Perioperative fluid therapy in neonates and infants

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1. Introduction

• Neonate = 0-4 weeks
• Infant = <2 y
• Why is fluid management in the neonate/infant so important?
  - Fluid and electrolyte imbalance → serious morbidity/mortality
  - Wrong fluids (quantity/composition) → neonatal kidney’s
    - Neonate/infant ≠ small adult!
  - Guidelines 2017

2. Physiology of the neonate
Total body water

Figure 1. Fetal and neonatal body water content changes with respect to time. TBW, total body water; ECF, extracellular fluid; ICF, intracellular fluid.

Figure 2. Schematic representation of total body water (TBW) and its distribution between extracellular and intracellular water (ECW and ICW, respectively) in four age categories [1]. Values reported for the Foetus refer to a healthy foetus of 7–8 months of gestational age; values reported for the Infant refer to a healthy infant of 7–8 months; values reported for the Child refer to a healthy child aged approximately 3 years; values reported for the Adult refer to an adult male. Of note, percentages of total body, intracellular, and extracellular water are referred to as percentages of total body weight.

Conditions determining water balance in the neonatal period (1)

- Gestational age/postnatal age
- Prenatal steroid exposure
- BSA
- Ambient temperature and humidity
- Neonate’s activity

Conditions determining water balance in the neonatal period (2)

- Gestational age/postnatal age
  - Sensible loss
    - Urine output (renal blood flow, GFR, maturity of renal tubules)
    - Stool output (maturation gut motility, mucosal function, diet)
  - Insensible Loss
    - Transepidermal
    - Respiratory tract (temperature and humidity inspired air, minute ventilation)

Conditions determining water balance in the neonatal period (3)

- Gestational age/postnatal age
- Prenatal steroid exposure
- BSA
- Ambient temperature and humidity
- Neonate’s activity
Physiologic controls of water balance (1)

- ADH
- Thirst
- Aldosterone
- Atrial natriuretic peptide

Physiologic controls of water balance (2)

ADH
- Hypothalamus – posterior pituitary
- V2: water-retaining function (renal collecting tubules)
- Stimuli:
  - Hyperosmolarity (osmoreceptors in hypothalamus)
  - Non-osmotic stimuli
    - Depletion of ECF (baroreceptors in carotid/aortic sinuses, left atrium)
    - Additional factors

Physiologic controls of water balance (3)

non-osmotic stimuli

Table 1: Non-osmotic stimuli for antidiuretic hormone release

Physiologic controls of water balance in the neonate (4)

- Preterm and term neonates
  - Intravascular volume = fluid intakes
  - able to excrete dilute urine
- Preterm neonates
  - only able to concentrate urine to 600 - 700 mOsm/L at term
  ↔ 1300 mOsm/L
3. Goal fluid therapy

Children, especially newborns and infants, are particularly prone to water and electrolyte imbalances:
- higher TBW content
- higher metabolic rate
- relatively higher insensible losses due to:
  - higher surface area to body mass ratio
  - relatively higher production of CO2 (higher minute ventilation)
- Immature regulatory mechanisms?

Fluid therapy in children is challenging and should be considered as a pharmacological treatment with precise indications, contraindications and side effects.

Goal fluid therapy (2)

Maintain or re-establish the child's normal physiological state
- Normovolemia
- Normal tissue perfusion
- Normal metabolic function
- Normal electrolytes and acid–base status

4. Intraoperative fluid therapy

a) Deficit (preoperative fasting times)
b) Maintenance/background infusion
c) Replacement/fluid therapy
d) Volume therapy (colloids)
e) Transfusion
f) Monitoring fluid therapy

Perioperative intravenous fluid therapy in children: guidelines from the Association of the Scientific Medical Societies in Germany
a) Deficit (preoperative fasting times)

Fasting times: 6-4-2 regimen

<table>
<thead>
<tr>
<th>Food Eaten</th>
<th>Suggested Time of Fasting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clear liquids (Water; tea; nonfibrous juice)</td>
<td>2</td>
</tr>
<tr>
<td>Breast milk</td>
<td>4</td>
</tr>
<tr>
<td>Formula/milk other than breast milk</td>
<td>6</td>
</tr>
<tr>
<td>Light foods (e.g., toast and tea)</td>
<td>6</td>
</tr>
<tr>
<td>Heavy foods</td>
<td>8</td>
</tr>
</tbody>
</table>

Fasting times: 6-4-2 regimen

Fasting times: are we putting them into practice?

