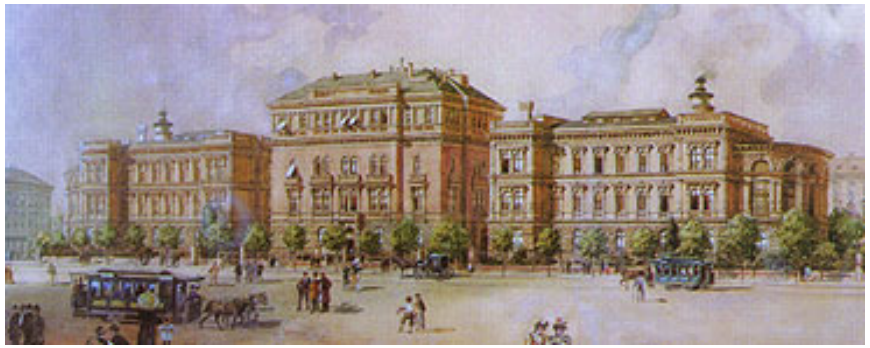

Fluid therapy in children

TJ Neuhaus and G Reusz

Lucerne and Budapest

ESPN 2012 Kraków

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Parenteral maintenance in children

Daily requirements - Holliday and Segar, 1957

		Patient weight: 25 kg
Fluid		
1 - 10 kg	100 ml/kg	1000
11 - 20 kg	+50 ml/kg	500
> 20 kg	+20 ml/kg	100
		1600 ml
Calories		
1 ml ≅ 1 kcal		1600 kcal
Electrolytes: calculation based on oral intake!		
Na^+: 2 - 3 mmol/100 ml (infants ≅ /kg)		40 mmol
K^+: 2 mmol/100 ml		30 mmol

Intravenous fluid in acutely ill children (1)

3 steps of fluid and (!) electrolytes administration

1. Rehydration / replacement of deficit ("rapidly" over 1 - 4 hrs)

2. Maintenance requirements

3. Replacement of ongoing losses

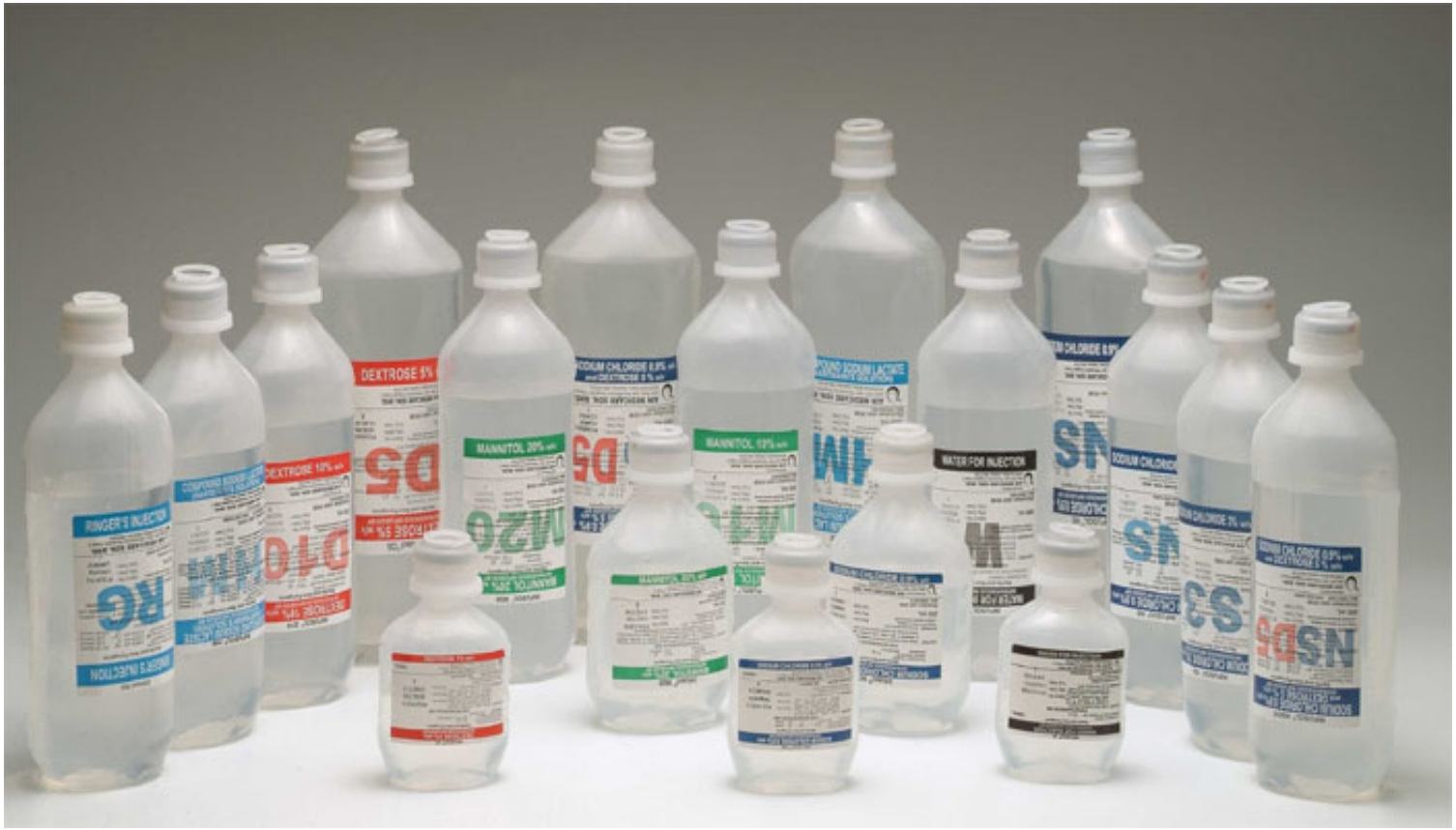
i.v. fluid in acutely ill children (2) - Your choice

