
  - In abnormal perfusion and ventilation
  - Incomplete alveolar emptying
  - Poor sampling

**Future Developments**

- Perfusion assessment derived from exhaled CO coupled with bioimpedance data.
Integrated Pulmonary Index™

IPI Values – fuzzy logic

<table>
<thead>
<tr>
<th>IPI</th>
<th>Patient Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>Normal</td>
</tr>
<tr>
<td>8-9</td>
<td>Within normal range</td>
</tr>
<tr>
<td>7</td>
<td>Close to normal range; requires attention</td>
</tr>
<tr>
<td>5-6</td>
<td>Requires attention</td>
</tr>
<tr>
<td>3-4</td>
<td>Requires attention or intervention</td>
</tr>
<tr>
<td>1-2</td>
<td>Requires intervention</td>
</tr>
</tbody>
</table>

Acoustic Resp Monitoring

- Released July 2010
- PizoElectric sensor based
- Reports RRa
- Future versions V_T
- Telemetry based
- May replace capnography?
How RRa Works:

Using acoustic signal processing, the respiratory signal is separated and processed to display continuous respiration rate.

Waveforms

FDA Accuracy Results: Similar to Capnography

Esophageal doppler (TED)

- Transducer probe inserted into distal esophagus
- Blood flow measured by doppler principle
- Nurse driven
TTE (Trans Thoracic Echo)

- Also nurse or medic driven
- Chest wall instead of esophageal

TED/TTE:

- Preload reduction
- Preload increase
- Afterload increase
- Afterload reduction
- Myocardial depression
- Positive inotropy

TEB (CardioDynamics BioZ®)
RELIANT
Non Invasive Hemodynamic Monitor

CAPTURES (14) PARAMETERS
“In Real Time”

CO Cardiac Output
CI Cardiac Index
SV Stroke Volume
SVV Stroke Volume Variance
SVI Stroke Volume Index
HR Heart Rate
TPR Total Peripheral Resistance
VET Ventricular Ejection Time
MAP Mean Arterial Pressure
NIBP Non Invasive Blood Pressure
TFC Thoracic Fluid Content
TFCd % Directional Change in TFC/T ime
CP Cardiac Power
CPI Cardiac Power Index

Bioimpedance

Volts

Amp.

Bioreactance

V₀

I₀

I₀
Perfusion Index

- Perfusion Index is an objective method for measuring a patient’s peripheral perfusion
- Perfusion Index is an early indicator of deterioration (PI of 1.4% best discriminated normal from abnormal)

Photoplethysmography
**Pleth Waveform**

![Pleth Waveform Image]

**A-line versus Pulse Ox Pleth**

![A-line versus Pulse Ox Pleth Image]

**Definition of PVI**

- Pleth Variability Index (PVI) is a measure of dynamic changes in PI that occur during the respiratory cycle.

\[
PVI = \frac{P_{\text{max}} - P_{\text{min}}}{P_{\text{min}}} \times 100\%
\]

- PVI is a percentage from 1 to 100%; 1 = no variability and 100 = maximum variability.
**Fluid Status/Volume Responsiveness**

- High variability (high PVI) = volume depletion
- 15 – 50% of patients are fluid non-responders – low variability (low PI) suggests the patient is a non-responder
  - The ventricle more sensitive to respiratory changes is more responsive to preload

---

**Pulse CO-Oximetry**

Oxygenated Hb and reduced Hb absorb different amounts of Red (RD) and Infrared (IR) Light

1. Carboxyhemoglobin
2. Methemoglobin
3. Hemoglobin
4. ? Glucose
5. ? Cyanide
6. ?
Less Invasive = less complex

Summary
- Perfusion is the goal
- Provider assessment alone is inadequate
- Less invasive is better
- The future is integration:
  - Multiple parameters (algorithmic)
  - Communication between devices

Thanks for your attention!
Slides available at:
www.mikemcevoy.com