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Median ± SEM</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fasting time (NPO [hours])</td>
<td>2 ± 0.2</td>
<td>NS</td>
</tr>
<tr>
<td>Fasting times (NPO [hours])</td>
<td>4 ± 0.2</td>
<td>NS</td>
</tr>
<tr>
<td>Fasting times (NPO [hours])</td>
<td>6 ± 0.2</td>
<td>NS</td>
</tr>
<tr>
<td>Fasting times (NPO [hours])</td>
<td>8 ± 0.2</td>
<td>NS</td>
</tr>
<tr>
<td>Fasting times (NPO [hours])</td>
<td>10 ± 0.2</td>
<td>NS</td>
</tr>
</tbody>
</table>
| Impact of preoperative fasting times on blood glucose concentration, ketone bodies and acid-base balance in children <36 months (n=100)

Optimized preoperative fasting times decrease ketone body concentration and stabilize mean arterial blood pressure during induction of anesthesia in children <36 months

Table 2 Comparison of fasting periods: duration from guide (OGI), mean arterial blood pressure after induction of anesthesia (MAP), glucose, lactate, ketone body levels, and ketone breakdown in children below 36 months after OGI (proportion of preoperative fasting times)

<table>
<thead>
<tr>
<th>Variable</th>
<th>OGI (n = 66)</th>
<th>OGI (n = 59)</th>
<th>Propa*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fasting period (h)</td>
<td>10.5 ± 1.1</td>
<td>10.5 ± 1.2</td>
<td>0.98</td>
</tr>
<tr>
<td>Glucose (mg/dL)</td>
<td>150 ± 25</td>
<td>150 ± 25</td>
<td>0.14</td>
</tr>
<tr>
<td>Lactate (mmol/L)</td>
<td>0.7 ± 0.4</td>
<td>0.7 ± 0.4</td>
<td>0.78</td>
</tr>
<tr>
<td>Ketone bodies (μmol/L)</td>
<td>59 ± 17.2</td>
<td>59 ± 17.2</td>
<td>0.92</td>
</tr>
<tr>
<td>MAP (mmHg)</td>
<td>74 ± 9.3</td>
<td>74 ± 9.3</td>
<td>0.99</td>
</tr>
<tr>
<td>MAP after induction (mmHg)</td>
<td>59 ± 6.3</td>
<td>59 ± 6.3</td>
<td>0.99</td>
</tr>
</tbody>
</table>


Introducing the 6-4-0 fasting regimen

- 6-4-2 fasting regimen (n = 66)
  - Median fasting time for clear fluids of 4.0 h
  - 33.3% >6 h

- 6-4-0 fasting regimen (n = 64)
  - Median fasting time for clear fluids of 1.0 h
  - 6.3% >6 h


Update current guidelines? (1)

- Metabolic acidosis, dehydration, (mild) hypoglycaemia, cardiovascular instability, discomfort, hunger, thirst, grumpiness
- Higher risk of pulmonary aspiration (?)

Preoperative fasting in children: review of existing guidelines and recent developments P. Frykholm, E. Schindler, R. Sümpelmann, R. Walker and M. Weiss; British Journal of Anaesthesia 2017

Update current guidelines? (2) - Consensus

- At least in small children arguments change >>> against
- Incidence aspiration low even with the very liberal 6-4-0 regimen
- No guarantee whichever fasting regimen is used
- The logistics informing every child when to stop drinking at the right time are inherently difficult

Preoperative fasting in children: review of existing guidelines and recent developments P. Frykholm, E. Schindler, R. Sümpelmann, R. Walker and M. Weiss; British Journal of Anaesthesia 2017
Update current guidelines? (3) - Consensus

Two small but significant changes to the 6-4-2 regimen are suggested
- Clear fluids until 1 h before anesthesia
- 4 h limit ‘light breakfast’ + more liberal fasting regimen for clear fluids?