1. Rehydration / replacement of deficit (over 1 - 4 hrs)
   - Which solution(s)?

2. Maintenance
   - Which solution(s)?

3. Replacement of ongoing losses
   - Which solution(s)?

Intravenous solutions ....



Fluid in acutely ill children (3)

- Main differences to "healthy" children
  - often parenteral = intravenous fluid administration AND
  - non-osmotic stimuli of antidiuretic hormone secretion
    - "stress"
    - hypovolaemia
    - pneumonia, bronchitis, CNS infections …
    - pain, nausea, emesis
    - hypoxia, trauma
    - drugs: narcotics and opiates …

→ increased tubular H_20 reabsorption → risk of hyponatraemia

Fluid in acutely ill children (4) - Studies

- **Oral therapy for rehydration**
  - Hypotonic ORS: Oral Rehydration Solution: Na = 60 - 90 mmol/l
    → safe: **no** risk of hyponatraemia
- **i.v. therapy for rehydration and maintenance**
  - NaCl 0.9% = iso-tonic vs hypo-tonic solution
    → NaCl 0.9%: - 17-fold ↓↓ risk of hypo-natraemia
    - no risk of hyper-natraemia
- **Current recommendation**
  - **i.v. fluid for rehydration and maintenance**
    → **isotonic solution(s)**

Intravenous fluid management for the acutely ill child

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Current Opinion in Pediatrics 2011, 23:186–193

Purpose of review

To review the principles of prescribing intravenous fluids (IVFs) to the acutely ill child and of adjusting sodium composition and fluid rate to prevent disorders in serum sodium or volume status from occurring.

Recent findings

Recent data have revealed that the historic approach of administering hypotonic IVFs results in a high incidence of hospital-acquired hyponatremia in children. The majority of hospitalized children requiring IVFs are at risk for developing hyponatremia from numerous stimuli for arginine vasopressin (AVP) production, such as volume depletion, pain, stress, nausea, vomiting, respiratory or central nervous system (CNS) disorders, or

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Table 1 Incidence of hyponatremia in hospitalized children

Author	Reference	Inclusion criteria serum Na (mEq/l)	Incidence (%)
Hyponatremia on admission			
Hasegawa *et al.*	[1•]	<135 on admission	17
Don *et al.*	[2]	<135 on admission with community-acquired pneumonia	45
Hoorn *et al.*	[3]	<135 in emergency department patients with serum sodium checked	22
Hospital-acquired hyponatremia in children receiving hypotonic fluids			
Eulmesekian *et al.*	[4••]	<135 in surgical patients	31
Hanna and Saberi	[5••]	<135 in gastroenteritis	18
Singhi and Jayashre	[6•]	<130 in ICU patient	31
Armon *et al.*	[7]	hospitalized patients on intravenous fluids	
		<135	24
		<130	5

