Resuscitation of the Critically ill Foal
Sick Cell Syndrome

- **Foal:** Wishful
- **Warm Blood filly**
- **DOB:** March 25 1 AM
- **Admission Date:** March 25 11:25 AM
- **10 hours old**
Wishful History

- **Born at 1 AM on March 25**
  - Foal began to breathe with nostril flaring
    - As soon as the nostrils cleared the canal
  - **Stage II 10 minutes**
    - Foal was pulled
  - **Stage III**
    - Placenta came with the foal
    - Placental horn retained

- **Foal “appeared slow”**
  - From the beginning...but normal
  - Able to stand with help
  - Not searching the mare
  - Became weaker
  - Developed periods of somnolence
Wishful Admission

- Recumbent on arrival
  - Transported to the NICU
- Rapid assessment of essential organ function
  - Severe sepsis
    - Poor pulse quality
    - Cold legs and ice cold hooves
    - Temperature 99.6
      - dropped during initial hospitalization 97
    - HR 104 bpm
    - RR 18 bpm,
    - BP 73/30(37)
Wishful Admission

- **Rapid, directed interventions**
- **Treatment of shock**
  - $INO_2$
  - Crystalloid boluses
    - Responded after 3 X 1 liter boluses
  - BP after fluids
    - 90/58(65)
  - PE – good perfusion
Wishful Admission

- Further examination after initial resuscitation
  - Bilateral entropion
  - Extreme scleral injection
  - Oral drying injuries
  - Icterus
  - Pseudopetechia
  - Moderate coronitis
  - Normal body condition
  - Neonatal skin wrinkling
  - Normally responsive
  - Searches, inducible suckle
  - Can stand with support with good balance
  - Somnolent periods
Wishful
Initial Laboratory Analysis

- PCV = 50
- TP = 7.4
- Fibrinogen = 370 mg/dl
- WBC = 7000
- Segs = 5110
- Bands = 210
- Lymphs = 1680
Wishful
Initial Laboratory Analysis

- Venous Dextrose = 20 mg/dl
- BUN = 24 mg/dl
- Total Ca = 16.38 mg/ml
- Ca++ = 6.84 mg/dl
- Mg++ = 2.79 mg/dl
- IgG = 776 mg/dl
- Total Bili = 4.5 mg/dl
# Initial Laboratory Analysis

<table>
<thead>
<tr>
<th>Value</th>
<th>Adm</th>
<th>1 hour</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>7.251</td>
<td>7.305</td>
</tr>
<tr>
<td>Pco2</td>
<td>47.3</td>
<td>50.2</td>
</tr>
<tr>
<td>Po2</td>
<td>64.0</td>
<td>285</td>
</tr>
<tr>
<td>HCO3</td>
<td>20.9</td>
<td>25.1</td>
</tr>
<tr>
<td>BE</td>
<td>-5.8</td>
<td>-0.9</td>
</tr>
<tr>
<td>SAT</td>
<td>94.5</td>
<td>100</td>
</tr>
<tr>
<td>Cont</td>
<td>17.9</td>
<td>15.9</td>
</tr>
<tr>
<td>Lactate</td>
<td>14.9</td>
<td>10.0</td>
</tr>
<tr>
<td>RA</td>
<td>10 lpm</td>
<td></td>
</tr>
</tbody>
</table>
### Wishful

**Initial Laboratory Analysis**

<table>
<thead>
<tr>
<th>Value</th>
<th>Adm Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Na</td>
<td>115</td>
</tr>
<tr>
<td>K</td>
<td>7.33</td>
</tr>
<tr>
<td>Cl</td>
<td>72</td>
</tr>
<tr>
<td>Cr</td>
<td>28</td>
</tr>
<tr>
<td>AST</td>
<td>657</td>
</tr>
<tr>
<td>CPK</td>
<td>3012</td>
</tr>
</tbody>
</table>
Wishful

- Major finding
  - Hyponatremia
  - Hypochloremia
  - Hyperkalemia

- Magnitude of changes
  - May require urgent intervention
  - Vital to understand the origin of the abnormalities
    - Direct rational therapy
    - Wrong choices – severe consequences
    - Many clinicians assume ruptured bladder
      - easily rule out
      - age
      - lack of fluid intake
Hyponatremia

- Spurious Hyponatremia
- Dilutional Hyponatremia
  - Ruptured bladder
  - Fenestrated ureters
  - Renal failure
  - Delayed renal transition from fetal to neonatal physiology
  - Water overload
- Depletional Hyponatremia:
  - Diarrhea
  - Sodium wasting nephropathy
  - Diuretics
- Redistribution Hyponatremia
  - Other osmolar changes in the blood
  - Hyperglycemia
  - Iatrogenic addition of osmolar agents (e.g., mannitol)
  - Sick Cell Syndrome
Wishful Hyponatremia

- Spurious hyponatremia
- Dilutional hyponatremia
  - No intake since birth
- Depletional hyponatremia
  - Not begun to urinate
  - Has not past meconium yet
- Redistribution hyponatremia
  - Water diluting Na come from cells
  - Some osmolyte other than sodium
    - Drawing water from cells
- Source of osmoles?
  - Hypoglycemic
  - Not received exogenous substances
  - Presence of endogenous osmolytes
    - Leaked from cells
Wishful Hyponatremia

