Perioperative Flüssigkeitstherapie:

Keep it simple?!

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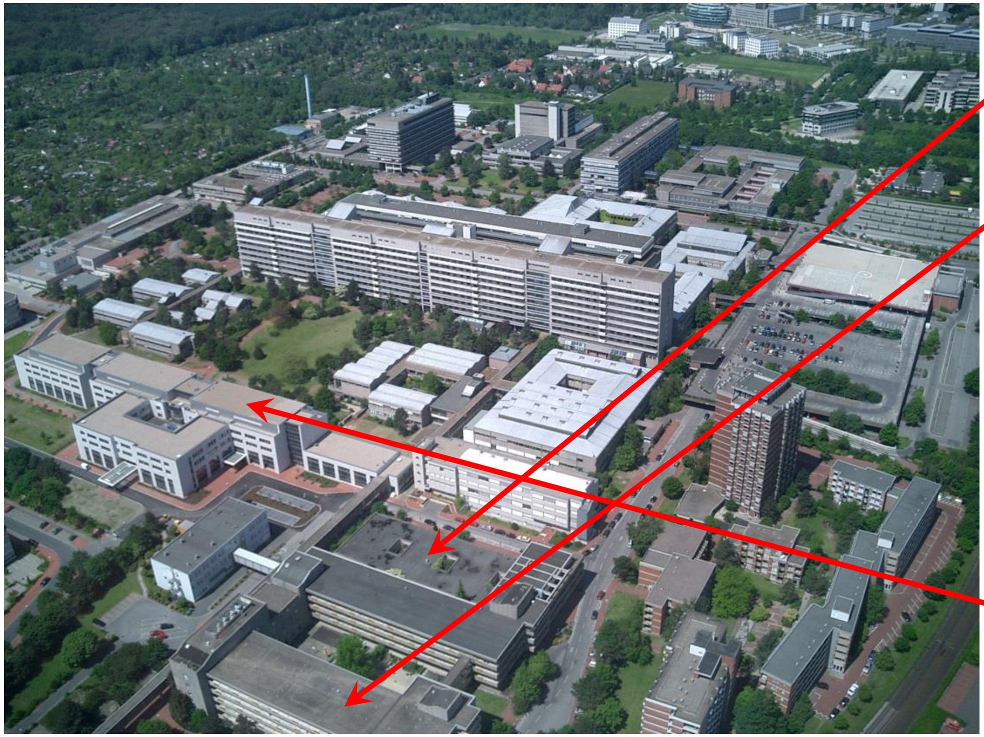


- Pädiatrie
- Kinderchirurgie

  Kinderherzchirurgie

  PICU + NICU

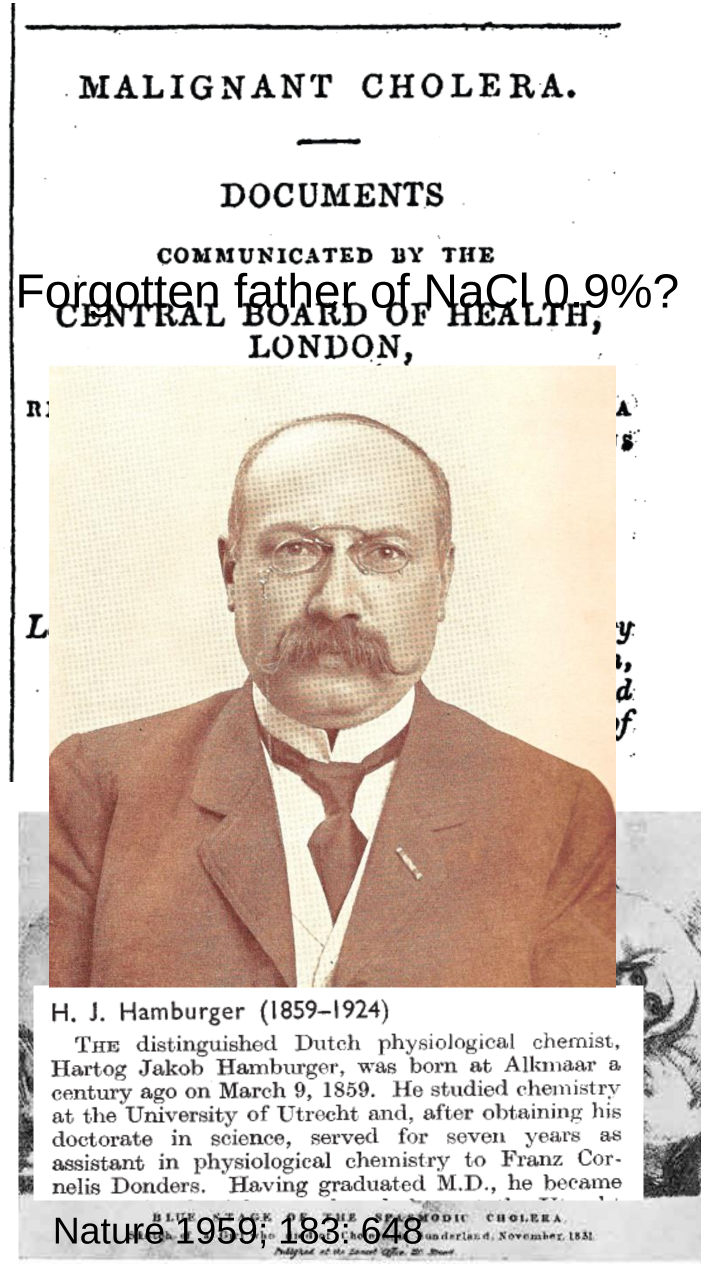
  Kinderanästhesie
- Gynäkologie,Geburtshilfe

Arbeitsgruppe Kinderanästhesie

Sponsoren: Abbott, Arrows, Baxter, B. Braun, Eusa Pharm, Fresenius, Osypka, Pulsion, Serumwerk Bernburg

Kochsalzlösung

- 1831 Choleraepidemie (UK)
- Standardtherapie
  - -Aderlass
  - -Erbrechen
  - -Lachgasinhalation
- William O'Shaugnessy
  - -Infusion von Salzlösung
  - -Tierversuche
  - -Letter in Lancet, 1831
- Thomas Latta
  - -Infusion bei vier Patienten
  - ⇒ „restore the blood to its natural state"
- Inhaltsstoffe
  - -Natrium
  - -Chlorid



Forgotten father of NaCl 0.9%?

Nature 1959; 183: 648

Awad S et al. The History of 0.9% Saline.
Clinical Nutrition (2008) 27: 179

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Sydney Ringer: Ringer- Lösung

- geboren 1834, Norwich (UK)
- 1860 Bachelor
- 1863 Doctor
- 1865- 1869 Children‘s Hospital, Great Ormond Street, London
- 1867 Professor of Clinical Medicine
- Kontraktionen von isolierten Froschherzen in verschiedenen Lösungen
- Inhaltsstoffe
  - -Natrium
  - -Chlorid
  - -Kalium
  - -Calcium

A FURTHER CONTRIBUTION REGARDING THE INFLUENCE OF THE DIFFERENT CONSTITUENTS OF THE BLOOD ON THE CONTRACTION OF THE HEART. By SYDNEY RINGER, M.D., *Professor of Medicine at University College, London.* (Plate I.)

