FLUID MANAGEMENT IN NEONATES AND INFANTS
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INTRODUCTION

• WHY IS FLUID MANAGEMENT IMPORTANT IN NEONATES --

  - Physiology different from adults.
  - All don’t need the same IV fluids (either in quantity or composition).
  - If wrong fluids are given, neonatal physiology is not well equipped to handle them.
  - Serious morbidity can result from fluid and electrolyte imbalance.
NEONATAL PHYSIOLOGY
HOW IT IS DIFFERENT???

- All babies are born with an excess of TBW, mainly ECF-

  - Adults have 60% water (20% ECF, 40% ICF)
  - Term neonates have 75% water (40% ECF, 35% ICF)
  - Preterm neonates have more water (23 wks: 90% : 60% ECF, 30% ICF)
DISTRIBUTION OF BODY WATER
NEONATAL PHYSIOLOGY

• High water content provides a large volume of distribution for water-soluble medications.

• Low fat and muscle content provides a small reservoir for drugs that depend on redistribution into these tissues for termination of drug effect.

• **ANAESTHETIC IMPLICATIONS** –
  - Water soluble drugs have larger volume of distribution, require larger initial dose eg., antibiotics, muscle relaxants
  - Drugs depending on redistribution into fat have longer clinical effect eg., thiopental
  - Drugs redistributing into muscle have longer clinical effect eg., fentanyl
NEONATAL PHYSIOLOGY

- After birth, there is efflux of fluid from (ICF) to (ECF).
- This floods the neonatal kidneys eventually resulting in a salt and water diuresis by 48-72 hours.
- This loss results in physiological weight loss in the first week of life.
- ECW compartment is larger in preterm neonates - the weight loss is greater.
- Term infants are loose up to 10% of their birth weight as compared to 15% weight loss in premature neonates.
- Failure to loose this ECF may be associated with morbidities like
  - Patent ductus arteriosus (PDA)
  - Necrotizing enterocolitis (NEC)
  - Chronic lung disease (CLD)
NEONATAL PHYSIOLOGY

• RENAL FUNCTION
  - At birth: Functionality is only 25% 
  - Complete maturation of renal function - by 2 yrs of age
  - t1/2 of drugs excreted by glomerular filtration is prolonged
  - The physiological range for urine osmolality in neonates 50mmol/L to 600 mmol/L in preterms and 800 mmol/L in term infants.
NEONATAL PHYSIOLOGY

• **Cardiovascular physiology**
  - Infants more sensitive to hypovolemia due to-
    relatively low contractile mass/gram of cardiac
tissue

      ↓

    limited ability to ↑ myocardial contractility

      ↓ in ventricular compliance

      ↓

    extremely limited ability to ↑ stroke volume

    need to ↑HR to ↑ cardiac output (Treppe effect)
NEONATAL PHYSIOLOGY

• Fluid losses-
  - Apart from sensible water loss, neonates have additional water losses due to evaporation from the skin and respiratory tract - insensible water loss (IWL)
  - Insensible water losses - higher in preterm infants
  - Evaporation through the skin - 70% of IWL
  - From the respiratory tract - 30% of IWL
NEONATAL PHYSIOLOGY

- Increased insensible water loss (IWL)
  - Increased respiratory rate
  - Surgical malformations (gastroschisis, omphalocele, neural tube defects)
  - Increased body temperature: 30% increase in IWL per C rise in temperature
  - High ambient temperature: 30% increase in IWL per C rise in temperature
  - Use of radiant warmer and phototherapy: 50% increase in IWL
  - Decreased ambient humidity.
  - Increased motor activity, crying: 50-70% increase in IWL
- Decreased insensible water loss (IWL)
  - Use of incubators
  - Humidification of inspired gases in head box and ventilators
  - Use of plexiglas heat shields
  - Increased ambient humidity
  - Thin transparent plastic barriers – reduce upto 30% IWL

Anaesthetic concerns
- Covering the neonate during transportation and during surgery
- Maintenance of OT temperature
FASTING GUIDELINES

• EARLIER GUIDELINES-

<table>
<thead>
<tr>
<th>Age</th>
<th>Milk &amp; Solids</th>
<th>Clear Liquids</th>
</tr>
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<tbody>
<tr>
<td>&lt;6 months</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>6-36 months</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>&gt;36 months</td>
<td>8</td>
<td>3</td>
</tr>
</tbody>
</table>
NEW FASTING GUIDELINES