Table 3 Prospective studies evaluating the relationship between intravenous fluid sodium concentration and change in serum sodium

Authors	Study design	*n*	Outcome
Kanda *et al.* [36••]	Prospective observational study. Change in serum sodium at 5 h in children following a percutaneous renal biopsy receiving either 0.6% NaCl or 0.9% NaCl and with elevated AVP levels	60	Fall in SNa in 0.6% NaCl group of 1.9 mEq/l Increase in SNa in 0.9% NaCl group of 0.9 mEq/l
Sumpelmann *et al.* [60]	Prospective observation study. Change in intra-operative serum sodium in patient receiving a balanced electrolyte solution (Na 140 mEq/l)	107	Increase in SNa of 1 mEq/l
Kannan *et al.* [37••]	Prospective randomized trial. Incidence of hyponatremia (SNa <130 mEq/l) within 72 h of initiated IVF in hospitalized children randomized to 0.18% NaCl at full or 2/3 maintenance and 0.9% NaCl at full maintenance	167	14.4% and 3.8% incidence of hyponatremia in 0.18% NaCl groups, respectively 1.7% incidence of hyponatremia with 0.9% NaCl group
Neville *et al.* [39••]	Prospective randomized trial. Incidence of hyponatremia (Na <135 mEq/l) with 24 h in postoperative patients receiving either 0.45% or 0.9% NaCl at either full or 1/2 maintenance	124	29% and 32% incidence of hyponatremia in the 0.45% NaCl groups, respectively 3% and 16% incidence of hyponatremia in the 0.9% NaCl groups, respectively
Yung and Keeley [40••]	Prospective randomized trial. Change in serum sodium at 12–24 h in children admitted to the ICU randomized to either 0.18% NaCl or 0.9% NaCl at 2/3 or full maintenance rate	50	Fall in SNa in 0.18% NaCl group by 3 mEq/l and 4.9 mEq/L, respectively Increase in SNa in the 0.9% NaCl group by 0.2 and 1.5 mEq/l, respectively.
Montañana *et al.* [38]	Prospective randomized trial. Incidence of hyponatremia (SNa <135 mEq/l) within 24 h in postoperative children admitted to the ICU receiving either hypotonic fluids (Na <100 mEq/l) or isotonic fluid (Na + K = 155 mEq/l)	122	20.6% incidence of hyponatremia in the hypotonic group 5.1% incidence of hyponatremia in the isotonic group

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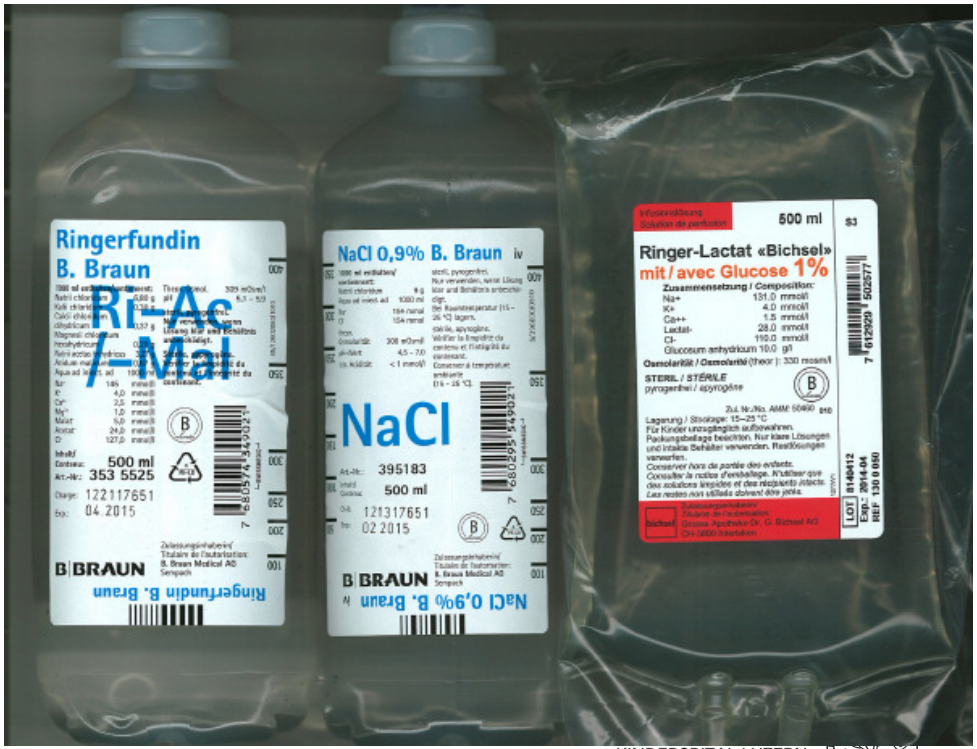

