Hemodynamic Simulation

Interactive Session

Nevin M. Katz, M.D.

George Washington University Medical Center
Washington Institute of Thoracic and CV Surgery
Foundation for the Advancement of CTS Care
Disclosures

- Participation on the Critical Care Scientific Advisory Board of Edwards Lifesciences - Dec 2008

- Opinions are my own, based on 20 + years of practicing CVT surgery and critical care and my interpretation of the literature
A Growing Crisis

• Despite medical progress, there is a growing crisis due to a shortage of professionals trained in CVT Critical Care

  • Surgical Resident Coverage Restricted by the 80-hour work-week
    • Predominant time spent in the OR
  • “Revolving-Door” Phenomenon
    • Rapid turnover in CVT Critical Care personnel
    • Challenge of training newly-recruited staff
A Recent Event Highlights the Importance of Education & Training in Professions Directly Related to the Well-Being & Safety of People
Skill, Training & Simulation
Flight 1549: All Lives Saved!
Challenges: Coordination of the Team

Optimal Care is dependent on Members of the Multi-Disciplinary Team:

- Sharing a Broad Understanding of the Inherent Complexities of the Specialty
- “Being on the Same Page”
Role of Industrial Collaboration in Education & Training

• Over the Years, Industry has Provided Valuable Education and Training to Professionals, especially when Innovative Products are introduced.

Examples: Systems for Minimally Invasive CPB

• New Monitoring Systems
• New Heart Valves and Methods of Implantation
• New Pharmaceutical Agents
Role of Industrial Collaboration in Creation of Medical Simulators

- Companies that Have Developed the Technology Have the Best Understanding of Its Potential and Limitations.

- As Medical Advances become more Complex and Training with Simulation becomes more possible, Companies have an Role.

- Parallel: Aircraft manufacturers have an important role in building flight simulators.
Advanced Hemodynamic Monitoring

- Parameters employed in this Hemodynamic Simulation, include Cont CO, SVV, Scv $O_2$

- Monitoring equipment to provide these parameters is available from at least 4 manufacturers.
Overall Management of Low Cardiac Output

• Initial Assessment Postop Cardiac Surgery

• Optimize the 6 Basic Hemodynamic Parameters:
  • Heart rate / Rhythm
  • Preload
  • Afterload
  • Contractility – Systolic Function
  • Ventricular Compliance - Diastolic Function
  • Surgical Result
    • Identify and Rx Mechanical/ Anatomic Problem

• Assess Perfusion: Whole Body & Specific Organs
  • Balance of $O_2$ Supply & Demand

• Adjust Hemodynamic Parameters
  • Consider Ventricular Assist Device
Optimizing Hemodynamics

- **Focus on 6 Basic Targets / Parameters:**
  - Heart rate / Rhythm
  - Preload
  - Afterload
  - Contractility – Systolic Function
  - Ventricular Compliance - Diastolic Function
  - Surgical Result
    - Rx Mechanical/ Anatomic Problem
  - + / - Consider Assist Device
Optimizing Hemodynamics: Focus on Additional Targets

• The Ventricular Function Curve
  • Which Curve
  • Position on the Curve

• Whole Body Perfusion
  • Oxygen Balance – Mixed or Central Venous $O_2$ Sat
  • Lactic Acid Production

• Specific Organ Perfusion
Classical Targets / Parameters

**Cardiac Output** (C.I. 2.2 – 4.4 L/ min/m²)

**Pressures:**
- Systemic BP:
  - Systolic: 90 – 140 mmHg
  - MAP: 70 – 90 mmHg
- LAP or PAOP (5 – 18 mmHg)
- RAP or CVP (5 – 15 mmHg)

**SVR** (900 – 1400 dynes/sec/cm²)
Quantification of Pulsus Paradoxus: Stroke Volume Variation

SVV > 15%
- On Ascending Limb of Curve
- Volume Responsive

SVV < 15%
- Volume Optimal
- Not Volume Responsive
Venous Oximetry

- Intermittent vs. Continuous

- PA Catheter or Central Venous Catheter

- True mixed venous from PA (SvO$_2$): 60 – 80%

- Central venous (ScvO$_2$): 70 - 80%
  - About 7% > SvO$_2$
  - ScvO$_2$ > SvO$_2$ in patients under critical care
Target Values