• EUROPEAN SOCIETY OF ANAESTHESIA (2011) FASTING GUIDELINES –
  - 2 hours for clear liquids
  - 4 hours for breast milk
  - 6 hours for non human milk, Infant formula
  - 8 hours for solid food

ADVANTAGES OF THESE LIBERAL GUIDELINES -
  - Prevent dehydration and hypoglycemia
  - Reduce the risk of aspiration
INTRAOPERATIVE FLUID THERAPY

- DEFICIT THERAPY - TO COMPENSATE FOR DEHYDRATION OR FASTING

- MAINTAINENCE THERAPY – TO COMPENSATE FOR LOSS DUE IWL AND URINE

- REPLACEMENT THERAPY- FOR BLOOD LOSS AND THIRD SPACE LOSSES
ASSESSMENT OF FLUID AND ELECTROLYTE STATUS

• History:

• Physical Examination:
  - Weight: Most important criteria
  - Skin/Mucosa: Altered skin turgor, sunken AF, dry mucosa, edema etc

• Cardiovascular:
  • Tachycardia can result from too much (ECF excess in CHF) or too little ECF (hypovolemia)
  • Delayed capillary refill can result from low cardiac output
  • Hepatomegaly can occur with ECF excess
  • Blood pressure changes very late
• Lab evaluation:
  - Serum electrolytes and plasma osmolarity
  - Urine output
  - Urine electrolytes, specific gravity
  - Blood urea, serum creatinine
  - ABG
<table>
<thead>
<tr>
<th>Clinical Sign</th>
<th>Mild dehydration (&lt;3% wt loss)</th>
<th>Moderate (3-10%)</th>
<th>Severe &gt;10%</th>
</tr>
</thead>
<tbody>
<tr>
<td>General condition</td>
<td>Alert, restless</td>
<td>Thirsty, lethargic</td>
<td>Cold, sweaty, limp</td>
</tr>
<tr>
<td>Pulse</td>
<td>Normal rate, volume</td>
<td>Rapid, weak</td>
<td>Rapid, feeble</td>
</tr>
<tr>
<td>respiration</td>
<td>Normal</td>
<td>Deep rapid</td>
<td>Deep</td>
</tr>
<tr>
<td>Systolic pressure</td>
<td>Normal</td>
<td>Normal or low</td>
<td>Low, Unrecordable</td>
</tr>
<tr>
<td>Reduced urine output</td>
<td>NO</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>Dry mouth</td>
<td>NO</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>Sunken eyes</td>
<td>NO</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>Ant. fontanellae</td>
<td>Normal</td>
<td>Sunken</td>
<td>Very sunken</td>
</tr>
<tr>
<td>Reduced skin turgor</td>
<td>NO (recoils instantly)</td>
<td>YES (1-2 secs)</td>
<td>YES (&gt;2secs)</td>
</tr>
<tr>
<td>Prolonged capillary refill</td>
<td>NO</td>
<td>May be slightly prolonged</td>
<td>YES (cool/mottled/pale peripheries)</td>
</tr>
<tr>
<td>time</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>drowsiness</td>
<td>NO</td>
<td>YES</td>
<td>Severe</td>
</tr>
<tr>
<td>Estimated deficit</td>
<td>30-50ml/kg</td>
<td>60-100ml/kg</td>
<td>&gt;100ml/kg</td>
</tr>
</tbody>
</table>
MANAGEMENT

Goal:

- Allow initial loss of ECF over first week (as reflected by wt loss), while maintaining normal intravascular volume and tonicity (as reflected by HR, U O, lytes, pH). Subsequently, maintain water and electrolyte balance, including requirements for body growth.

- Individualize approach according to response of the child and age.
DEFICIT DUE TO FASTING

- HOURLY REQUIREMENT BASED ON HOLLIDAY AND SEGAR – 100ml water for 100 calories expended

4-2-1 rule-based on b. wt.