Pädiatrische Klinik

Gastro 24

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Autor/en: Dr. med. J. Spalinger / Dr. med. Nicole Hagleitner / Prof. Dr. med. Thomas Berger /
Dr. med. Martin Stocker / Dr. med. Iris Bachmann Holzinger / Prof. Dr. med. Thomas J. Neuhaus

Version 04/12

Rehydrierung bei akuter Gastroenteritis

So banal und häufig eine unkomplizierte Gastroenteritis erscheinen mag, sie birgt immer wesentliche Gefahren und erfordert sowohl von ärztlicher als auch von pflegerischer Seite volle Aufmerksamkeit !

1. Einleitung

- 6 Grundpfeiler der Behandlung leicht bis mittelgradig dehydrierter Kinder

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8. Intravenöse Rehydrierung und Flüssigkeitstherapie (Berechnung s. Excel-Tabelle)

- **Indikation:**
  - Dehydrierung > 10% , Kreislaufschock
  - Fehlgeschlagene oder schwierige orale Rehydrierung (klinische Situation); kein Personal verfügbar.
  - Unklare Diagnose, Risikokinder, Irritabilität oder Benommenheit, Kinder < 3 Monaten.

- **Prinzipien:**
  - Unterscheidung von ***isotoner*** (Na 130 - 150 mmol/l), ***hypotoner*** (< 130mmol/l) oder ***hypertoner*** (> 150 mmol/l) **Dehydrierung.**
  - **Rehydrierung = Korrektur des Defizits innert 4 h mit Ringerfundin (falls im Schock: separater Bolus mit NaCl 0.9% = 20 ml/kg KG intravenös sofort)**
  - Azidose wird primär nicht mit Bicarbonat (Alkali) korrigiert
  - **Erhaltungsbedarf nach 4h: möglichst per os (bei Säuglingen möglichst mit Stillen weiterfahren); falls intravenös mit Ringerlactat 1% Glucose**
  - **Ersatz laufender Verluste (10 ml/kg KG pro flüssigen Stuhl) per os oder intravenös mit Ringerlactat 1% Glucose**
  - **Zufuhr von normaler Kost früh = nach 4 h Rehydrierung: Beginn mit Flüssigkeit per os und normaler Kost unter der Voraussetzung, dass AZ besser und Kind trinken und essen will.**

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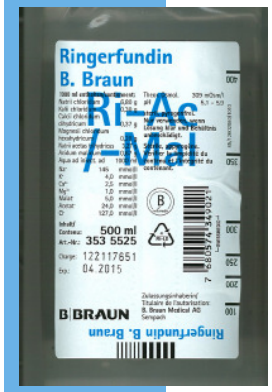
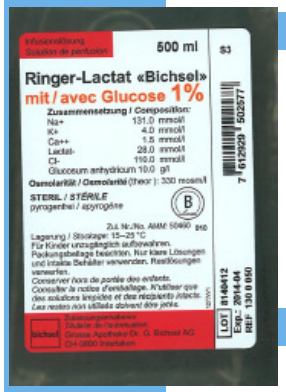
per 1000 ml = mmol/l		Ringerfundin	Ringer's with glucose 1%	NaCl 0.9%
Natrium	+	145	131	154
Potassium	+	4	4	
Calcium	+	2.5	1.5	
Magnesium	+	1		
Chloride	-	127	110	154
Lactate			28	
Malate		5		
Acetate		24		
Glucose		0	* 55 (= 10 g/l)	0
Tonicity		309	* 276	308
Osmolarity		309	* 330	308
Strong ion difference (SID) + / -		26	26	0

SID (= strong cations - anions): if low → risk of hyperchloraemic acidosis

i.v. fluid in acutely ill children (5) -



- 1. Rehydration / replacement of deficit over (1-) 4 hrs
  - Ringerfundin



- 2. Maintenance
  - Ringer's with 1% glucose
    low risk of hyperchloraemic acidosis / ketogenesis / hypoglycaemia
- 3. Replacement of ongoing losses
  - Ringer's with 1% glucose

and if necessary

- additional replacement of electrolytes and glucose
- in case of shock: rapid bolus(es) of NaCl 0.9%