Maltby JR: Notable Names in Anesthesia.
Royal Society of Medicine Press, 2002

Medizinische Hochschule Hannover

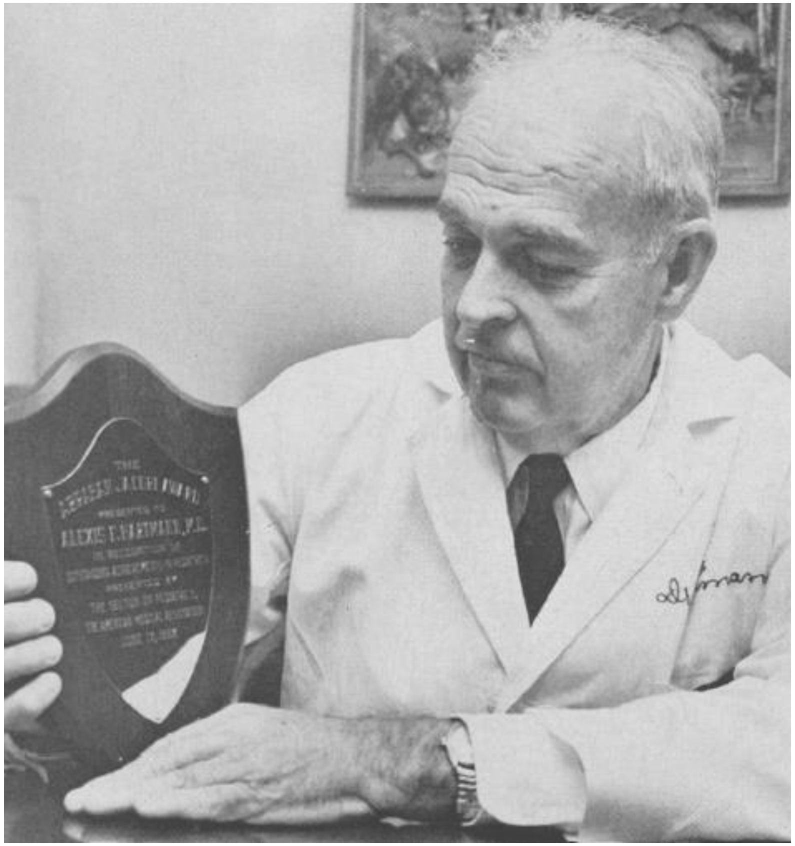
Alexis Frank Hartmann: Ringer‘s Lactat

- geboren 1898 in St. Louis, Missouri, USA
- 1921 Medical Doctor, St. Louis Children‘s Hospital
- 1936 Professor of Pediatrics
- > 20 pädiatrische Ordinarien
- 1932 Modifikation Ringer- Lsg.

  -Ringer $\rightarrow$ Azidose
  -Hitzesterilisation $\Rightarrow$ $\varnothing$ Bicarbonat
  -Zusatz von Laktat
  als Bikarbonatvorstufe

- Inhaltsstoffe

  -Natrium
  -Chlorid
  -Kalium
  -Calcium
  -Magnesium
  -Laktat



1963 Abraham Jacobi Prize Award

White PJ. Alexis F. Hartmann. J Pediatr (1964) 64: 783
Hartmann et al, J Clin Invest 11(1932): 327

Balancierte Lösungen: PlasmaLyte A

TABLE I

CONSTITUENTS OF RESUSCITATION SOLUTIONS

Abbreviations: NS, normal saline; RL, Ringer's lactate; PA, Plasmalyte-A; PR, Plasmalyte-R; HSA, human serum albumin; FFP-H, human fresh frozen plasma; FFP-S, swine fresh frozen plasma.

Lot No.	Solution	pH	Na	K	Mg	Ca	Cl	HCO_3 (Source)
			mEq/l					
Crystalloid solutions								
5C869RB	NS	5.0	154	0	0	0	154	0
6C857X4	RL	6.5	130	4	0	3	109	28 (lactate)
4C837A5	PA	7.4	140	5	3	0	98	27 (acetate) 23 (gluconate)
5C935P8	PR	5.5	140	10	3	5	103	47 (acetate) 8 (lactate)
Colloid solutions								
W18408	HSA	6.7	147	0	0	2.5	118	0
W18408	FFP-H	7.31	178	4.0	1.4	8.0	80	20 (HCO_3)
W18408	FFP-S	7.2	163	3.5	1.2	8.2	82	23 (HCO_3)

