Acid Base Balance Review

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Objectives

- Describe the differences between fetal venous and arterial blood gases
- Describe respiratory, metabolic and mixed acidosis in the fetus

Disclosure

- The instructors have no conflict of interests to disclose!

Life is a balance!

Metabolic ACIDS
Base buffers

Uteroplacental Physiology

- Placental Transport Mechanisms (all require energy!):
  - Diffusion:
    - O2, CO2, fatty acids, water, fat soluble vits, etc.
  - Facilitated diffusion:
    - glucose and other sugars
  - Active transport:
    - amino acids, water soluble vitamins, calcium, iron, iodine
  - Pinocytosis:
    - plasma microdroplets, serum proteins, antibodies
  - Bulk flow:
    - water, ions, and low molecular weight solutes
Aerobic/anaerobic (glucose) metabolism

- **Aerobic Metabolism**
  - In the presence of oxygen
    - Liberation of carbonic acid (byproduct of carbon dioxide)
    - CO2 diffuses easily across placenta (mom clears this)

- **Anaerobic Metabolism**
  - Absence of oxygen
    - (Non carbonic) Lactic acid accumulates (H+)

- Base buffers help keep pH normal
  - (hemoglobin, bicarbonate and plasma proteins)

Fetal Metabolism requires:

- Adequate UBF to IVS
- Sufficient placental surface area for gas and nutrient exchange
- Efficient diffusion of Oxygen/CO2
- Unimpaired fetal umbilical circulation

What maternal factors can decrease uterine blood flow to intervillous space?

- Position
- Cardiac output
- Blood pressure
- Stress
- Contractions

Aerobic Metabolism

- Oxygen/glucose
- From mother’s oxygen enriched blood through healthy functioning placenta
- Carbon Dioxide
- Water
- ATP (36)
- Heat (417 kcal)

Anaerobic Metabolism

- Glucose and glycogen stores
- In absence of oxygenated blood (acute or chronic) placental insufficiency
- Lactic acid
- ATP (2)
- Heat (32 kcal)

Ordinarily....

- Aerobic metabolism maintained until the available oxygen in the IVS decreases to ~50%
  - Shunting
  - Extra Hb
  - FHR slowing
  - Less movement
Fetal Response to Decreased Oxygen

- Redistribution of blood to vital organs
- Oxygen consumption decreases
  - Myocardium uses less oxygen
  - Changes in FHR
- Aerobic to anaerobic metabolism

Terminology:

- pH
  - “puissance hydrogen” (strength/power of hydrogen)
  - Concentration of hydrogen ions in blood
- Bicarbonate
  - Primary hydrogen buffering system in blood
- Base
  - Capable of accepting hydrogen (decreases acidity of blood)
- Base Deficit/Base Excess
  - How much base is left over to buffer hydrogen (higher number – BE/BD is bad)

Terminology, cont’d

- Respiratory acidosis:
  - High PCO2 with normal bicarbonate levels
- Metabolic acidosis:
  - Low bicarbonate in the presence of normal PCO2 levels
- Asphyxia:
  - Hypoxia with metabolic acidosis

In other words....

Fetal Response to Stressors

- Hypoxia and/or decreased umbilical blood flow
- Chemoreceptor/baroreceptor stimulation
- Cardiac stress
- Blood flow to periphery (gastrointestinal and renal)
- Blood flow to vital organs (brain, heart, and adrenal)
- FHR changes
  (Type of FHR change depends upon severity and timing of the stress)

Terminology

- Normoxia:
  - Normal levels of oxygen
- Hypoxia:
  - Inadequate cellular and tissue oxygenation
- Hypoxemia:
  - Inadequate oxygen in blood
- Hypercapnia:
  - Increased carbon dioxide in blood
- Acidemia:
  - Increased hydrogen ions in blood
- Acidosis:
  - Increased hydrogen ions in tissue

In a cord sample:

- Blood from the umbilical vein reflects uteroplacental status

  - Influenced by maternal problems such as anemia and hypoxia
  - Influenced by placental perfusion problems:
    - Maternal hyper/hypotension
    - Ruptured uterus
    - Abruption
    - Small placental size/lesions/infarcts/etc
Blood from umbilical arteries reflects uteroplacental AND fetal status:

- Fetal status is influenced by umbilical venous blood flow… and
- Intrinsic fetal problems such as anemia and heart failure… and
- Umbilical arterial blood flow (but umbilical artery occlusion is NOT reflected in umbilical arterial samples)

**Umbilical Cord Gases**

<table>
<thead>
<tr>
<th></th>
<th>Arterial</th>
<th>Venous</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>7.18-7.38</td>
<td>7.25-7.45</td>
</tr>
<tr>
<td>pCO2 mmHg</td>
<td>32.2-65.8</td>
<td>26.8-49.2</td>
</tr>
<tr>
<td>pO2 mmHg</td>
<td>5.6-30.8</td>
<td>17.2-40.8</td>
</tr>
<tr>
<td>HCO3 mmol/l</td>
<td>17.2-24.2</td>
<td>15.8-24.2</td>
</tr>
<tr>
<td>BE/BD mmol/l</td>
<td>-8 to 8</td>
<td>-8 to 8</td>
</tr>
</tbody>
</table>

**In simpler terms….. arterial gases**

- pH 7.10
- PCO2 < 60
- PO2 > 20
- Bicarb > 22
- BD < 12

These numbers are used as a study ‘guide’ (easy to memorize!)
Always need to have both venous and arterial values sent….