- **CI** \( \geq 2.2 \text{ L/min/m}^2 \)
- **SVI** \( \geq 35 \text{ ml/beat/m}^2 \)
- **SVV** \( < 10 – 15\% \)
- **SVR** \( 900 – 1400 \text{ dynes-sec/cm}^5 \)
- **ScvO}_2 \) \( \geq 70 - 80 \% \)
CVT Critical Care
Case Scenarios
Audience Response System (ARS)

Survey
  • Demographics

Case Scenarios
  • Intervention Choices
1. Thoracic Surgeon
2. Intensivist
3. Anesthesiologist
4. Physician Assistant
5. Critical Care Nurse
6. Perfusionist
7. Respiratory Therapist
8. Other Allied Professional
Case Scenarios

Format

- Sequence of Clinical Information
- Several Intervention Points
- For Each Intervention Point:
  - ARS - Intervention Choices
    - Limited Number of Interventions
    - Majority Rules
  - Computer Simulation
  - ARS - Follow-Up Intervention Choices
  - Follow-Up Computer Simulation
Case 1 – On Arrival in ICU

- 54 y/o man with recent non-Q-wave MI
- Cath showed 3-vessel CAD, EF 40%
- Underwent CABG x 4 with LIMA, RIMA, and Radial Artery Grafts using CPB at 34°C
- Uneventful Operation

- Postop in ICU:
  - BP 110/70, HR 90 (Sinus)
  - CVP 12, Temp 35°C
Case 1 – On Arrival in ICU

- Postop in ICU:
  - BP 110/70, HR 90 (Sinus), CVP 12
  - Sp O$_2$ 99%
  - Temp 35°C

- Advanced Monitoring Cables not yet connected.
1. Crystalloid
2. Colloid
3. PRBC
4. Norepinephrine
5. Vasopressin
6. Dopamine
7. Epinephrine
8. Milrinone
9. Nitroglycerin
10. Nitroprusside
Case 1 – 15 Minutes After Arrival

- Postop in ICU:
  - BP 110/70, HR 75, CVP 12
  - Temp 35°C

- Cables now connected

- SaO₂, CI, ScvO₂, SVV available
1. Crystalloid
2. Colloid
3. PRBC
4. Norepinephrine
5. Vasopressin
6. Dopamine
7. Epinephrine
8. Milrinone
9. Nitroglycerin
10. Nitroprusside
1. Crystalloid
2. Colloid
3. PRBC
4. Norepinephrine
5. Vasopressin
6. Dopamine
7. Epinephrine
8. Milrinone
9. Nitroglycerin
10. Nitroprusside
Case 1 – 3 hrs Postop

- 3 hrs Postop:
  - BP 100/70 (85), HR 100, CVP 12, Temp 38°C
  - SaO₂ 98, Hgb 8
  - On Dopamine 5 mcg/kg/min
1. Crystalloid
2. Colloid
3. PRBC
4. Norepinephrine
5. Vasopressin
6. Dopamine
7. Epinephrine
8. Milrinone
9. Nitroglycerin
10. Nitroprusside
Factors affecting Venous Saturation

- Oxygen Supply
  - Cardiac Output
  - $\text{SaO}_2$ – e.g. Pulmonary issue
  - Hemoglobin – O$_2$ carrying capacity

- Oxygen Demand / Consumption
Case 2 – Early After Arrival in ICU

- 62 year old man with hx previous CABG to LAD & RPDA and S/P Coronary Stent to LCX on clopidogrel
- Reoperation:
  - AVR with heterograft valve for severe Aortic Stenosis
- EF Preop 45%

- Postop BP 130/80 on NTG 10 mcg/min,
- HR 90 (AV Pacing), CVP 8
- Temp 36\(^\circ\)
- Hgb11
- Cables connected: SaO\(_2\), CI, ScvO\(_2\), SVV
Case 2 – 15 mins after Arrival in ICU