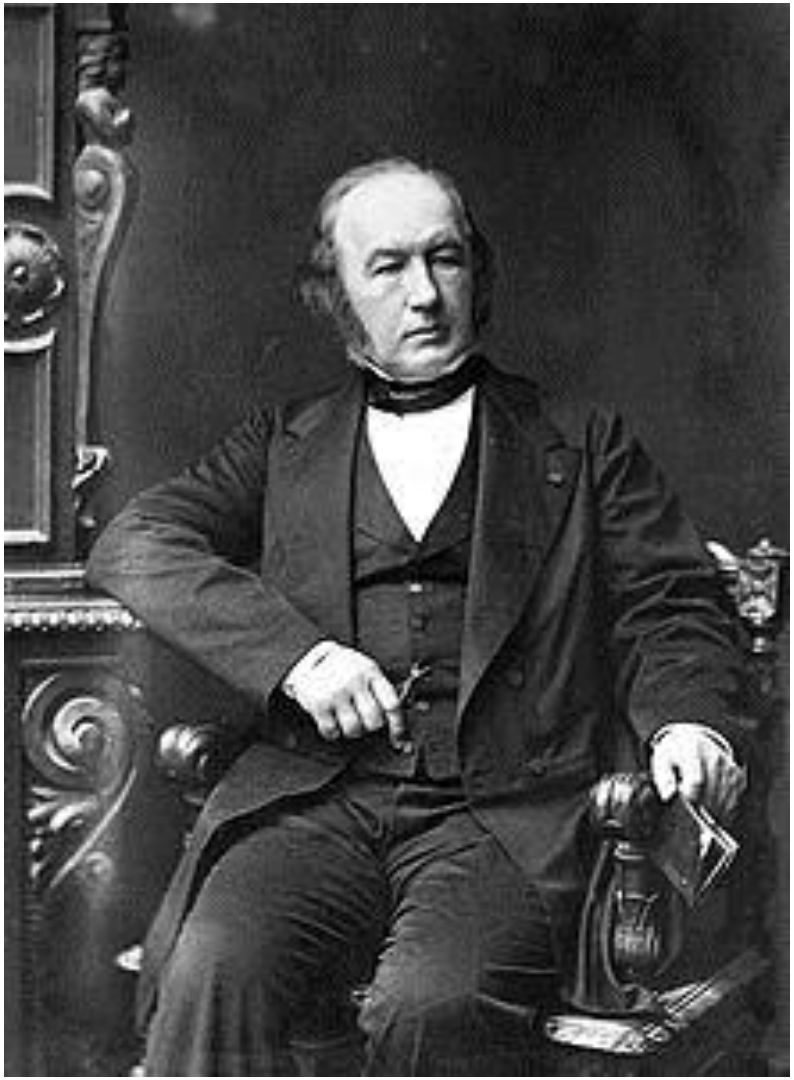
Kristalloide Infusionslösungen

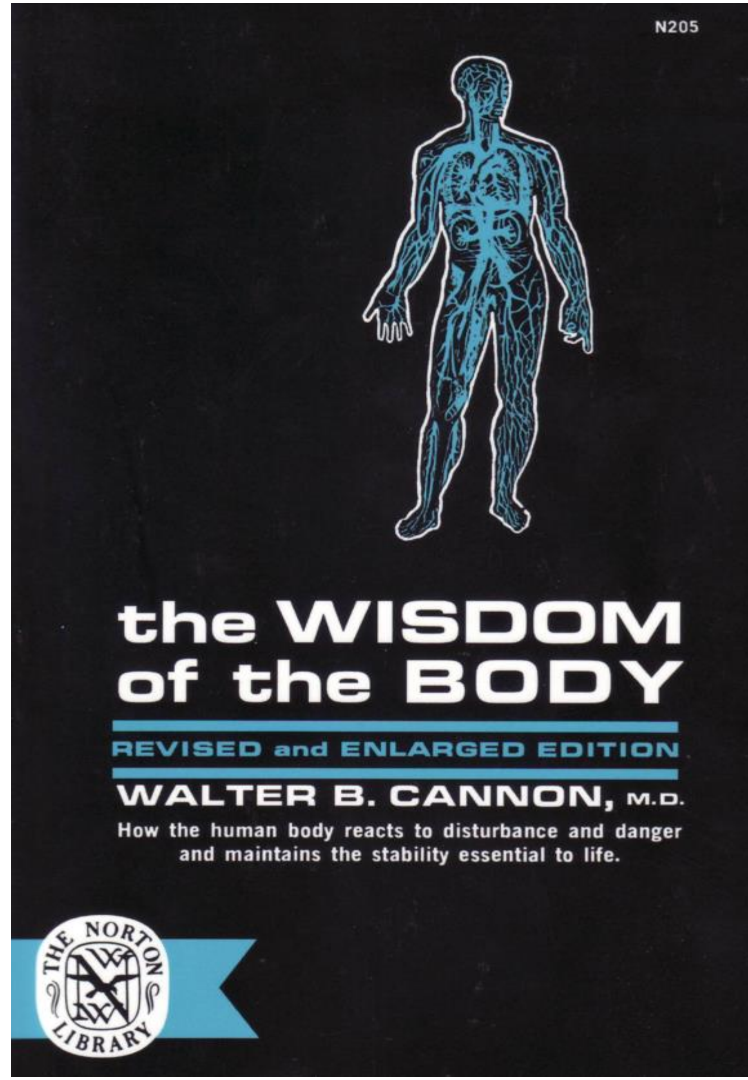
	Plasma	NaCl 0,9%[1]	Ringer[2]	RL[3]	PlasmaLyte A[4]
Kationen					
Na^+	142	154	147,2	130	140
K^+	4,5		4,02	5	5
Ca^{2+}	2,5		2,24	1	0
Mg^{2+}	1,25			1	3
Anionen					
Cl^-	103	154	155,7	112	98
HCO_3^-	24				
Laktat	1,5			27	
Acetat	-				27
Proteinat	20				Gluconat 23
Osmolarität[1]	291	308	309	276	296
Osmolalität[2]	287	286	287	256	282

[1]theor. (mosmol/l), [2]real (mosmol/kg H_2O)

⇒ isotone balancierte Lösungen auch für Kinder!

[1]Latta T, Lewins R. ca. 1830, [2]Ringer S (1834-1910),
[3]Hartmann A, J Clin Invest 11(1932): 327,
[4]Traverso LW et al. Resuscitation 1985; 12: 265

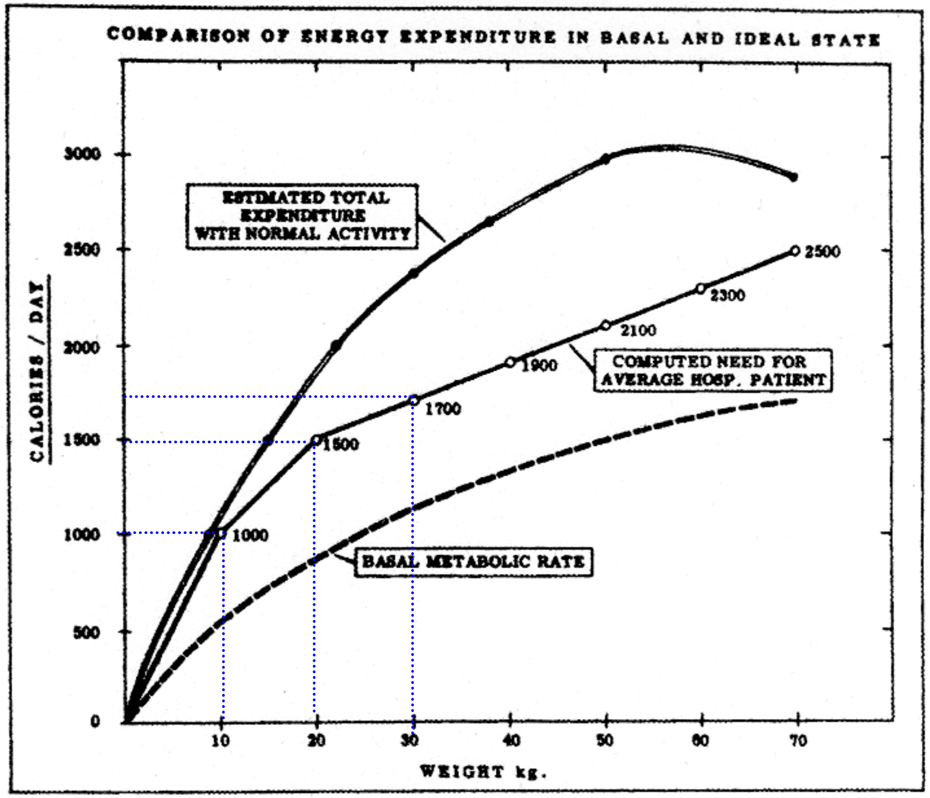




Claude Bernard, 1813- 1878
-Definition „Milieu intérieur“

Walter B. Cannon, 1871- 1945
-Homeostasis in the blood

Water in Parental Fluid Therapy



- <10 kg: 100 kcal/kg/d
- Wasserbedarf 1ml/1kcal
- 100 ml/kg/d

⇒ ≈ 4 ml/kg/h

Intake of Electrolytes Provided per Estimated 100 Calories on Various Regimens

Regimen	mEq/100 cal/day		
	Na	Cl	K
Human milk*	1.0	1.2	2.0
Cow's milk	3.5	4.5	6.0
Recommended†	3.0	2.0	2.0
Recommended (Darrow)	3.0	2.0	3.0
Recommended adult**	3.0	3.0	1.0

⇒ Dosierung: 4- 2- 1- Regel + Infusionslösung: hypoton

Holliday M et al. Pediatrics (1957) 19: 823

MHH Medizinische Hochschule Hannover

Pädiatrische Infusionslösungen

	Plasma	⅔ - EL G-5	½ -EL G-5	⅓ -EL G-5
Kationen				
Na^+	142	100	70	45
K^+	4,5	18	2	25
Ca^{2+}	2,5	2	1,25	
Mg^{2+}	1,25	3	0,5	2,5
Anionen				
Cl^-	103	90	65,5	45
HCO_3^-	24			
Laktat	1,5			
Acetat		38		20
Malat			10	
Glucose	2,78-5	277,5	277,5	277,5
Osmolarität[1]	291	529 (251*)	428 (151*)	425,5 (148*)

⇒ In vitro: hyperton, in vivo: hypoton

[1]theor. Osmolarität = ∑ Kationen + Anionen (mosmol/l); *ohne Glucose

Editorial

Postoperative hyponatraemic encephalopathy following elective surgery in children

ALLEN I. ARIEFF MD

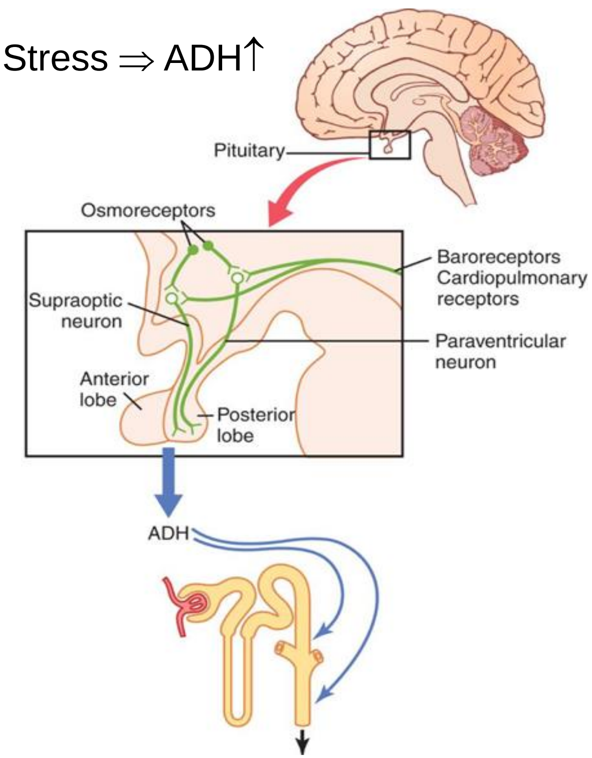
Department of Medicine, University of California School of Medicine, San Francisco, CA, USA