A comparison of three fluid regimens (n = 91) (1)

Postoperative hyperglycemia
- GSW 94%
- GNaCl 37%
- RA 0%

A comparison of three fluid regimens (n=91) (2)

Postoperative hyponatraemia
- GSW 36%
- GNaCl 3.7%
- RA 0%


Intraoperative fluid management in children — a comparison of three fluid regimens; M. Mierzewska Schmidt, Anaesthesiology Intensive Therapy 2015, 125-130
A novel balanced isotonic sodium solution vs normal saline during major surgery in children up to 36 months: a multicenter RCT

Disma N, Mameli L, Pistorio A, Davidson A et al; Paediatr Anaesth 2014 Sep;24(9):980-6.

A novel isotonic balanced electrolyte solution with 1% glucose for intraoperative fluid therapy in neonates (n=66)


Conclusion

- Hypotonic solutions with 5% glucose
  - Isotonic solutions: ↓hyponatremia
  - Glucose 1–2.5%: ↓hyperglycemia

- Normal saline
  - Lower chloride concentration: ↓hyperchloremic acidosis

Mainentance: consensus (1)

- Balanced isotonic electrolyte solution + 1–2.5% glucose
  - 10 ml/kg/h (target: normal ECFV).

Perioperative intravenous fluid therapy in children: guidelines from the Association of the Scientific Medical Societies in Germany 2017

Maintenance: consensus (2)

- Infusion rate or glucose concentration should be increased:
  - Catabolic state (e.g., long-fasting times)
  - High metabolic rates
  - Low glycogen reserves (e.g., premature infants/small neonates, parenteral nutrition, liver disease)

- Measure regularly! (target: normoglycemia and stable acid–base status)
  - Higher concentration infusion or syringe pump
  - Bolus in case of hypoglycemia (e.g., 200 mg/kg).

Maintenance: consensus (3)

- Glucose background not necessarily required:
  - Shorter surgeries (<1 h)
  - Beyond neonatal age
  - Short pre- and postoperative NPO times

Kidialyte

20,67€ (250ml)

↔ 500ml plasmalyte 3,37€

c) Replacement/ fluid therapy
**Deficit**
- Insufficient supply
  - Long-fasting time: fasting time x maintenance requirement (4-2-1 rule)
- Increased losses
  - Gastroenteritis, ileus, bleeding

**Replacement: consensus**
- Balanced isotonic electrolyte solution (target normal ECFV)
- Preoperative deficits should be replaced before anesthesia
- 10–20 ml/kg until desired effect (max three times) in case of circulatory instability
- Isotonic saline for chloride replacement in severe hypochloremic alkalosis (e.g., pyloric stenosis, gastroenteritis)

**Composition of ECF and various electrolyte solutions**

<table>
<thead>
<tr>
<th>Solution</th>
<th>Na⁺ (mmol/L)</th>
<th>K⁺ (mmol/L)</th>
<th>Ca²⁺ (mmol/L)</th>
<th>Mg²⁺ (mmol/L)</th>
<th>Cl⁻ (mmol/L)</th>
<th>HCO₃⁻ (mmol/L)</th>
<th>Glucose (g/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECF</td>
<td>140</td>
<td>4.5</td>
<td>2.5</td>
<td>1.25</td>
<td>112</td>
<td>24</td>
<td>0.5</td>
</tr>
<tr>
<td>Ringer</td>
<td>140</td>
<td>4.5</td>
<td>1.5</td>
<td>2</td>
<td>120</td>
<td>24</td>
<td>0.5</td>
</tr>
<tr>
<td>BS-6G</td>
<td>140</td>
<td>4.5</td>
<td>2</td>
<td>1</td>
<td>120</td>
<td>24</td>
<td>0.5</td>
</tr>
</tbody>
</table>