Intranet-based fluid prescription

i.v. Rehydration

Patient data

Current weight (kg)	**9.5 kg**
Extent of dehydration (%)	**5 %**
Previous weight (kg)	**10 kg**

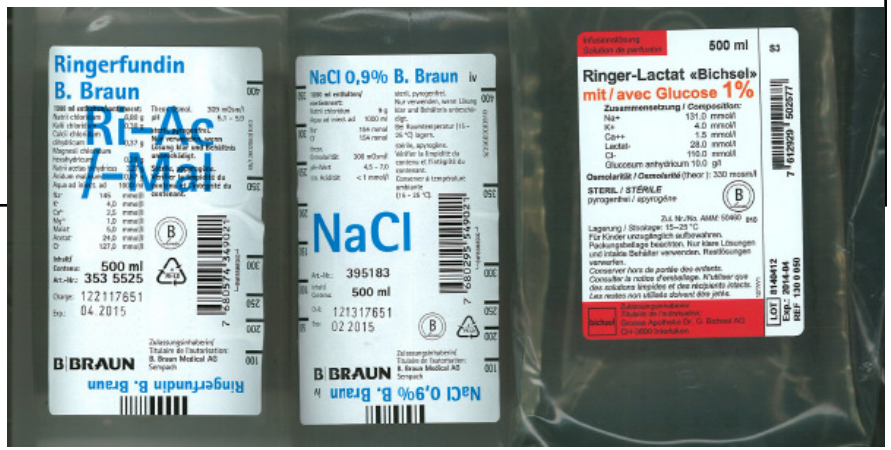
	Volume	Time	Infusion rate	Sodium replac.	Potassium replac.	Glucose replac.
Rehydration with Ringerfundin	**500 ml**	**hours 1-4**	**125 ml/h**	**72.5 mmol**	**2 mmol**	**0 mg/kg/Min**
Maintenance	**1000 ml**	**hours 1-24**				
(P)ortion Mother's milk	**500 ml**	**hours 1-24**		**4 mmol**	**6.5 mmol**	**2.7 mg/kg/Min**
P Formula Milk	0 ml	hours 1-24		0 mmol	0 mmol	#DIV/0! mg/kg/Min
P Oral rehydration solution	0 ml	hours 1-24		0 mmol	0 mmol	#DIV/0! mg/kg/Min
P RL 1% Glucose	**500 ml**	**hours 1-24**	**21 ml/h**	**65 mmol**	**2 mmol**	**0.3 mg/kg/Min**
RL = Ringerlactate						
Total (volume/day)	1500 ml/day			141 mmol/d	10.5 mmol/d	3 mg/kg/Min
Total (volume/kg BW x day)	150 ml/kg x day			14 mmol/kg x day	1 mmol/kg x day	4.4 g/kg/Tag

Additional glucose

	amount
Amount of glucose	mg/kg/Min
Glucose 40%	0 ml/h
Glucose 40%	0 ml/h

If symptomatic hyponatremia

ongoing losses: 1:1 replacement with Ringer 1% Glucose



Vignette 1: History

- Male infant, born in Switzerland at term
- Prenatal/postnatal
  - ultrasound: mild left hydronephrosis (dilatation: 10 mm)
  - neonatal screening: normal
- Since age 3 months
  - reduced appetite, intermittent "diarrhea" and weight loss
- Failure to thrive / dystrophy → referral at 4 months
  - body weight (BW) 5 kg: < 3rd centile
  - height 60 cm: 10th centile
  - skin/mucous membranes dry, otherwise normal examination

Vignette 1: Blood tests (1)

- Na 122 mmol/l
- K 5.2 mmol/l

- your choice for next steps?

