Point-of-Care Testing:
A Cardiovascular Perfusionist’s Perspective

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Objectives / Overview

✓ What is a perfusionist?
✓ Describe the basics of extracorporeal circulation
✓ Concepts that are unique to extracorporeal circulation
✓ Discuss standards and guidelines
What is a perfusionist?

CCP = certified clinical perfusionist

A skilled allied health professional, trained and educated in the following areas:

- Extracorporeal circulation
- Blood management
- Circulatory assist devices
Extracorporeal = “situated or occurring outside the body”

Cardiopulmonary Bypass!
Extracorporeal = “situated or occurring outside the body”

Cardiopulmonary Bypass!

ECMO
Cardiopulmonary Bypass

Keeps the heart still or empty (or both) in order to perform surgery.
Cardiopulmonary Bypass

Venous cannula for draining blood from the patient
Cardiopulmonary Bypass

Arterial cannula for returning blood to the patient
How did we get from this...
...to spaghetti??
Cardiopulmonary Bypass

Circuit Complexities:

1. Cardioplegia
2. Suction and vents
3. Hemoconcentration
4. Temperature control
5. Circuit monitoring
   ✓ Circuit pressures
   ✓ Temperatures
   ✓ Laboratory values
Cardiopulmonary Bypass

Circuit Complexities:

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Cardioplegia

1. Stops the heart so that it remains still for surgery
2. Cools the heart to lower it’s metabolism
3. Allows opening of the heart
Cardioplegia

How do we stop the heart?

Cold, high potassium
Cardioplegia

How do we stop the heart?

Cold, high potassium
Cardiopulmonary Bypass

Circuit Complexities:

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Despite being on CPB and the heart stopped, blood can still enter the heart.

It must be vented out to keep the surgical field clean and prevent heart distension.
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Cardiopulmonary Bypass

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Terumo CDI-500
In-Line Blood Monitoring System
optical fluorescence

optical reflectance
optical fluorescence  

optical reflectance  

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recalibration 10:28
Enter new values and press the OK (J) key...
Concepts unique to Extracorporeal Circulation
Unique Concepts

1. Rapid, dramatic changes in laboratory values
   - Blood gases
   - Electrolytes and pH
   - Anticoagulation

2. Hypothermia and blood gas management

3. Blood mixing and regional perfusion (ECMO)
Rapid Changes in Blood Gases

- We can quickly and easily manipulate $pO_2$ and $pCO_2$ of the blood using the rate of gas flow across the oxygenator, and the $FiO_2$
- $pO_2$ and $pCO_2$ are not completely predictable due to the artificial nature of oxygenators. No two are the same.
- Efficiency changes with time, temperature, anticoagulation, viscosity, etc
Rapid Changes in Blood Gases

- We can quickly and easily manipulate pO2 and pCO2 of the blood using the rate of gas flow across the oxygenator, and the FiO2.
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Rapid Changes in Blood Gases

- We can quickly and easily manipulate pO$_2$ and pCO$_2$ of the blood using the rate of gas flow across the oxygenator, and the FiO$_2$.

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- Efficiency changes with time, temperature, anticoagulation, viscosity, etc.
Rapid Changes in pH

Why does pH change rapidly?

– Changes in pCO2
– Changes in temperature
– Drugs such as sodium bicarbonate, THAM, etc
  • Sometimes boluses, sometimes drips
– Solutions such as NaCl
Rapid Changes in Electrolytes

What other values do we monitor closely?

– Potassium!
  • Delivery of cardioplegia can result in the patient getting as much as 30 mEq of potassium in only a few minutes

– Sodium and chloride (Saline)

– Calcium
  • We want this low during bypass, correcting it prior to weaning from bypass
  • Can cause ischemic damage due to contracture

– Bicarbonate (drugs such as sodium bicarbonate)
  • Lactic acidosis can occur during CPB
Rapid Changes in Anticoagulation
Rapid Changes in Anticoagulation

Activated clotting time (ACT)

- Target ACT during bypass = >480 seconds
  - Normal = ~120 seconds
- Without large doses of anticoagulant such as heparin, the bypass circuit would clot off within seconds
Unique Concepts

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Unique Concepts: Hypothermia

- Heart and brain are most vital organs to protect.
- Heart gets cooled to below 10°C when arrested to protect against ischemic injury.
- We sometimes cool the brain to as low as 16°C during circulatory arrest.
- These changes in temperature can have a dramatic affect on blood gases.
Unique Concepts: Hypothermia

Hypothermia is cytoprotective and organ protective

7°C temperature decrease = 50% decreased metabolism

30°C = 50%
23°C = 25%
16°C = 12.5%
9°C = 6.25%
Why cool the heart?
Why cool the brain?

Deep Hypothermic Circulatory Arrest
Why cool the brain?

Deep Hypothermic Circulatory Arrest

Source: Cohn LH: Cardiac Surgery in The Adult, 4th Edition; www.accesssurgery.com
Blood Temperature

“Normal” values for pH and pCO$_2$ are usually thought of as 7.40 and 40 mmHg. However, these values are only appropriate at 37°C.
“Normal” values for pH and pCO₂ are usually thought of as 7.40 and 40 mmHg. However, these values are only appropriate at 37°C.