<table>
<thead>
<tr>
<th>Weight</th>
<th>Hourly fluid requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;10 kg</td>
<td>4 ml/kg</td>
</tr>
<tr>
<td>10-20 kg</td>
<td>40 ml + 2 ml/kg Above 10 kg</td>
</tr>
<tr>
<td>&gt;20 kg</td>
<td>60 ml + 1 ml/kg Above 20 kg</td>
</tr>
</tbody>
</table>

CHILDREN'S RESPONSE TO FLUID THERAPY SHOULD ALWAYS BE MONITORED

Millers anaesthesia 7th edition
Fluid deficit due to fasting

MANAGEMENT -
- Hourly maintenance requirements x hours of fluid restriction
- 50% 1st hour
- 25% each in next 2 hours
**MAINTAINENCE FLUID IN NEONATES**

- MEETS THE LOSSES DUE TO IWL AND URINE

<table>
<thead>
<tr>
<th>Birth weight</th>
<th>Day 1</th>
<th>Day 2</th>
<th>Day 3</th>
<th>Day 4</th>
<th>Day 5</th>
<th>Day 6</th>
<th>Day 7</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;1000g</td>
<td>80</td>
<td>100</td>
<td>120</td>
<td>130</td>
<td>140</td>
<td>150</td>
<td>160</td>
</tr>
<tr>
<td>1000 to 1500g</td>
<td>80</td>
<td>95</td>
<td>110</td>
<td>120</td>
<td>130</td>
<td>140</td>
<td>150</td>
</tr>
<tr>
<td>&gt;1500g</td>
<td>60</td>
<td>75</td>
<td>90</td>
<td>105</td>
<td>120</td>
<td>135</td>
<td>150</td>
</tr>
</tbody>
</table>

* Fluid and Electrolyte Management in Term and Preterm Neonates, Indian journal of pediatrics, volume 75 - March 2008
MAINTAINENCE FLUID

• CHOICE OF FLUID ??????

- Term Babies and Babies With Birth Weight > 1500 Grams
  DAY 1 - 10% Dextrose to maintain a glucose infusion of 4-6mg/kg/min
  DAY 2 TO 7 - 10% Dextrose and sodium and potassium to be added after 48 hours

- Preterm Baby With Birth Weight 1000-1500 Grams
  DAY 1 - 10% Dextrose
  DAY 2 TO 7 - 10% Dextrose and sodium and potassium to be added after 48 hours
  AFTER DAY 7 - Fluids should be given at 150-160 ml/kg/day and sodium supplementation at 3-5 mEq/kg should continue till 32-34 weeks corrected gestational age.
MAINTAINENCE FLUID DURING SURGERY

- The maintenance fluid used during surgery should be isotonic such as 0.9% sodium chloride or Ringer lactate/Hartmann’s solution in infants.

- Neonates in the first 48 hours of life should be given dextrose during surgery.

- Maintenance fluid to be calculated by Holliday and segar for patients more than 4 wks of age.
Guide for Maintenance Fluid Therapy

Newborn Term

<table>
<thead>
<tr>
<th>Day</th>
<th>Fluid Requirement</th>
<th>Electrolyte Preparation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Day 1</td>
<td>50-60 ml/kg/day</td>
<td>D10 W</td>
</tr>
<tr>
<td>Day 2</td>
<td>80 ml/kg/day</td>
<td>D10 W</td>
</tr>
<tr>
<td>&gt;Day 7</td>
<td>100-150 ml/kg/day</td>
<td>D5-D10 1/4 NS</td>
</tr>
</tbody>
</table>

Older Child

4-2-1 rule (Holliday & Segar method)
ROLE OF GLUCOSE IN PERIOPERATIVE PERIOD

• Lack glycogen stores
• Hyperglycemia is more commonly encountered
  – Response to anaesthesia and surgery
  – Anxiety
  – Pain
• Hypoglycaemia → brain damage
• Hyperglycemia → Osmotic diuresis → dehydration and electrolyte imbalance

The present recommendations is that the replacement fluid used should either be free of dextrose or should not have more than 1% dextrose.*

*Perioperative fluid therapy in pediatrics, Pediatric Anesthesia 2008 18: 363–370
EXCEPTIONS TO THIS ????

- Neonates in the first 48 hours of life
- Preterm and term infants already receiving dextrose containing solutions
- Children on parenteral nutrition preoperatively
- Children of low body weight (less than 3rd %tile) or having prolonged surgery.
- Children with diminished sympathetic response to regional anaesthesia.
RELACEMENT THERAPY

• FLUID MANAGEMENT FOR -
  - Third space losses
  - Blood loss
## THIRD SPACE LOSS