Introduction

In the United States, there are an estimated 15,000 deaths per year as a consequence of postoperative hyponatraemia…

brain damage…primarily affects menstruant women and prepubertal children…

Stress ⇒ ADH↑



H_2O- + Na^+- Retention

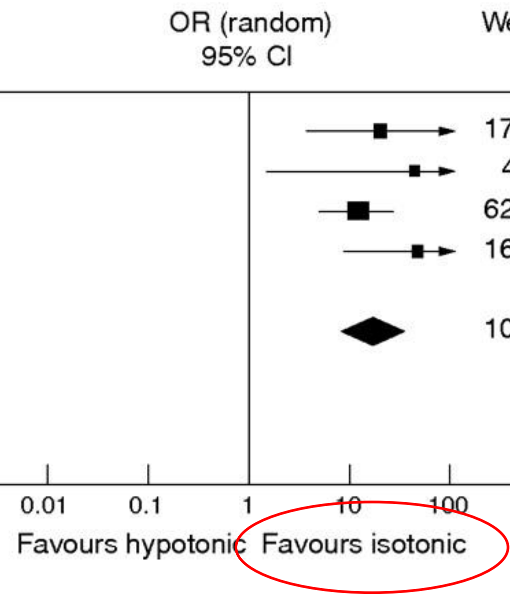
Meta- analysis iv fluids in children:

-hypotonic vs. isotonic-

Review: Hypotonic versus isotonic IV maintenance fluids in children: Meta-analysis
Comparison: 01 Hypotonic vs isotonic solution
Outcome: 01 Development of hyponatremia

Study or sub-category	Hypotonic n/N	Isotonic n/N	Weight %	OR (random) 95% CI
Neville	21/31	2/21	17.51	19.95 (3.87, 102.86)
Brazel	7/7	1/5	4.06	45.00 (1.49, 1358.27)
Hoorn	28/53	9/105	62.15	11.95 (5.00, 28.53)
Wilkinson	20/26	2/30	16.29	46.67 (8.52, 255.47)
Total (95% CI)	117	161	100.0	17.22 (8.67, 34.20)

Total events: 76 (hypotonic), 14 (isotonic)
Test for heterogeneity: $\chi^2 = 2.35$, df = 3 (p = 0.50), $I^2 = 0\%$
Test for overall effect: Z = 8.13 ($p < 0.00001$)



Isotonic solutions ⇒ Hyponatremia↓

NHS
National Patient Safety Agency

Patient safety alert 22

Alert

28 March 2007

Reducing the risk of hyponatraemia when administering intravenous infusions to children

The National Patient Safety Agency (NPSA) is issuing advice to healthcare organisations on how to minimise the risks associated with administering infusions to children.

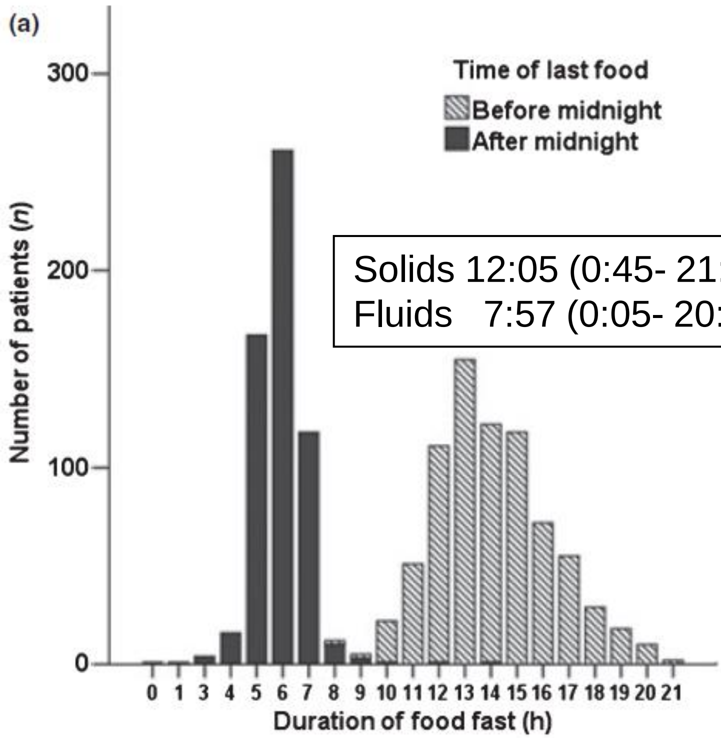
The development of fluid-induced hyponatraemia in the previously well child undergoing elective surgery or with mild illness may not be well recognised by clinicians. To date, the NPSA's National Reporting and Learning System (NRLS) has received only one incident report (that resulted in no harm), but it is likely that incidents have gone unreported in the UK.

Since 2000, there have been four child deaths (and one near miss) following neurological injury from hospital-acquired hyponatraemia (see definition on page 7) reported in the UK.[1-3] International literature cites more than 50 cases of serious injury or child death from the same cause, and associated with the administration of hypotonic infusions.[4]

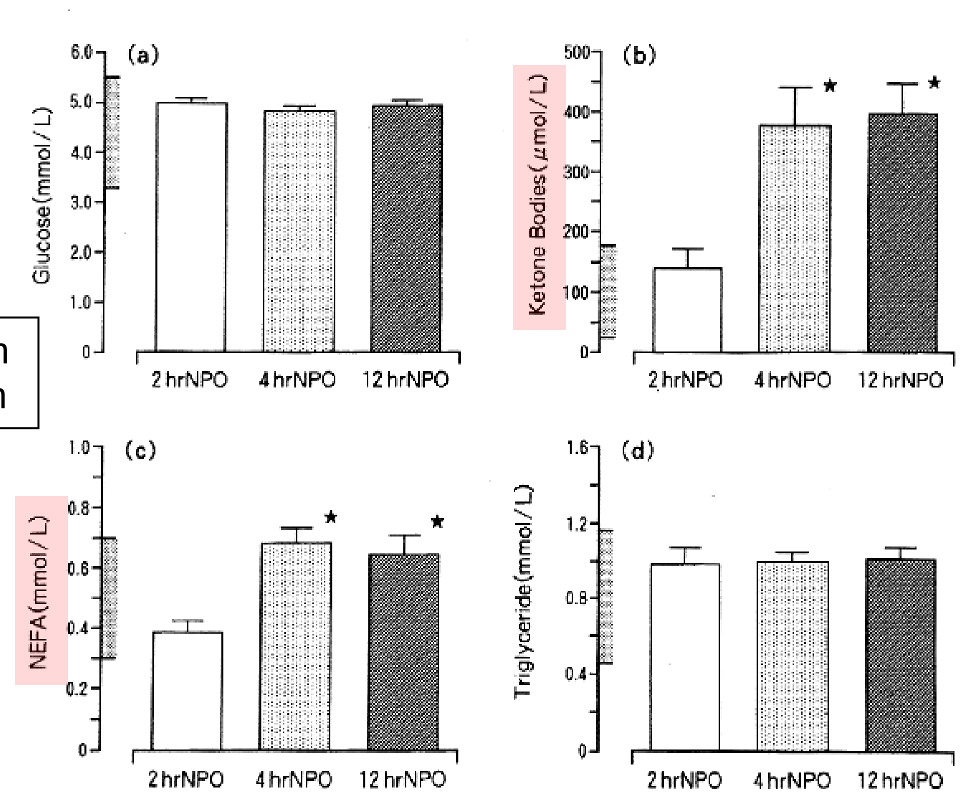
Further information on the action points