Why is this, and how is this important during extracorporeal circulation?
Henry’s Law – the concentration of a gas is determined by the product of partial pressure and solubility

Gas content = Partial pressure x solubility
Blood Temperature

Gases are more soluble at decreased temperature, but gas content does not change.
Blood Temperature

What MUST happen to partial pressure if temperature decreases?

Temperature ↓ → Gas Solubility ↑ → Partial Pressure ↓
Heart is 37°C
$pCO_2$ = 40 mmHg

Skin is 25°C
$pCO_2$ = 25 mmHg

Perfusionists are totally HOT
Blood Temperature

Decreased temperature = Decreased pCO$_2$

The problem with decreased pCO$_2$?
- Cerebral vasoconstriction
- Poor unloading of oxygen
Left Shift

Hb has an increased affinity for oxygen
What should we do?
Blood Temperature

pH versus alpha stat

Both are methods of pCO2 management.

Goal of BOTH techniques is to keep the pH at 7.4 and the pCO₂ near 40 mmHg.

Main difference = temperature correction
Blood is drawn from 28°C patient

Blood is placed in analyzer and warmed to 37°C

Analyzer reports as if 37°C

pH = 7.40
pCO₂ = 40 mmHg
Blood is drawn from 28°C patient

Blood is placed in analyzer and warmed to 37°C

Analyzer reports as if 37°C

pH = 7.40
pCO₂ = 40 mmHg
Blood is drawn from 28°C patient

Blood is placed in analyzer and warmed to 37°C

- **Analyzer reports as if 37°C**
  - pH = 7.40
  - pCO$_2$ = 40 mmHg
- **Analyzer corrects to 28°C**
  - pH = 7.56
  - pCO$_2$ = 26 mmHg
Arguments for pH stat

✔ High pCO2 dilates cerebral vessels
✔ Good for cerebral blood flow
✔ Better homogenous cooling
✔ Counteracts the left-shift in the dissociation curve
✔ Better unloading of oxygen
Arguments for Alpha stat

✔ Preserved cellular transmembrane pH gradients
✔ Preserved enzyme activity
✔ Avoids intracranial hypertension and microembolism
Which is better?

We aren’t totally sure!
<table>
<thead>
<tr>
<th>Gas</th>
<th>Actual Solubility*</th>
<th>Relative Solubility</th>
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<tr>
<td>Carbon Dioxide</td>
<td>.57</td>
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*Units = mL of gas / mL of solution / atmospheric pressure
Unique Concepts

1. Rapid, dramatic changes in laboratory values
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What is ECMO?

ExtraCorporeal Membrane Oxygenation
ECMO

no venous reservoir!!
ECMO

no venous reservoir!!
What is ECMO?

Similar to CPB, but:
- No venous reservoir
- Less capabilities (no cardioplegia, suction, etc)
- Designed for longer-term use
- No deep hypothermia

Circuit monitoring is still important:
- Temperatures
- Pressures
- Laboratory values
What is ECMO?

✔ ECMO is a temporary form of support for any recoverable cardiac and/or respiratory failure

✔ Support can last from a few hours to a few months

✔ Not a therapeutic intervention – only buys time
Respiratory ECMO
1990 - 2016
Cardiac ECMO
1990 - 2016
Two types of ECMO:

1. Veno-arterial (VA) ECMO
   - Provides cardiac and respiratory support
   - Similar to cardiopulmonary bypass

2. Veno-venous (VV) ECMO
   - Provides NO cardiac support, only respiratory
   - Analogous to an artificial lung in the right atrium
Venoarterial (VA) ECMO

Patient Venous Blood

Native Heart/Lung

Artificial Heart/Lung

Patient Arterial Blood
VA ECMO: Central
VA ECMO: Peripheral
Blood Mixing During ECMO:

We often draw blood samples from multiple sites during VA ECMO.

Why?
pO2 120 mmHg

pO2 70 mmHg
Venovenous (VV) ECMO

1. Patient Venous Blood
2. Artificial Lung
3. Native Lung
4. Patient Arterial Blood
Venovenous (VV) ECMO

Blood from the ECMO circuit may not look at all like blood drawn from the actual patient.
Standards and Guidelines
Standards and Guidelines – Cardiopulmonary Bypass

Guideline 9.2:
Point-of-care hemostasis monitoring should be utilized to minimize blood loss

Guideline 10.1:
Point-of-care testing should be considered to provide accurate and timely information for blood gas analysis
Standards and Guidelines – ECMO (General Guidelines)

Guideline 4a1:

ACT is measured at the bedside (not sent to the laboratory) because heparin dosing decisions are often required immediately.
Standards and Guidelines – ECMO (Transport)

Guidelines for transport equipment:

A mobile ECMO system shall consist of...

✓ Point-of-Care anticoagulation monitoring equipment
✓ Point-of-care device for monitoring blood gases, electrolytes, glucose, and hemoglobin
The End