Hemodynamic Monitoring in Critical Care

Dr. Leanna R. Miller  
DNP, RN, CCRN-CSC, PCCN-CMC, CEN, CNRN, NP  
LRM Consulting  
Nashville, TN

• Learning Objectives
  – Evaluate the effect of falling hemoglobin and decreased CO on oxygen delivery to the tissues.
  – Correlate physical signs and symptoms, diagnostic studies, and hemodynamic alterations to develop a plan of care for the patient in shock.
  – Integrate oxygen delivery and oxygen consumption parameters into clinical decision making and selection of therapeutic modalities.

Hemodynamic Monitoring

Parameters Used to Assess Shock

• Vital Signs
• Hemodynamic Parameters
• Global Indices
• Organ Specific Indices

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Traditional Hemodynamic Parameters
• HR, MAP, CVP, PAOP
• insensitive
• often misleading in the assessment of circulating blood

Dynamic Hemodynamic Parameters
• Continuous arterial pressure
• Arterial Pulse Pressure Variation (PPV)
• Systolic Pressure Variation (SPV)
• Stroke Volume Variation (SVV)

Assessing Shock
• Majority of patients in decompensated shock even though VS, CI, UO & SvO2 have returned to normal
• 80% of trauma patients with normal BP showed signs of hypoperfusion
Assessing Shock

- 85% has increased lactate and decreased SvO\(_2\) even though HR, BP, UO were normal
- Compensatory mechanisms mask true organ perfusion

Hemodynamic Monitoring

Shock Index

- HR / systolic blood pressure
- inversely related to LVSW
- abnormal > 0.9
- application: persistently abnormal shock index in patient with normal VS suggests need for more invasive monitoring

Lactate Levels

- liver is efficient at metabolizing lactate
- acute alcohol intoxication affects lactate metabolism
- liver injury will slow lactate clearance


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Hemodynamic Monitoring

Lactate Levels

- arterial more precise
- normal < 1 mEq/L
- > 3 - 4 mEq/L significant hypoperfusion – associated with higher mortality
- will decrease 5-10% / hr when appropriate therapy used

Lactate Levels

Lab Studies – Base Excess

- Normal value: -2 to +2
- reflects the extent to which the body buffers have been exhausted
- rapidity of normalizing base deficit decreases morbidity & mortality

Lab Studies – Base Excess

values
- -2 to -5 mild
- -6 to -15 moderate
- -16 or higher severe
- global indicator
- trending is best use of info
- more prognostic if used with lactate
**Hemodynamic Monitoring**

- **SvO** sub 2:
  - Near infrared light illuminates tissue
  - Light scatters and is absorbed differently by oxygenated and deoxygenated hemoglobin in the microcirculation
  - Light returns to sensor and is analyzed and displayed as % StO sub 2

**Resuscitate to a mean arterial pressure of > 65 mmHg**

- **SvO** sub 2:
  - Normal (20-40%)
  - Low (<15%)

- **SaO** sub 2:
  - Oxygen therapy, increase PEEP

- **Cardiac output**
  - High (>2.5 L/min/MF)
  - Low (<2.5 L/min/MF)

- **Hemoglobin**
  - < 8 g/dL:
    - Anemia
    - Mood alteration
    - Dehydration
  - > 18 mmHg:
    - Hypovolemia
    - Hypotension

- **StO** sub 2:
  - Normal (75-80%)
  - Low (60-75%)

- **ScvO** sub 2:
  - Normal (75-80%)
  - Low (60-75%)
Lactate | Base Excess | ScvO₂ | StO₂
---|---|---|---
Early | Early | Delay ed | Early
Global | Global | Global | Organ Specific
Invasive | Invasive | Invasive | Non-invasive
Intermittent | Intermittent | Continuous | Continuous
Delay ed Info | Delay ed Info | Real – time | Real – time
Multiple Variables | Multiple Variables | Multiple Variables | Specific

Requires additional info to direct appropriate interventions
82-year-old female admitted with perforated diverticular abscess. HR 123, BP 110/60/77, SaO₂ 96, SI 1.1. lrmmiller@msn.com.
Hemodynamic Monitoring

HR 123
BP 110/60/77
SI 1.1
RAP / PAOP 8 / 10
PAP 24 / 10
CI 3.1
ScvO₂ .78
SaO₂ .96
Hemoglobin 10.2

DO₂I = CI (1.38 x Hgb x SaO₂) 10
3.1 x 1.38 x 10.2 x 0.96 x 10
419 mL/min/m²
(normal = 360 - 600 mL/min/m²)

VO₂I = CI X 1.38 X Hgb X (SaO₂ – ScvO₂) X 10
3.1 x 1.38 x 10.2 x (.96 - .78) x 10
79 mL/min/m²
(Normal 108 - 165 mL/min/m²)
Sepsis
- ↑ O₂ demand 55%
- peripheral shunting & delivery-limited VO₂
- sudden ↓ in VO₂ = early warning
- VO₂ remains low = poor outcome