- Significant therapeutic implications
  - No sodium deficiency
  - Not water overloaded
  - Not hyposmotic
    - May be hyperosmotic
- Don’t give sodium
- Don’t induce an unsupported diuresis
Hyperkalemia

- **Mechanisms**
  - High intake
    - Dietary
    - Parenteral
  - Blocked excretion
    - Must have continued intake
  - Leak from cell
- **Wishful**
  - No intake
  - Must be cell leak
Sick Cell Syndrome

- Global loss of integrity of cell membranes
- Acute, severe hypoxic ischemic insult
  - Globally affect cells
  - Loss of cell wall integrity
    - Transient or permanent
    - Allowing solutes to leak
    - Drawing fluid with them
    - Dilution of extracellular sodium
- Redistribution hyponatremia
  - Osmolar Gap (OG)
    - Unmeasured osmolytes
    - \( OG = Osm_m - Osm_c \)
    - \( Osm_m = (2X [Na]) + (\text{glucose}/18) + (\text{BUN}/2.8) \)
Sick Cell Syndrome

- OG > 10 mOsm
  - osmoles other than Na or glucose
  - Associated with
    - MODS
    - High fatality rate

- What are the osmoles?
  - Organic phosphate
  - Pyruvate
  - Lactate
  - Amino acids,
  - Unidentified middle molecular weight substances
<table>
<thead>
<tr>
<th>Value</th>
<th>Adm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Na</td>
<td>115</td>
</tr>
<tr>
<td>K</td>
<td>7.33</td>
</tr>
<tr>
<td>Cl</td>
<td>72</td>
</tr>
<tr>
<td>Cr</td>
<td>28</td>
</tr>
<tr>
<td>AST</td>
<td>657</td>
</tr>
<tr>
<td>CPK</td>
<td>3012</td>
</tr>
<tr>
<td>Osm$_m$</td>
<td>312</td>
</tr>
<tr>
<td>Osm$_c$</td>
<td>240</td>
</tr>
<tr>
<td>Osm Gap</td>
<td>72</td>
</tr>
</tbody>
</table>
Regulatory Volume Decrease

- Another explanation
- Regulatory Volume Decrease (RVD)
  - Fluid overloaded cells
  - All mammalian cells
  - Protective mechanism
    - Limits cell swelling
- Reasons cells swell
  - Hyponatremia
    - Hyposmotic interstitium
  - Initial stages of hypoxic ischemic insults
    - Hyperosmotic cell interior
Regulatory Volume Decrease Mechanism

Voltage-independent, volume-sensitive channels
- Activated by cell swelling
- Allow outflow of
  - K+
  - Cl-
  - Amino acids
  - Other organic molecules

Water follows
- Restoring cell volume.
Redistribution Hyponatremia
Neonatal Foals

- Both SCS and RVD are involved
- Mild insults
  - Compromise cellular function
  - Allow fluid to leak
  - RVD - protective mechanism
- More severe damage
  - Initially result in RVD
  - Evolve into SCS
Sick Cell Syndrome

- Other cell constituents also leak
  - K+ leak
    - Both RVD and SCS
    - High intracellular levels of K
    - Mild increase in efflux globally
      - Increase plasma K levels significantly
  - CPK
  - AST

- Outcome
  - About 60% of SCS cases do not survive
  - Identification of SCS - guarded to poor prognosis.
Sick Cell Syndrome
Therapy

- Don’t treat hyponatremia
  - Not sodium deficit
    - Osmolarity high normal
  - Not water overload
- Hyperkalemia
  - If ECG changes
    - Mg
  - Enhance cell entry
    - Insulin
    - B₂ adrenergic
      - Albuterol
    - Na HCO₃ – not recommended
- Enhance excretion
  - Osmotic diuresis
  - Furosemide
  - GI cation exchange resin
- Is treatment necessary??
# Wishful Outcome

<table>
<thead>
<tr>
<th>Value</th>
<th>Adm</th>
<th>HD 2</th>
<th>HD 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Na</td>
<td>115</td>
<td>126</td>
<td>132</td>
</tr>
<tr>
<td>K</td>
<td>7.33</td>
<td>4.26</td>
<td>4.76</td>
</tr>
<tr>
<td>Cl</td>
<td>72</td>
<td>87</td>
<td>96</td>
</tr>
<tr>
<td>Cr</td>
<td>28</td>
<td>9.24</td>
<td>1.74</td>
</tr>
<tr>
<td>AST</td>
<td>657</td>
<td>781</td>
<td>534</td>
</tr>
<tr>
<td>CPK</td>
<td>3012</td>
<td>625</td>
<td>74</td>
</tr>
<tr>
<td>Osm&lt;sub&gt;m&lt;/sub&gt;</td>
<td>312</td>
<td>312</td>
<td>295</td>
</tr>
<tr>
<td>Osm&lt;sub&gt;c&lt;/sub&gt;</td>
<td>240</td>
<td>270</td>
<td>275</td>
</tr>
<tr>
<td>Osm Gap</td>
<td>72</td>
<td>43</td>
<td>20</td>
</tr>
</tbody>
</table>
Wishful Outcome

- **Intrauterine Insult – catabolism, SIRS**
- **Sepsis**
  - High fibrinogen, left shift
  - Inject, icterus
  - Shock, increased lactate, acidosis
  - Admission blood culture
    - Flavobacterium
- **Neonatal Encephalopathy**
  - Inconsistent nursing behavior
  - HD 6 - nursing from mare