Vignette 1: Blood tests (2)

- Na 122 mmol/l
- K 5.2 mmol/l
- blood gas pH 7.41, $HCO3^-$ 19.9 mmol/l
- creatinine 19 umol/l (0.2 mg/dl)
- CRP 1 mg/l

- your choice for next steps?
  - diagnostic procedures
  - fluid management
  - diagnosis

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Vignette 1: Further tests

- Urine
  - Na: 26 mmol/l — FeNa: 0.7% ("normal" < 1%) → cave!
  - K: 60 mmol/l — FeK: 5%
  - Urine culture — 10^6 CFU/ml *E. coli* (after 24 hrs)
- Blood
  - Cortisol — 1174 nmol/l (n: 171 - 537)
  - Renin — 47'130 mU/l (n: < 46)
  - Aldosterone — > 10'000 ng/l (n: < 800)
- Ultrasound
  - "unchanged" mild left hydronephrosis → **diagnosis?**

Vignette 1: Diagnosis

- Pyelonephritis
  - afebrile, subacute and oligosymptomatic
- 2° (transient) Pseudo-Hypo-Aldosteronism
  - typical triad
    - pyelonephritis
    - obstructive uropathy: pelvic dilatation
    - male infant
- Antibiotic therapy
  - ceftriaxone i.v. x 4 days → ceftibuten orally x 10 days

Vignette 1: Fluid management - Your choice

Na: 122 mmol/l
K: 5.2 mmol/l

- Rehydration?
  - Solution? dose?
- Maintenance?
  - Solution? dose?
- Electrolyte substitution?
  - Solution? dose?
- Fluid administration
  - Oral - i.v.?
  - Rapid - slow?

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Vignette 1: Fluid management -

- *"Pragmatic Rehydration"* (weight on admission: 5 kg)
  - i.v. 20 ml/kg BW = 100 ml **NaCl 0.9%** over 4 hrs
  - ≅ 15 mmol Na = 3 mmol/kg
- Maintenance
  - i.v. 100 ml **NaCl 0.9%** over 20 (24) hrs = 15 mmol Na x 3 days
  - oral ≅ 1/6 of BW ≅ 800 ml breast milk / bottle (tube) feeding
    → total extra i.v. sodium = 30 mmol/1st day = 24 hrs
- *Calculation for correction of sodium*
  - maximal correction of Δ10 mmol/l per day (122 → 132)
  - replacement dose = 10 mmol x kg BW (5) x 0.6 = *30 mmol/d extra*

Vignette 1: Follow up

- Clinical findings: improved activity and appetite, afebrile
- Blood tests
  - after 24 hrs: Na: 126 mmol/l K: 4.0 mmol/l
  - after 48 hrs: Na: 130 K: 4.0
  - after 72 hrs: Na: 132 K: 3.7

    → NaCl 0.9% i.v. stop

    → NaCl 23.4% oral: 4 x 1 ml = 4 x 4 mmol / d

    ≅ 3 mmol/kg per day for 3 months
- 3 months later
  - Restitutio ad integrum → pyeloplasty

Vignette 2: History

- Male black infant: born abroad at term, birth weight 2.9 kg
  - family: subsaharian African asylum seeker
- Emergency unit at 3 weeks of age (10 p.m.)
  - repeated vomiting and reduced activity
  - clinical presentation
    - body weight (BW) 2.9 kg
    - afebrile, mucous membranes "a bit dry"
    - vomiting after breast feeding
- your choice for next steps?

Vignette 2: Preliminary results...

- Na 125 mmol/l
- K 4.5 mmol/l

- your choice for next steps?

Vignette 2: Further results...

- Na 125 mmol/l
- K 4.5 mmol/l
- blood gas pH 7.52, $HCO3^-$ 30.9 mmol/l
- chloride 79 mmol/l
- CRP 2 mg/l

- Ultrasound: hypertrophic pyloric stenosis

Vignette 2: Fluid management - Your choice

Na: 122 mmol/l
K: 4.5 mmol/l
Cl: 79 mmol/l

- Rehydration?
  - Solution? dose?
- Maintenance?
  - Solution? dose?
- Electrolyte substitution?
  - Solution? dose?
- Fluid administration
  - Oral - i.v.?
  - Rapid - slow?