*Normal saline.*
*Ringer’s lactate.*
*Balanced electrolyte solution with 1% glucose.*
*% isotonic mannitol.*

**Perioperative intravenous fluid therapy in children: guidelines from the Association of the Scientific Medical Societies in Germany 2017**
*Sumpelmann R, Becker K, Brenner S, Bruschan C, Eich C et al; Pediatric Anesthesia 2017*

**d) Volume therapy (colloids)**

*Perioperative intravenous fluid therapy in children: guidelines from the Association of the Scientific Medical Societies in Germany 2017*
*Sumpelmann R, Becker K, Brenner S, Bruschan C, Eich C et al; Pediatric Anesthesia 2017*
Colloids (albumin, gelatin, HES)

- More effective BUT
  - Allergy
    - impairment of hemostasis
    - renal function
- GEL >> HES allergic reactions in adults (1)
  - GEL or frozen plasma in neonates showed no difference in morbidity and mortality compared to control group (2)

Hydroxyethyl starch 130 for perioperative plasma volume replacement in 1130 children

The mean infused HES volume was 10.6 ± 5.8 (0.83–50) ml/kg. No serious and no severe ADR directly related to HES (i.e. anaphylactoid reaction, clotting disorders, renal failure) were observed.

Moderate doses of HES 130 for perioperative plasma volume replacement seem to be safe even in neonates and small infants. The probability of serious ADR is lower than 0.3%. Changes in acid-base balance may be decreased when HES is used in an acetate-containing balanced electrolyte solution instead of normal saline. Caution should be exercised in patients with renal function disturbances and those with an increased bleeding risk.

HES 130 (Voluven) or human albumin in children younger than 2 yr undergoing non-cardiac surgery

A total of 81 patients were treated. Comparable amounts of both study solutions (16.0 ml kg⁻¹ hydroxyethyl starch 130 vs. 16.9 ml kg⁻¹ human albumin 5%) as well as add-on crystalloids were used until 4-6 h postoperatively. No differences were detected between the two treatment groups regarding perioperative stabilization of hemodynamics, coagulation parameters, blood gas analyses or other laboratory values. Blood loss was 96 +/- 143 ml for hydroxyethyl starch and 145 +/- 290 ml for human albumin (P > 0.05). There were no relevant differences in the amount of red blood cells, fresh frozen plasma or platelet concentrates in both treatment groups.

Conclusions: Both HES 130 and human albumin 5% were effective for haemodynamic stabilization in non-cardiac surgery of young infants with no adverse impact on coagulation or other safety parameters.

Colloids: consensus

- In circulatory instability when crystalloids not sufficiently effective and blood products not indicated
  - Repeat doses of 5–10 ml/kg until desired effect
  - If HES: third-generation (HES 130) with fewer adverse reactions
- Short period – max dose 50 ml/kg/d
- Colloid overdose disturbance of the vascular endothelial barrier function and dilutional coagulopathy
  - Restrictive approach! (target normal BV)
Fluid overload independent of acute kidney injury predicts poor outcomes in neonates following congenital heart surgery.


e) Transfusion

- Higher O2 consumption/- and higher CO/blood volume ratio
- Neonatal myocardium operates at near maximum level of performance at baseline

<table>
<thead>
<tr>
<th></th>
<th>Full term (g/dl of blood)</th>
<th>Premature (g/dl of blood)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Birth</td>
<td>15.3</td>
<td>Slightly less than full term</td>
</tr>
<tr>
<td>0.5 months</td>
<td>16.6</td>
<td>15.4</td>
</tr>
<tr>
<td>1 month</td>
<td>13.9</td>
<td>11.6</td>
</tr>
<tr>
<td>Age at haemoglobin nadir</td>
<td>9–12 weeks</td>
<td>6–10 weeks</td>
</tr>
<tr>
<td>Mean haemoglobin at nadir</td>
<td>11.2</td>
<td>9.4</td>
</tr>
<tr>
<td>4 months</td>
<td>12.2</td>
<td>11.9</td>
</tr>
<tr>
<td>6 months</td>
<td>12.8</td>
<td>12.5</td>
</tr>
<tr>
<td>6 months</td>
<td>12.5</td>
<td>12.4</td>
</tr>
</tbody>
</table>


Massive blood transfusion = loss of one or more circulating blood volumes.