1 Remove sodium chloride 0.18% with glucose 4% intravenous infusions from stock and general use in areas that treat children. Suitable alternatives must be

Nüchternzeiten und Stoffwechsel



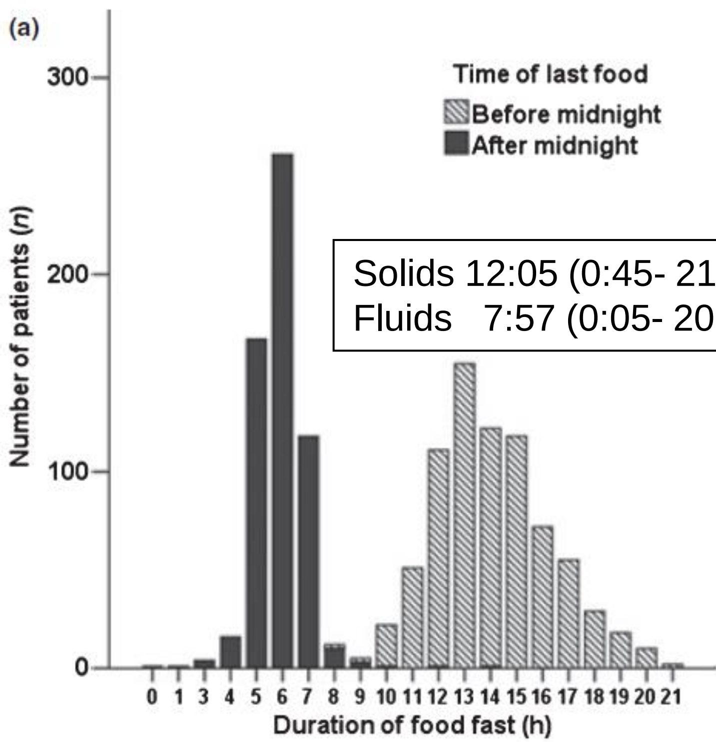
Solids 12:05 (0:45- 21:50) h
Fluids 7:57 (0:05- 20:50) h



Nüchternzeit > 2h ⇒ Ketoazidose↑

Engelhardt T et al. Paediatr Anaesth 2011; 21: 964
Maekawa N et al. Acta Anaestesiol Scand 1993; 37: 783

Nüchternzeiten und Stoffwechsel



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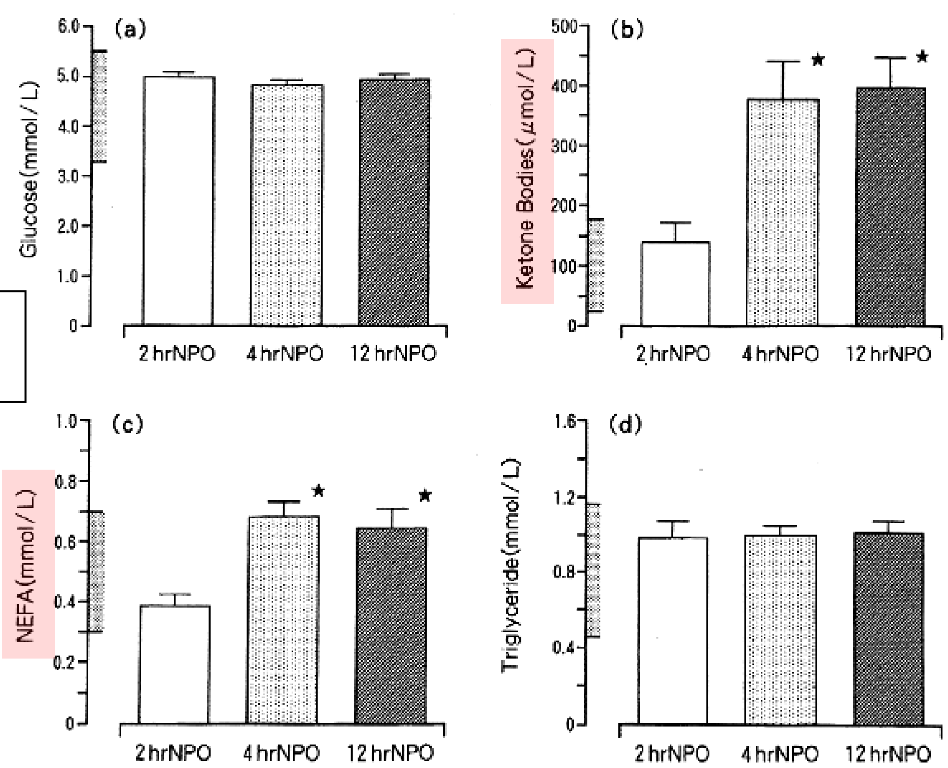
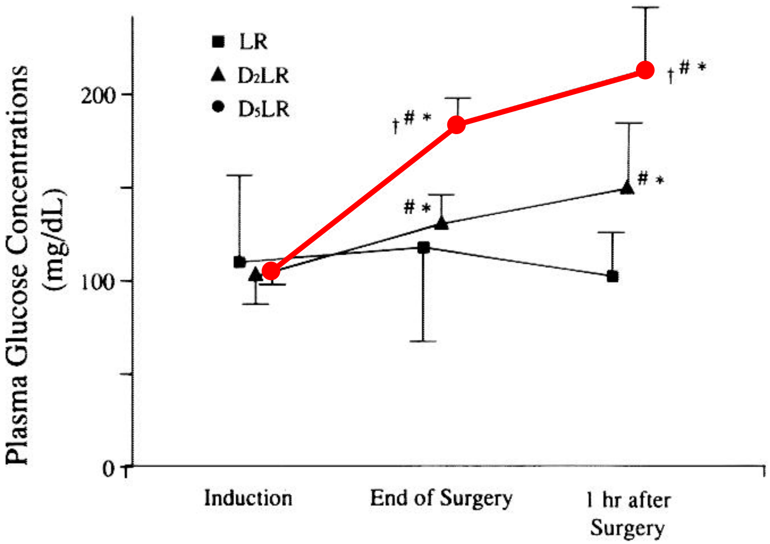
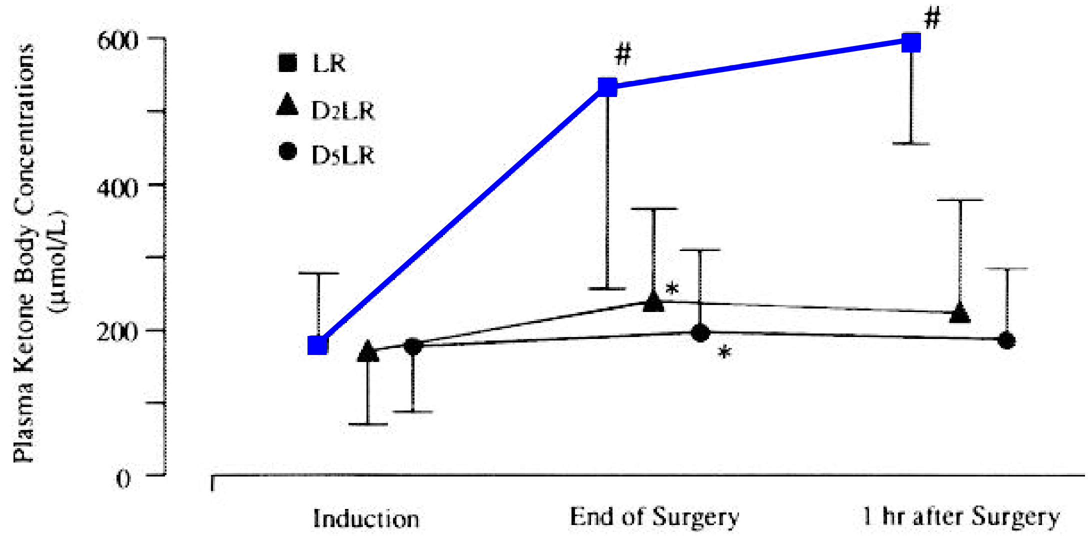