<table>
<thead>
<tr>
<th>SURGICAL TRAUMA</th>
<th>3rd SPACE LOSS</th>
</tr>
</thead>
<tbody>
<tr>
<td>MINIMAL</td>
<td>1-2 ml/Kg/hr</td>
</tr>
<tr>
<td>MODERATE</td>
<td>4-7 ml/Kg/hr</td>
</tr>
<tr>
<td>SEVERE</td>
<td>6-10 ml/Kg/hr</td>
</tr>
<tr>
<td>15-20ml/kg/hr</td>
<td>– major abdominal</td>
</tr>
<tr>
<td>50ml/kg/hr</td>
<td>– surgery of NEC in premature infants</td>
</tr>
<tr>
<td>Balanced salt solution</td>
<td>– preferred</td>
</tr>
</tbody>
</table>
BLOOD LOSS

Determinants of Blood Transfusion

1) Estimated Blood Volume
2) Preoperative Hematocrit
3) Co-existing Illness
ESTIMATED BLOOD VOLUME

Premature Neonates           95 -100 ml  /kg
Full Term Neonates           85-90 ml / kg
Infants                      80 ml / kg
BLOOD LOSS

- “Davenport’s law”

- $MABL = EBV \times (\text{Starting Hct} - \text{Target Hct})$

  Starting Hct

  1:1 blood/colloid

  3:1 crystalloid

- Replaced by PRBC

- Vol of PRBC = \((\text{Desired Hct} - \text{Present Hct}) \times EBV\)

  Hct of PRBC
POSTOPERATIVE FLUID MANAGEMENT

• RECOMMENDATIONS –
  - Avoid dehydration and correct hypovolemia
  - Composition of fluid to be administered
    should be a compromise between sodium,
    energy requirements and osmolarity.
  - Beware of hidden fluid administration
    (drugs).
  - Monitoring of serum sodium and glucose in sick
    patients at least once daily.
- Early oral intake
- If oral intake is delayed, fluid therapy should be administered:
  Provide basic metabolic requirements (4-2-1)
  Replace ongoing losses (isotonic fluids)
ELECTROLYTE IMBALANCE IN PERIOPERATIVE PERIOD
ELECTROLYTE PHYSIOLOGY

SODIUM
• Daily sodium requirement- 2-4 meq/kg/day

• OBLIGATE SODIUM LOSERS

• Positive pressure ventilation and PEEP → natriuresis, water retention

POTASSIUM
• Daily requirement- 2-4 meq/kg/day
SODIUM IMBALANCE

HYPONATREMIA

• The most frequent electrolyte disorder
  $S \cdot Na^+ < 135$ meq/L
• Most common cause - administration of hypotonic fluids
• Others - Pituitary or adrenal insufficiency, brain injuries, brain tumours, stress, pain, nausea and vomiting are all potent causes of ADH release.
• It has been recommended that hypotonic fluids should not be used for postoperative maintenance.

SMITHS Anaesthesia for Infants and Children 7th edition
The early signs - non-specific
The first presenting feature is a seizure or respiratory arrest. (s. sodium <125 meq/L)

Management
- Medical emergency and transfer to PICU.
- Hyponatraemic seizures - respond poorly to anticonvulsants
- Initial management is to give an infusion of 3% NaCl Sol.
- One ml/kg of 3% sodium chloride will normally raise the serum sodium by 1 mmol/l.
• The amount of Na required can be calculated according to the following formula:
  \[
  \text{mmol of Na} = (130 - \text{present serum Na}) \times 0.6 \times \text{Wt (kg)}
  \]

• Targeted rate of correction 0.5meq/l/hr

• Rapid treatment- pontine myelinolysis

• Correction should be stopped if child is asymptomatic, or serum sodium > 125meq/l.

• The child with asymptomatic hyponatraemia does not require active correction with 3% sodium chloride solution.
HYPERNATREMIA

Common cause- excessive water loss, restricted water intake.

- Signs of hypernatraemia are more severe when it develops rapidly or when the serum Na > 150mmol/l.

**Management**

- **Replacement with 0.9% sodium chloride** given in boluses of 20ml/kg to restore normovolaemia.(hypovolemic hypernatremia)
- Complete correction : very **slowly over at least 48 hours**
- The serum Na should be corrected at a rate of no more that 12mmol/kg/day.
- In hypervolemic hypernatremia - diuresis followed by replacement with hypotonic fluids.
POTASSIUM IMBALANCE

HYPOKALEMIA

• Serum K< 3.5mmol/l
• Symptoms - cramps
  - arrhythmias
  - paralytic ileus

Management

• oral supplements
• severe cases: IV correction not faster than 0.25meq/kg/hr to a maximum of 0.5meq/kg/hr
POTASSIUM IMBALANCE