- **EBV**
- **MABL**
- **XBL**

\[
\text{MABL} = \left( \text{starting haematocrit} - \text{target haematocrit} \right) \times \text{EBV}
\]

Volume of 100% RBCs blood to be transfused = XBL = desired haematocrit (30%)

As the approximate haematocrit in packed RBCs is 70%, the volume of packed RBCs in millilitres to be transfused will be = \[\text{XBL} \times \text{desired haematocrit} \times \text{suppose 39%}] = 0.79

\[0.5 \text{ ml RBC for each ml of blood loss beyond the MABL}\]

RBC

- Paedipack = adult-sized unit of RBC divided into four aliquots (min 50 ml) → to minimize exposure of infants to multiple donors
- Small volume, “top-up” - transfusions 15 ml/kg over 4h
  - Volumes greater than 20 ml/kg may increase the risk of volume overload
- “EPO”: may reduce red cell transfusion requirements in neonates
There is more and more evidence suggesting that liberal transfusion of blood products may increase morbidity in children. Use of blood products should therefore be reduced by preoperative optimization, use of blood conservation techniques during surgery and a restrictive approach to transfusion.

Table I. Suggested transfusion thresholds for preterm neonates.

<table>
<thead>
<tr>
<th>Postnatal age</th>
<th>Suggested transfusion threshold Hb (g/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Ventilated</td>
</tr>
<tr>
<td>First 24 h</td>
<td>&lt;120</td>
</tr>
<tr>
<td>≤ week 1 (d 1–7)</td>
<td>&lt;120</td>
</tr>
<tr>
<td>week 2 (8–14)</td>
<td>&lt;100</td>
</tr>
<tr>
<td>≥ week 3 (15 onwards)</td>
<td>&lt;100</td>
</tr>
</tbody>
</table>

Platelets

- Guidelines on transfusion for fetuses, neonates and older children. New HV, Berryman J. BJH 2010; 175, 784-828

- Complications:
  - AHTR
  - TRALI
  - PTP
  - VTE
  - NEC
  -...

- Fresh frozen plasma (FFP)
  - 10-15 ml/kg
  - 1:1
  - Low evidence

- Table II. Suggested thresholds of platelet count for neonatal platelet transfusion

<table>
<thead>
<tr>
<th>Platelet count (x 10^9/L)</th>
<th>Indication for platelet transfusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;55</td>
<td>Neonates with no bleeding (including neonates with NAIT if no bleeding and no family history of ICH)</td>
</tr>
<tr>
<td>&lt;70</td>
<td>Neonates with bleeding, current coagulopathy, before surgery, or infants with NAIT if previously affected sibling with ICH</td>
</tr>
<tr>
<td>&lt;100</td>
<td>Neonates with major bleeding or requiring major surgery (e.g., pneumonectomy)</td>
</tr>
</tbody>
</table>

Platelet transfusion in children and neonates.


- Massive transfusion in children and neonates.
f) Monitoring fluid therapy

**Clinical examination**

<table>
<thead>
<tr>
<th>Clinical Sign</th>
<th>Mild dehydration (&lt;5% of body mass)</th>
<th>Moderate (5-10%)</th>
<th>Severe (&gt;10%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>General condition</td>
<td>Alert, restless</td>
<td>Thierry, jerky</td>
<td>Cold, cyanotic, limp</td>
</tr>
<tr>
<td>Pulse</td>
<td>Normal rate, volume</td>
<td>Rapid, weak</td>
<td>Rapid, frigid</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, Unacceptable</td>
</tr>
<tr>
<td>Reduced urine output</td>
<td>NO</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>Dry mucous</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. fontanelle</td>
<td>Normal</td>
<td>Sunken</td>
<td>Very sunken</td>
</tr>
<tr>
<td>Reduced skin turgor</td>
<td>NO</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>(eases instantly)</td>
<td>(1-2 secs)</td>
<td>(&gt;2 secs)</td>
<td></td>
</tr>
<tr>
<td>Prolonged capillary refill time</td>
<td>NO</td>
<td>May be slightly prolonged</td>
<td>YES (normal/moist/pulse perceptible)</td>
</tr>
<tr>
<td>Drowsiness</td>
<td>NO</td>
<td>YES</td>
<td>Severe</td>
</tr>
<tr>
<td>Estimated deficit</td>
<td>30-50 ml/kg</td>
<td>60-100 ml/kg</td>
<td>&gt;100 ml/kg</td>
</tr>
</tbody>
</table>

