Perioperative fluid management in children

Gersten Jonker, paediatric anaesthetist

BAPA-SKA Refresher Course
January 2016, Leuven
Disclosure

Perioperatief Vochtbeleid Bij Kinderen

Inhoud
1. Vooraf
2. Theoretische achtergronden
   A. Vochtbehoefte
   B. Elektrolytbehoefte
   C. Energiebehoefte
   D. Neonaten
3. Praktische uitvoering
4. Bijzonderheden en complicaties
5. Stroomdiagram

Disclaimer
Protocolen geven aan hoe lokaal uitvoering wordt gegeven aan beroepskaders, -normen, standpunten en richtlijnen. Protocolen worden lokaal/plaatselijk vastgesteld, rekening houdend met de typische omstandigheden van de eigen praktijk en het ziekenhuis. Het opstellen van protocolen is een eigen verantwoordelijkheid van afdelingen en maatschappij anesthesiologie. De protocolen van de Sectie Kinderanesthesiologie van de NVA zijn een handvat om hieraan lokaal invulling te geven.
APA website (www.apagbi.org)
Poll question 1

• What fluid would you routinely prescribe for postoperative maintenance?

A. NaCl 0.45% + glucose 2.5%
B. NaCl 0.9% + glucose 5%
C. NaCl 0.9% or Ringer’s acetate/lactate
Poll question 2

• Which is true about hypoglycaemia?

A. Children easily become hypoglycaemic intraoperatively, because of their high metabolic rate and low glycogen reserves
B. Children seldomly become hypoglycaemic intraoperatively
C. The above are both incorrect
Poll question 3

Which is true about sodium (Na)?

A. Children do not deal well with administered Na; so give them hypotonic iv fluids to prevent hypernatraemia
B. Children easily become hyponatraemic intraoperatively; so give them enough Na
C. The above are both incorrect
Take Home Messages

Isotonic iv fluids pre-, intra-, and postoperatively

Hyponatraemia is the most common electrolyte disturbance in children

There is a risk for hypoglycaemia in children at risk
Outline

Fluid requirements
  Maintenance
  Deficits
Electrolyte requirements
  Tonicity
  Hyponatraemia
Energy requirements
  Hyper- and hypoglycaemia
Wrapping it up
Fluid requirements

• Aim is to maintain homeostasis and cardiovascular stability pre-, intra-, postoperatively, *taking into account the influence of surgery, surgical stress and anaesthetics*

• Maintenance
• Deficits
THE MAINTENANCE NEED FOR WATER IN PARENTERAL FLUID THERAPY

By Malcolm A. Holliday, M.D., and William E. Segar, M.D.
Department of Pediatrics, Indiana University Medical Center

- 0-10 kg: 100 cal/kg
- 10-20 kg: 1000 cal + 50 cal/kg over 10 kg
- 20+ kg: 1500 cal + 20 cal/kg over 20 kg

- 100 ml H2O/100 cal/day → 100 ml/kg/day

1957!
## The 4-2-1-rule for maintenance

<table>
<thead>
<tr>
<th>Body weight</th>
<th>Maintenance need / h</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-10 kg</td>
<td>4 ml/kg</td>
</tr>
<tr>
<td>11-20 kg</td>
<td>40 ml + 2 ml/kg for every kg between 11 and 20 kg</td>
</tr>
<tr>
<td>&gt;20 kg</td>
<td>40 + 20 + 1 ml/kg for every kg over 20 kg</td>
</tr>
</tbody>
</table>
Deficits

• Preoperatively
  – Fasting: maintenance need x no. hours fasting
  – Fever: + 10% / °C above 37.5 °C
  – GI losses: vomiting, diarrhea, bowel prep

• Intraoperatively
  – Surgical bloodloss
  – Interstitial fluid shift

• Postoperatively
  – Surgical bloodloss
  – Interstitial fluid shift

  • Replenish fasting deficit?
  • 10 ml/kg in 1st hour
  • 50% in 1st hour, 50% in 2nd-3rd
  • 10-20 ml/kg bolus if hypovolaemic
  • Replace ongoing losses
Electrolytes

- Solute

- Tonicity: the capacity of a fluid to generate osmotic force over a semi-permeable membrane (in vivo)

- Osmolarity: number of osmoles of solute particles in a volume of fluid (penetrating and non-penetrating)

- All Guidelines stress isotonicity of iv fluids in children
Na and hypotonicity

• Na is most important kation extracellularly, and in iv fluids
• Until recent the administration of hypotonic fluids was commonplace
• Post ≥ pre > intraoperatively
  – Snaith, PA 2008: 94% pre, 29% intra, 92% post
• Usually fluids like NaCl 0.45% or 0.225%...
Hypotonic fluid

- NaCl 0.45% / glucose 2.5%
- Isoosmolar
- “In vitro isotonic”
- In vivo hypotonic!
- Na 77 mmol/l
Hyponatraemia