Nüchternzeiten↓ ⇒ Milch 4h + Apfelsaft 2h

Perioperative Glucose Supply





RL + G 5 % ⇒ Hyperglycemia
RL ⇒ Cataboly
RL + G 2 % ⇒ Normoglycemia

Alter↓ + OP- Dauer↑ ⇒ BEL- Glc1% (Glc 5- 10 mmol/l)

Isotonic Solutions + 1- 2.5% Glucose

	Plasma	Polionique*	RL-Glc#	ELO-PAED	E148G1#
Cations					
Na^+	142	120	131	142	140
K^+	4,5	4,2	4	4	4
Ca^{2+}	2,5	2,8	3	1	2
Mg^{2+}	1,25			1	2
Anions					
Cl^-	103	108,3	110	126	118
HCO_3^-	24				
Lactate	1,5	20,7	28		
Acetate				24	30
Malate					
Glucose	2,78-5	50,5	55,5	55,5	55,5
Osmolarity[1]	291	309 (258*)	331,5 (276*)	355,5 (300*)	352 (296*)
Osmolality[2]	287	286 (239*)	308,5 (256*)	329 (277*)	326 (274*)

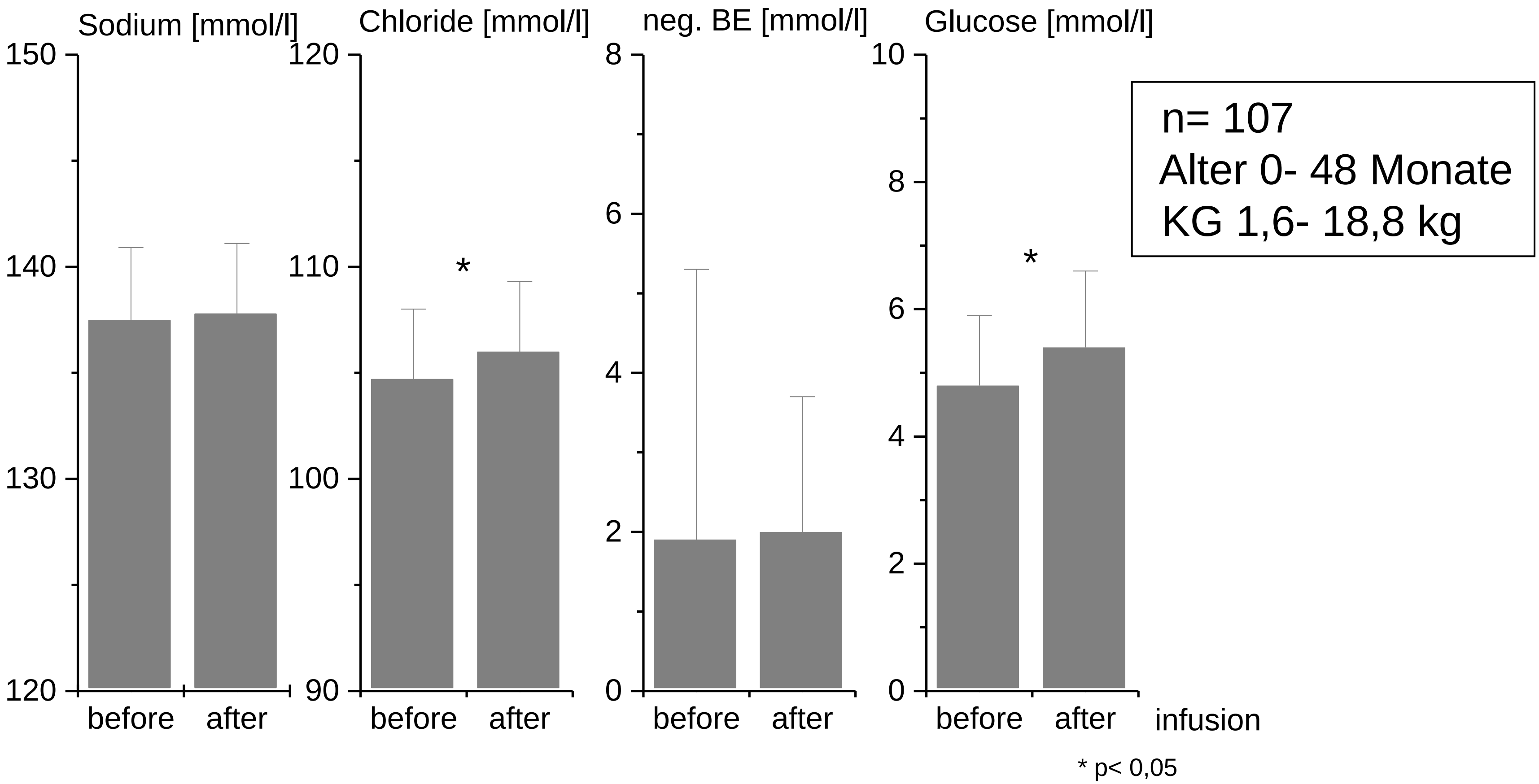
[1]theor. (mosmol/l), [2]real (mosmol/kg H_2O)