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Vignette 2: Fluid management -

- Rehydration: deficit 3%?! (weight on admission: 2.9 kg)
  - i.v. 30 ml/kg BW = 3% BW = 90 ml over 4 hrs
  - **Ringerfundin** ≅ 13 mmol Na ≅ 4 mmol/kg
- Maintenance
  - i.v. 300 ml **Ringer's 1% glucose**: 20 hrs = 39 mmol Na
  - no oral intake - gastric tube to release tension

    → total (i.v.) sodium = **52** mmol/24 hrs
- Sodium requirements
  - maximal correction of Δ10 mmol/l per day (125 → 135)
  - replacement dose = 10 mmol x kg BW (3) x 0.6 = 18 mmol/d extra
  - (oral) maintenance = 2 - 3 mmol/kg ≅ 9 mmol/d

Vignette 2: Fluid management - KISS

- Rehydration
  - no
- Maintenance
  - i.v. 390 ml **Ringer's 1% glucose** over 24 hrs = 51 mmol Na
  - no oral intake - gastric tube to release tension

  → total (i.v.) sodium = **51** mmol/24 hrs
- Sodium requirements
  - replacement dose: 18 mmol/d extra
  - maintenance ≅ 9 mmol/d

Vignette 2: Fluid management - Studies

- Rehydration
  - i.v. 30 ml/kg **NaCl 0.9%** = 90 ml over 4 hrs = 14 mmol Na
- Maintenance
  - i.v. 300 ml **NaCl 0.9%** over 20 hrs = 46 mmol Na + glucose
  - no oral intake - gastric tube to release tension

    → total (i.v.) sodium = **60** mmol/24 hrs
- Sodium requirements
  - replacement dose: 18 mmol/d extra
  - maintenance ≅ 9 mmol/d

Vignette 2: Follow up -

- Blood tests
  - after 4 hrs: Na: 127 mmol/l K: 4.0 mmol/l
  - after 8 hrs: Na: 132 K: 4.2
  - after 12 hrs: Na: 136 K: 4.0
    pH: 7.40
- after 16 hrs: operation - pyloric myotomy

i.v. fluid in acutely ill children: Conclusions

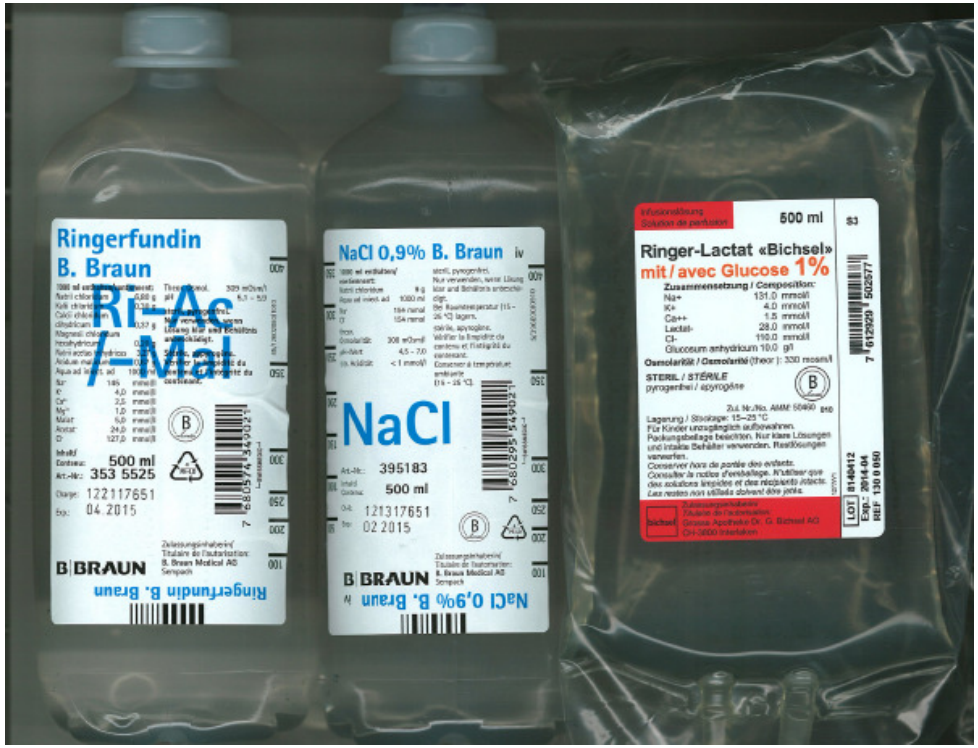
- **Holliday and Segar principles**
  - i.v. maintenance fluid based on calories / energy expenditure
  - electrolyte requirements: based on oral intake

- **Recommendation: i.v. fluid for rehydration and maintenance**
  - **Isotonic solutions …**

    and
  - (for safety reasons) **Intranet-based prescription**

    and …

… KISS: Keep It Simple and Safe



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