- Basic monitoring (pulse oximetry, capnography, blood pressure, ECG, body temperature)
- In case of surgeries with larger volume turnovers monitoring should be extended (e.g., arterial and central venous catheters)
- Lab evaluation:
  - Serum electrolytes and plasma osmolarity
  - Urine electrolytes
  - Blood urea, serum creatinine (renal function)
- In case of major surgeries, regular BGAs should be performed, and in case of negative trends (ScvO2↓, BE↓, lactate↑), countermeasures should be taken early.
- Fluid responsiveness: autotransfusion maneuver (e.g., pressure on liver)
- Urinary excretion (1-3 ml/kg/h)

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**Echocardiographic measurements?**

**Fluid responsiveness in the neonate**

Ability of stroke volume to be increased by a fluid bolus.

Stroke volume is fixed in the neonate
CO is totally heart-rate dependent
Neonatal myocardium is preload dependent cardiac output

Increase in heart rate only increases if accompanied by increase in the filling time of the left and right atrium

Monitoring CO by TED in neonates and young infants without cardiac dysfunction undergoing surgical anesthesia can be used to predict response to VtE in infants with a sensitivity of 80% and a specificity of 50%. In this study, TED showed that VtE based on standard clinical monitoring data may be inappropriate in as much as 60% of patients in this age group. Furthermore, the lack of responsiveness to VtE was not detected in over 25% of patients, possibly leading to unwise fluid loading. TED is a minimally invasive and quickly learned monitoring technique that is useful to guide intravenous VtE and could be shown in the future to improve postoperative outcomes in neonates and young infants.
5. Electrolyte imbalance in the perioperative period

- **a) Hyponatremia**
  - **Most frequent electrolyte disorder in hospitalized infants:**
  - **Na⁺ < 135 meq/L (critical < 125 meq/L)**
  - **Causes:**
    - Administration of hypotonic fluids (iatrogenic hyponatremia)
      Hypotonic solutions and i.v. free water intake of more than 6.5 ml/kg/hour are associated with reductions in postoperative plasma sodium measurements ≥ 4 mM
    - Stress, pain, nausea and vomiting = non osmotic stimuli for ADH production
    - Pituitary or adrenal insufficiency
    - SIADH
    - Brain injuries/ tumours
  - **Symptoms**
    - Early signs = non specific
      - nausea, confusion, cramps, tachycardia, headache, ...
    - Lethargy
    - Seizure, coma
    - Respiratory arrest (Na⁺ < 125 meq/L)

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![Image of a baby with a needle in their arm](image1.png)

**Postoperative decrease in plasma sodium concentration after infusion of hypotonic intravenous solutions in neonatal surgery**

**Conclusions.** Hypotonic solutions and i.v. free water intake of more than 6.5 ml/kg h⁻¹ are associated with reductions in postoperative plasma sodium measurements ≥ 4 mM. In the context of neonatal surgery, close monitoring of plasma sodium is mandatory. Routine use of hypotonic i.v. solutions during neonatal surgery should be questioned as they are likely to reduce plasma sodium.