*without Glucose

#mit nationaler Zulassung

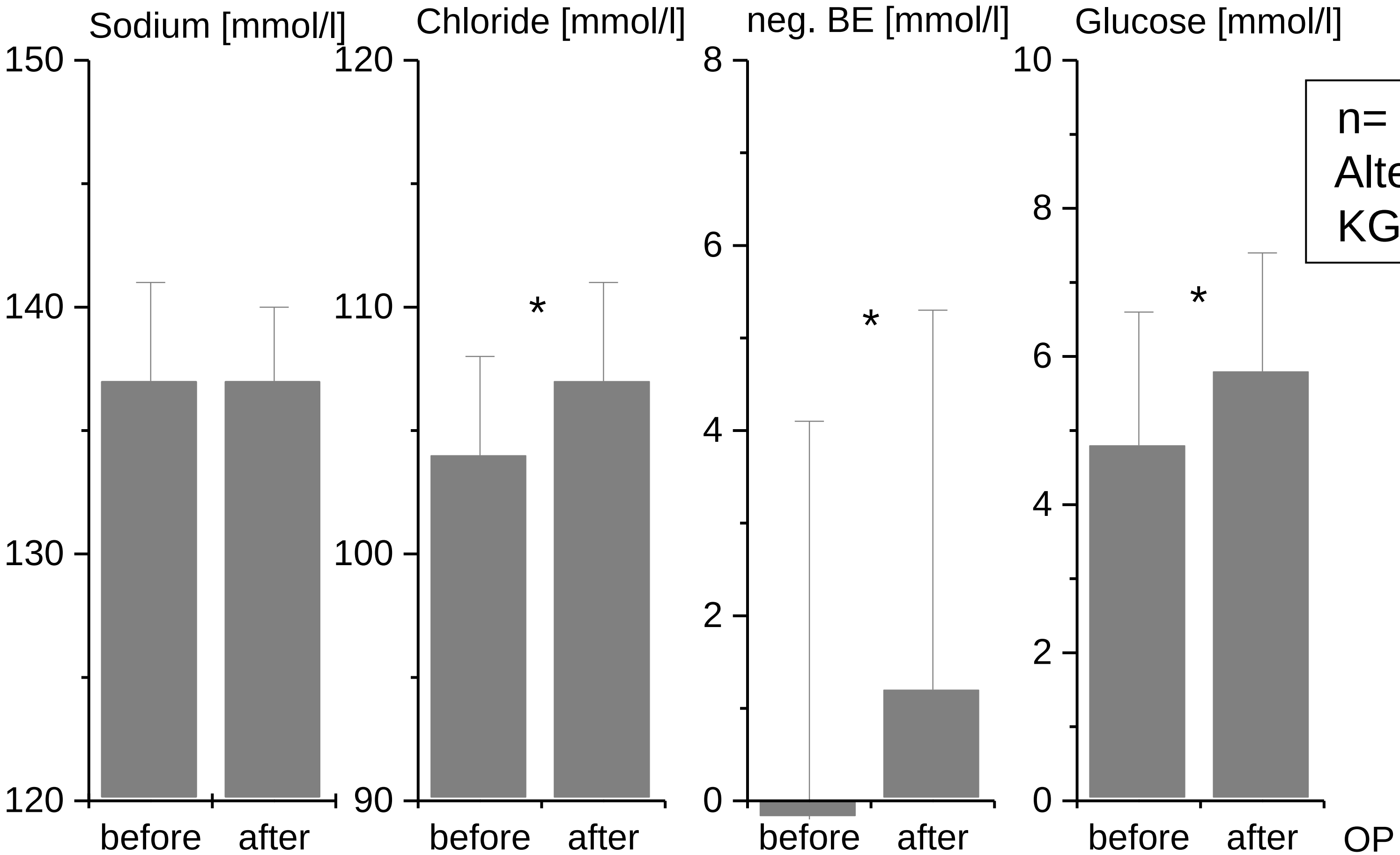
Pfenninger J, Paediatr Anaesth 1992; 2: 86
*Berleur MP, J Clin Pharm Ther 2003; 28: 31

A novel isotonic balanced electrolyte solution with 1% glucose for intraoperative fluid therapy in children



Infusionsrate10 ml/kg/h ⇒ SBEH + KH- Stoffwechsel stabil

A novel isotonic balanced electrolyte solution with 1% glucose for intraoperative fluid therapy in neonates

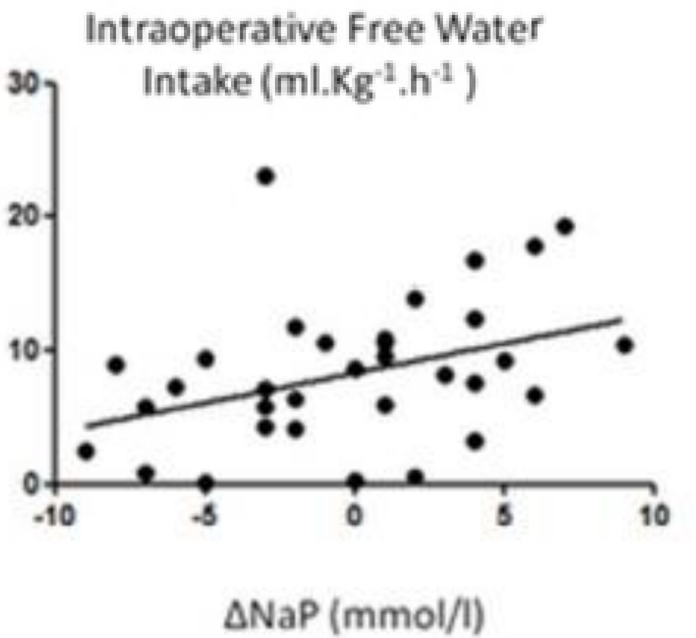


n= 66
Alter 0- 1 Monat
KG 0,65- 4,6 kg

Infusionsrate 10 ml/kg/h ⇒ SBEH + KH- Stoffwechsel stabil

Decreases in plasma sodium concentration following the infusion of hypotonic fluids during neonatal surgery

- 34 Neugeborene
- 11,9% postop. Hyponatriämie
- Korr. freie Wasserzufuhr + Δ NaP
- > 6,5 ml/kg freies Wasser
  ⇒ Δ NaP ≥ 4 mmol/l



The routine use of hypotonic solutions during neonatal surgery should be questioned

Effect of intravenous fluid therapy on postoperative vomiting in children undergoing tonsillectomy

n=100, Alter 1-12 Jahre, 10 ml/kg/h vs. 30 ml/kg/h RL

Table 4 Multivariable logistic regression analysis, composite outcome retching, vomiting or both (0–24 h). OR, odds ratio; CI, confidence interval; PACU, post-anaesthetic care unit; POV, postoperative retching, vomiting or both. *Variables age, gender, and weight did not significantly improve the model fit. Hosmer and Lemeshow's goodness-of-fit test P=0.53. †Reference group is Group 2 (30 ml kg^{-1})

	Unadjusted		Adjusted	
	OR (95% CI)	*P*-value	OR (95% CI)	*P*-value
Model POV (*n*=100)*				
Group 1 (10 ml kg^{-1} h^{-1})†	2.79 (1.11, 7.01)	0.029	2.92 (1.14, 7.51)	0.026
Morphine given in the PACU (1 mg)			1.15 (1.00, 1.33)	0.056

-30 ml/kg/h RL significantly reduced POV 24 h postoperatively
-superhydration is an alternative way to reduce the risk of POV

Fluid overload is associated with impaired oxygenation and morbidity in critically ill children

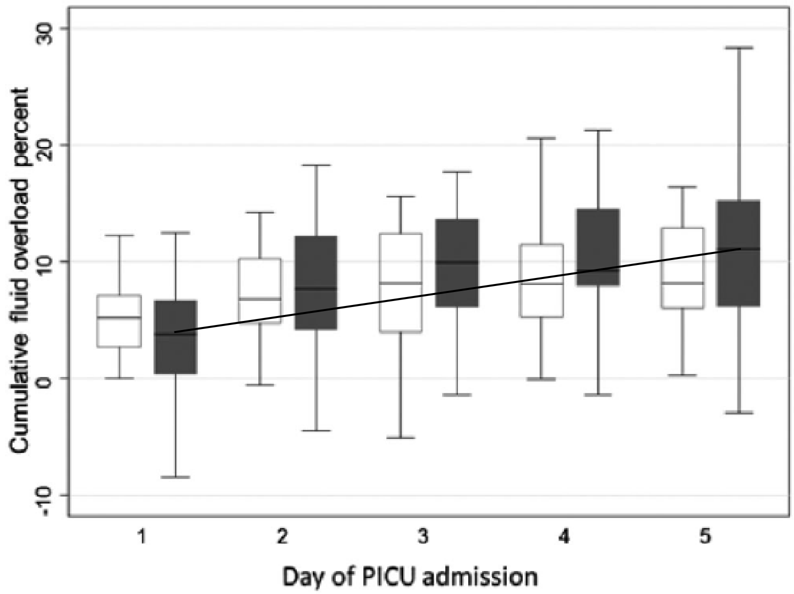


Table 3. Relationship between total fluid overload percent and oxygenation index

Total Fluid Overload %	Regression Coefficient	p
2.5%	0.05	.76
5%	0.05	.92
7.5%	0.05	.56
10%	0.08	.38
12.5%	0.10	.16
15%	0.12	.004
17.5%	0.20	<.001
20%	0.31	<.001

„…liberal fluid resuscitation need to be shifted to the goal of maintaining euvolemia once hemodynamic stability is achieved."