- Tissue oedema
- Neurological symptoms: oedema, headache, nausea, lethargy
- Children at risk!
  - At relatively high [Na] symptomatic
    - Na < 125: 50% symptomatic
  - Higher ratio brain/intracranial volume
  - Limited Na excreting capacity brain
  - Postoperatively: ADH
ADH secretion in postoperative and ill children

- 2-3 days
- With pulmonary and neurological disease
- After cardiac-, neuro- en spinal surgery
- ADH ↑ in 84% of children after minor surgery
- Non-osmotic stimuli: pain, stress, fear, PONV, morphine

- Waterretention

- Reduce waterintake
- Probably reduce maintenance rate to 50-80%
Hyponatraemic encephalopathy

- Diminished consciousness, respiratory insufficiency, seizures, herniation, coma, death

- Moritz: 50 cases in literature
  - 50% mortality
  - 50% postoperatively

- Arieff, Moritz:
  - 8.4% mortality
  - 0.5% incidence

- Several deaths in healthy children undergoing elective surgery (UK)
ADH + hypotonic fluid = hyponatraemia

- Hypotonic fluids postoperatively: 20-35%
- Isotonic fluids
- RR 0.48 (CI 95% 0.38-0.60)
- No hypernatraemia or overhydration
• Use isotonic crystalloids that contain sodium in the range 131-154 mmol/litre
### NICE “IV fluids in children”

#### Table 6: Intravenous fluid types for children and young people

<table>
<thead>
<tr>
<th>Fluid with recommendation reference</th>
<th>Fluid type(a)</th>
<th>Osmolality (compared with plasma)</th>
<th>Tonicity (with reference to cell membrane)</th>
<th>Sodium content (mmol/litre)</th>
<th>Potassium content (mmol/litre)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Isotonic crystalloids that contain sodium in the range 131–154 mmol/litre [10, 11, 17, 26, 29, 32]</td>
<td>0.9% sodium chloride</td>
<td>Isosmolar</td>
<td>Isotonic</td>
<td>154</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Hartmann’s solution</td>
<td>Isosmolar</td>
<td>Isotonic</td>
<td>131</td>
<td>5</td>
</tr>
<tr>
<td>Isotonic crystalloids with glucose that contain sodium in the range 131–154 mmol/litre [21]</td>
<td>0.9% sodium chloride with 5% glucose</td>
<td>Hyperosmolar</td>
<td>Isotonic</td>
<td>150</td>
<td>0</td>
</tr>
<tr>
<td>Hypotonic fluids [29, 32]</td>
<td>0.45% sodium chloride with 5% glucose</td>
<td>Hyperosmolar</td>
<td>Hypotonic</td>
<td>75</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>0.45% sodium chloride with 2.5% glucose</td>
<td>Isosmolar</td>
<td>Hypotonic</td>
<td>75</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>0.45% sodium chloride</td>
<td>Hyposmolar</td>
<td>Hypotonic</td>
<td>75</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>5% glucose</td>
<td>Isosmolar</td>
<td>Hypotonic</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>10% glucose</td>
<td>Hyperosmolar</td>
<td>Hypotonic</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

\(a\) Fluids given are examples of appropriate fluids; for further details, see the British national formulary for children.
How about colloids?

- Did not make it into the summary
- No convincing evidence for clinical benefit of synthetic and non-synthetic colloids
- Not cost-effective
- Caution in situations with capillary leak
- Sepsis, trauma, perioperatively
Coffee and dehydration

High dose caffeine increases RBF and inhibits Na reabsorption. After abstinence, caffeine works as a mild diuretic. When you feel you need a coffee, you may have experienced a period of reduced fluid intake that reduces your urine production.

Effect of coffee on concentration: high interindividual variability.
Hypoglycaemia

• “Children easily become hypoglycaemic”
• Studies from the 1980s: 0 - 10%
• Old-fashioned fasting rules
• Recent: 0 - 0.25%?

• Neurological sequelae
  – Superficial cortex and hippocampus
Glucose response

Lipshutz, *Anesthesiology* 2009; 110: 408-21
Hyperglycaemia: consequences

- Osmotic diuresis
  - Glucose >10 mmol/l: dehydration and electrolyte disturbances
- Increased injury ischaemic event CNS
- Infection rate ↑

- Administering glucose 10%, 5%, 2.5%: hyperglycaemia
- Glucose requirements under GA close to basal requirement
Glucose-containing fluids intraoperatively

- Ayers, PA 2001 10-75%
- Soderlind, PA 2001 40-70%, 50-90%
- Almenrader, PA 2009 40%

- Sümpelmann: Vollelektrolytlösung + 1% glucose
  - 2010. n=144 < 4 y, 10 ml/kg/h, no hypo, no hyper
  - 2011. n=66 neonates, 10 ml/kg/h, no hypo, no hyper
Glucose-containing iv fluids

• In children at risk for hypoglycaemia
  – Cachexia
  – Metabolic disease
  – Severe infections, sepsis
  – Term and premature neonates
  – Ex-prematures < 60 weeks postconception
  – Children with preoperative infusion of glucose or TPN
  – Long duration of fasting and/or surgery
Recommendations