Endpoints of Resuscitation
- CI > 5.5
- DO₂I 250 - 500
- VO₂I 70 - 90

Case Study 1
DOI₂ = CI (1.38 x Hgb x SaO₂) 10
4.5 x 1.38 x 8.8 x 0.88 x 10

481 mL/min/m²
(normal = 360 - 600 mL/min/m²)
Case Study 1

\[ \text{VO}_2 = \text{CO} \times 1.38 \times \text{Hgb} \times (\text{SaO}_2 - \text{ScvO}_2) \times 10 \]

\[ 4.5 \times 1.38 \times 8.8 \times (.88 - .82) \times 10 \]

33 mL/min/m²

(Normal 220 - 290 mL/min/m²)
**Case Study 2**
- 54-year-old male with suspected large anteroseptal MI
- new episode pain
- restless, dusky, new systolic murmur LLSB
Case Study 2

HR: 118
BP: 80 / 42 / 55
SI: 1.5
SaO₂: .88
Lactate: 5.3

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Case Study 2

HR: 118
BP: 80 / 42 / 55
CO / CI: 3.2 / 1.56
PAP: 58 / 32 / 40
PAOP / CVP: 29 / 15

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Case Study 2

PVRI: 564
SVRI: 2051
SVI: 25
LVSWI / RVSWI: 8.84 / 5.78

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Case Study 2

ABGs (.40 FiO₂)
- pH: 7.49
- pCO₂: 25
- pO₂: 56
- SaO₂: 88
- HCO₃: 21
- ScvO₂: 60%

PaO₂ / FiO₂ Ratio (P/F)
- 56 / .40
- 140

- Normal = > 300
- ALI = < 250
- ARDS = < 200

Laboratory Values
- Sodium: 144
- Chloride: 98
- Hgb / Hct: 12.1 / 36.3
- CO₂: 21
Case Study 2

**Anion Gap**
- \( \text{Na} - (\text{CO}_2 + \text{Cl}) \)
- \( 144 - (98 + 21) \)
- 25
  (Normal = 12 – 15)

↓ CO threatens DOI\(_2\) levels
- \( \mathrm{O}_2 \) demands are seldom ↑ except when catecholamines are used

**Hemodynamic Monitoring**
- DOI\(_2\) 300 - 400
- VOI\(_2\) > 125
- ScvO\(_2\) > 50%
- \( \mathrm{O}_2 \)ER < 30%

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**Case Study 2**

\[ \text{DO}_{2} = \text{CI} \times (1.38 \times \text{Hgb} \times \text{SaO}_2) \times 10 \]
\[1.56 \times 1.38 \times 12.1 \times 0.88 \times 10\]

\[ 229 \text{ mL/min/m}^2 \]
(normal = 360 - 600 mL/min/m²)

**Cardiogenic Shock**

**Goals of Therapy**

- Increase Cardiac Index

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Cardiogenic
• Increase contractility
• Decrease afterload
• Optimize preload
• Optimize heart rate

ingestion

Ventricular Assist
• IABP
• VAD
• ECMO

• 48 – year – old alcoholic
• develops GI bleeding & acute pancreatitis
• hemodynamically unstable with signs of refractory hypoxemia
HR 130  
BP 85/50/62  
SI 1.5  
SaO₂ .83  

HR 130  
BP 85/50/62  
RAP / PAOP 1/2  
PVRI/SVRI 290/2218  
CI 2.2  
ScvO₂ .60
Case Study 3

Laboratory Values

- Na: 150
- Cl: 96
- Hgb / Hct: 12.1 / 36.3
- CO₂: 26

Anion Gap

Na - (Cl + CO₂)
150 - (96 + 26)
28
(Normal 12 - 15)
**Hemodynamic Monitoring**

- **paO₂ / SaO₂** 50 / .83
- **pH** 7.38
- **paCO₂ / HCO₃** 45 / 27
- **FiO₂** .70

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**Hemodynamic Monitoring**

- **paO₂ / FiO₂ ratio** 50 / .7
- 71
  - (Normal > 300)
  - Respiratory Failure < 250
  - ARDS < 200

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**Hemodynamic Monitoring**

\[
DO₂ = CI \times (1.38 \times \text{Hgb} \times \text{SaO₂} \times 10)
\]
\[
2.2 \times 1.38 \times 12.1 \times 0.83 \times 10
\]

**305 mL/min/m²**

(normal = 360 - 600 mL/min/m²)

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\[ \text{VO}_2 = \text{Cl} \times 1.38 \times \text{Hgb} \times (\text{SaO}_2 - \text{ScvO}_2) \times 10 \\
 2.2 \times 1.38 \times 12.1 \times (.83 - .60) \times 10 \\
 \text{84 mL/min/m}^2 \\
 \text{(Normal 108 - 165 mL/min/m}^2) \]
- PEEP can ↓ DO₂
- WOB ↑ VO₂
- triggers inflammatory response
- maldistributed blood flow → ↓ VO₂
- ideal Hgb is 12

^ DO₂ until VO₂ plateaus

In Conclusion