- Peep added for low SaO$_2$

- SaO$_2$ corrected

- Re-evaluation

- Issues:
  - Correction of Low Cardiac Output
  - Will volume improve hemodynamics?
<table>
<thead>
<tr>
<th></th>
<th>Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Crystalloid</td>
</tr>
<tr>
<td>2</td>
<td>Colloid</td>
</tr>
<tr>
<td>3</td>
<td>PRBC</td>
</tr>
<tr>
<td>4</td>
<td>Vasopressin</td>
</tr>
<tr>
<td>5</td>
<td>Phenylephrine</td>
</tr>
<tr>
<td>6</td>
<td>Dopamine</td>
</tr>
<tr>
<td>7</td>
<td>Epinephrine</td>
</tr>
<tr>
<td>8</td>
<td>Dobutamine</td>
</tr>
<tr>
<td>9</td>
<td>Nitroglycerin</td>
</tr>
<tr>
<td>10</td>
<td>Nitroprusside</td>
</tr>
</tbody>
</table>
Case 2 – 3 hrs Postop

- BP 105/70 w/ NTG off, MAP 80, HR 105 (AV Pacing off)
- CVP 10

- SaO₂ 97%

- Hgb 7, PT 18, INR 1.6, PTT 55, Platelet Ct. 95,000

- Hourly CT drainage: 150, 350, 250

- SaO₂, CI, ScvO₂, SVV available
Treatment?

1. Crystalloid
2. Colloid
3. PRBC
4. Norepinephrine
5. Vasopressin
6. Dopamine
7. Epinephrine
8. Milrinone
9. Nitroglycerin
10. Nitroprusside
1. Crystalloid
2. Colloid
3. PRBC
4. Norepinephrine
5. Vasopressin
6. Dopamine
7. Epinephrine
8. Milrinone
9. Nitroglycerin
10. Nitroprusside
Case 3

- 76 y/o man admitted with Unstable Angina
- Hx:
  - S/P MI one week ago
  - HT, DM
- Cath: Diffuse 3 vessel CAD, EF 40%
- Op: CABG x 5. Myocardial cooling noted to be suboptimal 2nd to non-coronary collaterals. Perfusate temp 32° eventually to 24° C. Visualization / vessels difficult. XCT120 minutes.
- Came off bypass on Dobutamine 10 with CI 1.8.
- Intraop echo showed diffuse hypokinesis, EF 20%.
Case 3

- Postop:
- BP 130/80, HR 90 (Atrial Pacing)
- CVP 16, Temp 34\(^\circ\)C
- SaO\(_2\) 98%, Hgb 12
- On Dobutamine 10 mcg/kg/min
- Cables connected: CI, SVR, ScvO\(_2\), SVV
1. Crystalloid
2. Colloid
3. PRBC
4. Norepinephrine
5. Vasopressin
6. Dopamine
7. Epinephrine
8. Milrinone
9. Nitroglycerin
10. Nitroprusside
1. Crystalloid
2. Colloid
3. PRBC
4. Norepinephrine
5. Vasopressin
6. Dopamine
7. Epinephrine
8. Milrinone
9. Nitroglycerin
10. Nitroprusside
1. Crystalloid
2. Colloid
3. PRBC
4. Norepinephrine
5. Vasopressin
6. Dopamine
7. Epinephrine
8. Milrinone
9. Nitroglycerin
10. Nitroprusside
1. Crystalloid
2. Colloid
3. PRBC
4. Norepinephrine
5. Vasopressin
6. Dopamine
7. Epinephrine
8. Milrinone
9. Nitroglycerin
10. Nitroprusside
Key Points

- Simulation provides unique training opportunities.

- Basic Hemodynamic Parameters, BP, HR, CVP, and Sp O₂ do not provide specific-enough data to optimize hemodynamics in non-routine cases.
Key Points

• Advanced Hemodynamic Monitoring, for example, Cont CI, SVV, ScO2 / SvO2 can guide precise hemodynamic management.

• Advanced Hemodynamic Monitoring can now be accomplished minimally invasively using
  • Arterial line with arterial pressure-derived CO, SVV
  • Central venous catheter with continuous oximetry (ScvO2)
Discussion