![Graph showing linear correlation between hypotonic i.v. free water intake and postoperative plasma sodium concentration](image2.png)
• Potential for long term neurocognitive developmental delay in neonates suffering from hyponatremia
  - Risk for hyponatremia up to 24% in preterm infants receiving i.v. fluids

• Hyponatremic encephalopathy
  - RF: underlying CNS disease, female, hypoxia
  - Headache, nausea, vomiting, weakness, lethargy, confusion
  - Altered consciousness, seizure, coma, myocardial ischemia, arrhythmias
  - Neurogenic pulmonary edema (= Ayus Arieff Syndrome)
  - Poor prognosis

Management
- Medical emergency!
- Hyponatraemic seizures respond poorly to anticonvulsants
- 3% NaCl, 6ml/kg over 1 hour, further correction over 48h
  \[ \rightarrow 1 \text{ ml/kg will raise serum sodium by } 1 \text{ mmol/L} \]
- Treat the cause
- Targeted rate of correction: 0.5 meq/L/hr
- Stop correction if child is asymptomatic, or serum sodium > 125 meq/L

CORRECTION OF HYPONATREMIA
To prevent brain herniation and neurologic damage from cerebral oedema, cases of symptomatic hyponatremia require urgent correction of sodium levels to 140-145 mmol/L with 3.5% sodium chloride. The rate of correction does not need to be restricted in patients with true acute hypotonicity, and modulation of excessive correction is not indicated. However, limits for correction are warranted if there is any uncertainty as to whether the hypotonicity is chronic or acute. It should be noted that convalescent hypernatremia is likely in the presence of hyponatraemic encephalopathy.

b) Hypernatremia
• Na⁺ > 150 mmol/L
• Causes (Hypovolemic hypernatremia)
  - Excessive water loss (polyuria)
  - Restricted water intake
  - Medication and infusions with high [Na⁺]
• Management
  - 0.9% NaCl \rightarrow boluses of 20 ml/kg until normovolaemia
  - Slow correction, max 12 mmol/kg/day
  - Diuresis + replacement with hypotonic fluids

CORRECTION OF HYPERNATREMIA
0.45% sodium chloride is given, with maximum fluid correction of 12 mmol/kg/day. Depending on the serum sodium level, a normal intake of sodium is given. The rate of correction should not exceed 12 mmol/kg/day to prevent cerebral oedema.

c) Hypokalemia
• Serum K < 3.5 mmol/L (critical < 3 mmol/L)
• Symptoms
  - Cramps
  - Arrhythmia
  - Paralytic ileus
• Management
  Oral supplements
  IV correction, 0.25 MEQ/kg/hour

Prominent U Wave
Depressed ST segment
Biphasic T wave
d) Hyperkalemia

- Serum K > 5.5 meq/L (> 6 meq/L in neonates)
- Management
  - 10% Calcium gluconate (100 mg/kg per dose)
  - Removal of potassium
    - Furosemide 1 mg/kg
    - Dialysis or haemofiltration
  - Increase intracellular shift of potassium
    - Na bicarbonate 1-2 mmol/kg
    - Glucose 0.3-0.5 g/kg/hr + 1 unit of insulin for every 5 g of glucose
    - Salbutamol 2.5-5 mg

e) Glucose

- Definition
  - Hyperglycaemia:
    - Glucose concentration in IV fluid, surgery
    - Fasting glucose levels > 120 mg/dl
    - Glucose levels > 200 mg/dl after fluid infusion
  - Hypoglycaemia: < 45 mg/dl
    - Fasting period

- Hypoxia

Surgical stress

Glucose supply

Cortisol

Glucagon

Gluconeogenesis

Fat mobilisation

Protein catabolism

Vasopressin

Insulin

Blood glucose concentration

Hyperglycaemia ➔ risk for morbidity ➔

- Intraventricular hemorrhage
- Retinopathy of prematurity
- Necrotizing enterocolitis
- Bronchopulmonary dysplasia
- Osmotic diuresis
- Delayed wound healing
- Renal injury
- Neuronal lactic acidosis
6. Conclusion

Administration of hypotonic fluids perioperatively is unacceptable in neonates and small infants!


References


Postoperative decrease in plasma sodium concentration after infusion of hypotonic intravenous solutions in neonatal surgery. Edjo Nkilly; Br J Anaesth 2014; 112: 540-545.