• Aim for [glucose] 3.5-10 mmol/l
• Monitoring!
• Glucose 10%
• Or add 10 ml glucose 50% to 500 ml isotonic fluid: glucose 1%

• Hypo: 2 ml/kg glucose 10%
• TPN or glucose preop: continue

<table>
<thead>
<tr>
<th>Patient</th>
<th>Dose mg/kg/min</th>
<th>Rate gluc 10% ml/kg/h</th>
</tr>
</thead>
<tbody>
<tr>
<td>Child</td>
<td>2</td>
<td>1.2</td>
</tr>
<tr>
<td>Infant</td>
<td>3</td>
<td>1.8</td>
</tr>
<tr>
<td>Neonate</td>
<td>3-5</td>
<td>1.8 – 3</td>
</tr>
<tr>
<td>Premature</td>
<td>5-6</td>
<td>3 – 3.6</td>
</tr>
<tr>
<td>Crit ill infant</td>
<td>5-8</td>
<td>3 – 4.8</td>
</tr>
</tbody>
</table>
Postoperative fluid management

• Glucose requirements (much) higher
• ADH, water retention
• Monitor electrolytes and glucose
Wrapping it up
Preoperatively

- Sugary clear fluids 0 – 2h preoperatively
- IV: isotonic, 4-2-1-rule, add glucose with very long fasting
Intraoperatively

- Compensate for deficits
  - maintenance x h of fasting = deficit
  - 1. 50% in 1\textsuperscript{st} h, 50% in subsequent 2 hours
  - 2. 1\textsuperscript{st} h 10 ml/kg/h
- After compensation: 4-2-1-rule
  - ...plus an estimated volume for evaporation wound, bloodloss, interstitial shift
- With hypovolaemia 10 - 20 ml/kg bolus
- Always isotonic crystalloid
- Healthy, > 1 month, short fast, postop oral intake allowable: glucose-free
Intraoperatively (2)

- Do not exclusively use fluids with glucose > 2%
- Aim for [glucose] 3.5-10 mmol/l
- Glucose needs to be dose prescribed
- Monitor [glucose]
- Continue glucose-containing fluids administered preop
Postoperatively

• 4-2-1-rule
• Or reduce to 50-80% of 4-2-1
• Isotonic and glucose 5%
  – NaCl 0.45% / glucose 2.5% = too little salt and too little sugar
  – NaCl 0.9% / glucose 5%
Poll question 1

• What fluid would you routinely prescribe for postoperative maintenance?

• NaCl 0.45% + glucose 2.5%
• NaCl 0.9% + glucose 5%
• NaCl 0.9% or Ringer’s acetate/lactate
Poll question 1

• What fluid would you routinely prescribe for postoperative maintenance?
  
• NaCl 0.45% + glucose 2.5%
• NaCl 0.9% + glucose 5%
• NaCl 0.9% or Ringer’s acetate/lactate
Poll question 2

- Which is true about hypoglycaemia?

- Children easily become hypoglycaemic intraoperatively, because of their high metabolic rate and low glycogen reserves
- Children seldomly become hypoglycaemic intraoperatively
- The above are both incorrect
Poll question 2

• Which is true about hypoglycaemia?

• Children easily become hypoglycaemic intraoperatively, because of their high metabolic rate and low glycogen reserves

• Children seldomly become hypoglycaemic intraoperatively

• The above are both incorrect
Poll question 3

• Which is true about sodium (Na)?

• Children do not deal well with administered sodium (Na); so give them hypotonic iv fluids to prevent hypernatraemia

• Children easily become hyponatraemic intraoperatively; so give them enough sodium (Na)

• The above are both incorrect
Take Home Messages

Isotonic iv fluids pre-, intra-, and postoperatively
Hyponatraemia is the most common electrolyte disturbance in children
There is a risk for hypoglycaemia in children at risk
Time for your questions!

g.jonker-4@umcutrecht.nl

http://www.apagbi.org.uk/sites/default/files/images/NICE%20Fluids%20Full%20guideline%2020151209.pdf

Pediatric electrolyte requirement

- "Half 4-2-1-rule"

<table>
<thead>
<tr>
<th>Body weight</th>
<th>Na, K requirement / 24 h</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-10 kg</td>
<td>2 mmol/kg</td>
</tr>
<tr>
<td>11-20 kg</td>
<td>20 mmol + 1 mmol/kg for every kg between 11-20 kg</td>
</tr>
<tr>
<td>&gt;20 kg</td>
<td>20+ 10+ 0.5 mmol/kg for every kg above 20 kg</td>
</tr>
</tbody>
</table>
Neonates

• Physiological decrease extracellular component
  – Lower fluid requirement in first week
  – 70 → 150 ml/kg/d

• Prematures larger body surface area, immature skin
  – Larger fluid requirements than term neonate
  – + 20 ml/kg/d
Neonates (2)

- Especially prematures:
  - Immature kidney, less Na reabsorption, natriuresis
  - Tend to get hypernatraemia
  - Little to no Na iv in first days
  - Less HCO3 reabsorption: tend to get metabolic acidosis
  - Later tend to get hyponatraemia, esp with hypotonic fluids