**Respiratory Acidosis**

- Low pH
- ↑ CO2 levels (hi PCO2, low O2)
- Develops rapidly
- Cleared rapidly

**Metabolic Acidosis**

- Low pH
- ↑ lactic acid levels
- Results from anaerobic metabolism
- Takes longer to develop
- Takes longer to clear
When do cord gases NOT reflect fetal condition?

- Cord occlusion (prolapse)
- Heart failure
- Acute fetal hemorrhage
- Chronic fetal/maternal transfusion
- Breech delivery with trapped head

Blood Gas Analysis

- Direct analysis for:
  - pH
  - pCO2
  - pO2
- Values calculated for:
  - HCO3
  - BE/BD
- BD is calculated from pH and PCO2

Hemoglobin and O2 Saturation

- Ignore O2 sat analysis in newborns (not typically reported in umbilical values)
  - Blood gas analyzers assume adult hemoglobin
    - At term, 75% of hemoglobin is fetal
    - At 28wks, 90% of hemoglobin is fetal
- Analyzers assume hemoglobin of 15 mg/dl and temp of 37°C

UA and UV values

- Umbilical venous values ALWAYS higher than arterial values
- Umbilical venous pCO2 ALWAYS lower than arterial
- Umbilical venous pO2 ALWAYS higher than arterial
- BE/BD and Bicarb pretty much the same in UA/UV (but if one is significantly worse, it’s the arterial value)

Minimum Differences between Art and Venous values

- When arterial pCO2 is <4mmHg greater than venous, suspect that samples are from the same vessel
- pH < .04 difference between arterial and venous values = same vessel (in borderline [.03] difference, check PO2/PCO2 differences- if narrowed, probably same vessel)

Impaired Cord Blood Flow

- Cord occlusion occurs by
  - Stretch
    - Short cord
    - Nuchal cord
    - True knot (stretch/compression)
    - Descent
    - Spasm from sudden stretch
  - Compression
    - Torsion
    - Mono/mono twins
    - Hematoma
    - prolapse
Occlusion

- Vein easier to occlude than artery
- When vein occluded, sample only reflects UP status before occlusion
- Hallmark of venous occlusion is widened differences between vein/artery pH, PCO2 and BE
- Difference of >.10 suggests vein occlusion

What does labor do to the fetus?

- Normal labor
  - Fetus enters labor with BD of ~2
  - In normal active phase, BD increases by 1 mmol for every 3–6 hours of labor
  - 2nd stage, increase of BD by 1 mmol/hour
- With repetitive decelerations
  - BD increases ~1 mmol/30 min
  - BD increases ~1 mmol/6 minutes (in last 60 min)
  - So......

Fetal stress in Labor: by the numbers!

- Repetitive (severe) variables, etc reduce base buffers (increase base deficit!)
  - ~ 1 mmol/30 min
- Subacute fetal compromise
  - ~1 mmol/15 minutes
- Acute, severe fetal compromise (ex. Terminal bradycardia, uterine rupture)
  - ~ 1 mmol/2-3 minutes

Progressive variable decelerations then prolonged deceleration delivered by forceps (tight nuchal cord) – Apgars 6/9

<table>
<thead>
<tr>
<th></th>
<th>Vein</th>
<th>Artery</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>7.22</td>
<td>7.10</td>
</tr>
<tr>
<td>PCO2</td>
<td>52</td>
<td>70</td>
</tr>
<tr>
<td>PO2</td>
<td>18</td>
<td>10</td>
</tr>
<tr>
<td>BE</td>
<td>-7</td>
<td>-11</td>
</tr>
</tbody>
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Respiratory Acidemia/Acidosis

- Free H+ ions in fetal blood (blood moves too slowly to clear metabolites H2O and CO2)
- Typically caused by cord compression
- Acids accumulate and cause pH to drop
- Birth (breathing) generally resolves problem
- If significant time (multiple variable decels) or insufficient oxygen (cord prolapse?), anaerobic metabolism will occur (lack of O2) and glucose will be used for fetal metabolic processes
Metabolic Acidemia/Acidosis

- Insufficient oxygen creates shift from aerobic to anaerobic metabolism (no O2) =>
- glucose used and glycogen broken down to glucose (for energy)
- Lactic acid is the byproduct
- Lactic acid must be buffered
- Deficits in base buffers result from anaerobic metabolism => metabolic acidemia => acidosis