HYPERKALEMIA
serum K > 5.5meq/l in infants and > 6meq/l in neonates

Immediate treatment
• 10% Calcium gluconate- 100mg/kg per dose

Increase intracellular shift of potassium:
• sodium bicarbonate-1-2mmol/Kg
• glucose-0.3-0.5g/kg/hr with 1 unit of insulin for every 5g of glucose
• nebulised salbutamol -2.5 to 5mg

Removal of potassium: calcium resonium 1g/kg per dose
furosemide -1 mg/kg
dialysis or haemofiltration
### COMMONLY USED IV FLUIDS

<table>
<thead>
<tr>
<th></th>
<th>NS</th>
<th>RL</th>
<th>Iso lyte P</th>
<th>Plasma lyte A</th>
<th>5D</th>
<th>Album in 5%</th>
<th>Hetastarch 6%</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Na</strong></td>
<td>154</td>
<td>130</td>
<td>26</td>
<td>140</td>
<td></td>
<td>150</td>
<td>154</td>
</tr>
<tr>
<td><strong>K</strong></td>
<td>4</td>
<td>21</td>
<td>5</td>
<td>&lt;2.5</td>
<td></td>
<td>&lt;2.5</td>
<td>&lt;2.5</td>
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<tr>
<td><strong>Cl</strong></td>
<td>154</td>
<td>109</td>
<td>21</td>
<td>98</td>
<td></td>
<td>100</td>
<td>154</td>
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<td><strong>Ca</strong></td>
<td></td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Mg</strong></td>
<td></td>
<td>3</td>
<td>3</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td><strong>Acetate</strong></td>
<td>28</td>
<td>24</td>
<td>27</td>
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<tr>
<td><strong>Lactate</strong></td>
<td></td>
<td>24</td>
<td></td>
<td></td>
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<tr>
<td><strong>Glucose</strong></td>
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<td>5</td>
<td></td>
<td>5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Phosphate</strong></td>
<td></td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Osmolality</strong></td>
<td>308</td>
<td>274</td>
<td>295</td>
<td>252</td>
<td>330</td>
<td>310</td>
<td></td>
</tr>
</tbody>
</table>
Isolyte-P

- Earlier, most widely used maintenance fluid for younger children
- Ideal electrolyte concentration (Na 25 & K + 20 mEq/l)
- Contains acetate, which provides bicarbonate
- Provides magnesium and phosphate
- Provides 50 g /l of glucose to provide calories
- Uniform administration of fluid and electrolytes
• Not an ideal maintenance fluid for older children

• In children as weight increases, water requirement reduces rapidly,

• Sodium requirement remains static (2.5 mEq/kg)

• Children with greater weight will need I.V. fluids with greater sodium concentration

• For children with weight greater than 15 kg, additional sodium supplementation is needed

• Isolyte-M contains greater (Na = 40 mEq/l) sodium
GOALS OF PERIOPERATIVE FLUID THERAPY

• Urine output 1 – 3 ml/kg/hr.
• Allow a weight loss 1 – 2% / day in 1st wk.
• Absence of Edema / Dehydration/ Hepatomegaly
• Urine Sp. gravity 1005 – 1015
• Euglycaemia 75 – 100 mg / dl
• Normonatremia 135 - 145 mEq / lit
• Normokaleemia 4 – 5 mEq / lit
CONCLUSION

• Understanding of neonatal physiology is important.
• Preoperative fasting should be confined to a minimum.
• Glucose containing fluids are best avoided.
• Restoration of the circulating volume and vital organ perfusion is the first priority in perioperative fluid management and is best accomplished with isotonic crystalloid.
• Replacement of fluid should be based on individual response to therapy.
• Symptomatic hyponatraemia and hyperkalaemia are the electrolyte disturbances that warrant emergency management.
THANK YOU
Calculate the fluid requirement of a 10kg breast feed infant scheduled for herniotomy??
• Fasting – 4 hours for breast milk, 2 hours for liquids
  Deficit due to fasting – 40ml x 4hr = 160ml

Fluid requirement in 1st hour
  80ml to be given in first hour + maintenance
  fluid requirement i.e 4ml/kg/hr + 3rd space
  loss i.e 1ml/kg/hr + blood loss

Fluid requirement in 2nd hour
  40ml + 40ml + 10ml + blood loss

Fluid requirement in 3rd hour
  40ml + 40ml + 10ml + blood loss

After 3rd hour in each hour
  40ml + 10ml + blood loss

Choice of fluid - ringer lactate or balanced salt solution