Hypotone vs. isotone Erhaltungsinfusion nach Operationen bei Kindern

- n= 258
- Alter 0,5- 16 J
- Erhaltungsinfusion
- NaCl 0,45 vs. 0,9%

TABLE 2 Primary and Key Secondary Outcomes

	Isotonic PMS	Hypotonic PMS	RR (95% CI)	*P*
Intention-to-treat analysis after 10 imputations, *N*	128	130	—	—
Hyponatremia, *n* (%)	29 (22.7)	53 (40.8)	1.82 (1.21–2.74)	.004
Severe hyponatremia, *n* (%)	1 (0.8)	8 (6.2)	7.21 (0.93–55.83)	.059
Hypernatremia, *n* (%)	4 (3.1)	5 (3.9)	1.30 (0.30–5.59)	.722
Sensitivity analysis using complete data only, *N*	106	112	—	—
Hyponatremia, *n* (%)	26 (24.5)	47 (42.0)	1.78 (1.18–2.69)	.006
Severe hyponatremia, *n* (%)	1 (0.9)	7 (6.3)	6.63 (0.83–52.93)	.075
Hypernatremia, *n* (%)	3 (2.8)	4 (3.3)	1.26 (0.29–5.51)	.757

⇒ - NaCl 0,45% → Hyponatriämierisiko↑ (40,8% vs. 22,7%)

- NaCl 0,9% → Hypernatriämierisiko nicht verschieden

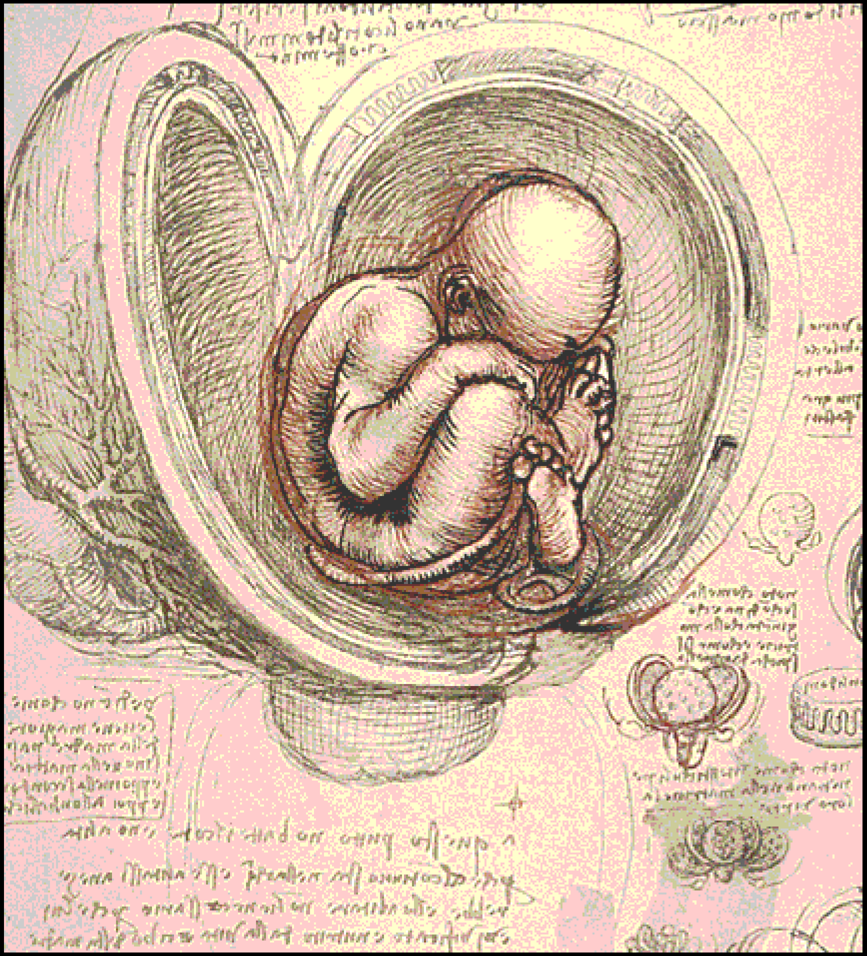
- ADH und Inzidenz unerwünschter Ereignisse gleich

Postoperativ höhere Sicherheit mit isotonen Lösungen

Choong K et al. Pediatrics 2011; 128: 857

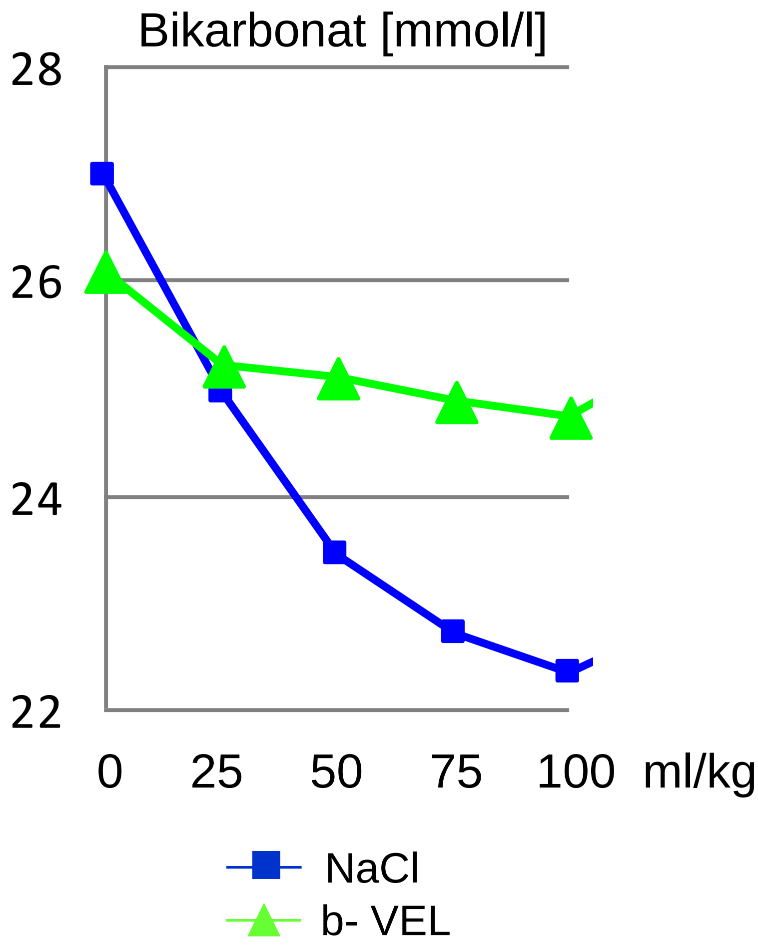
Flüssigkeitstherapie: Simple and Safe!

- Nüchternzeiten kurz halten: Milch 4h, A‘saft 2h
- balancierte Lösungen (möglichst wie EZF)
- Alter↓ + OP↑ ⇒ Zusatz Glucose 1- 2%
  ⇒ Ziel: Glucose 5- 10 mmol/l + Katabolie↓
- Basisinfusionsrate intraop. z.B. 10 ml/kg/h
  + Bolus 10 ml/kg bei Bedarf
- Perfusor, Infusomat, 250 ml Flaschen
- postoperativ balancierte Lösung + Glucose 5%
- oder: schneller Flüssigkeits- und Kostaufbau



Keep
It
Safe and
Simple

Bikarbonatvorstufe vs. NaCl 0,9%



Infusion von NaCl 0,9% (bikarbonatfrei)

⇒

EZR: HCO_3^- wird verdünnt

+

pCO_2 bleibt konstant

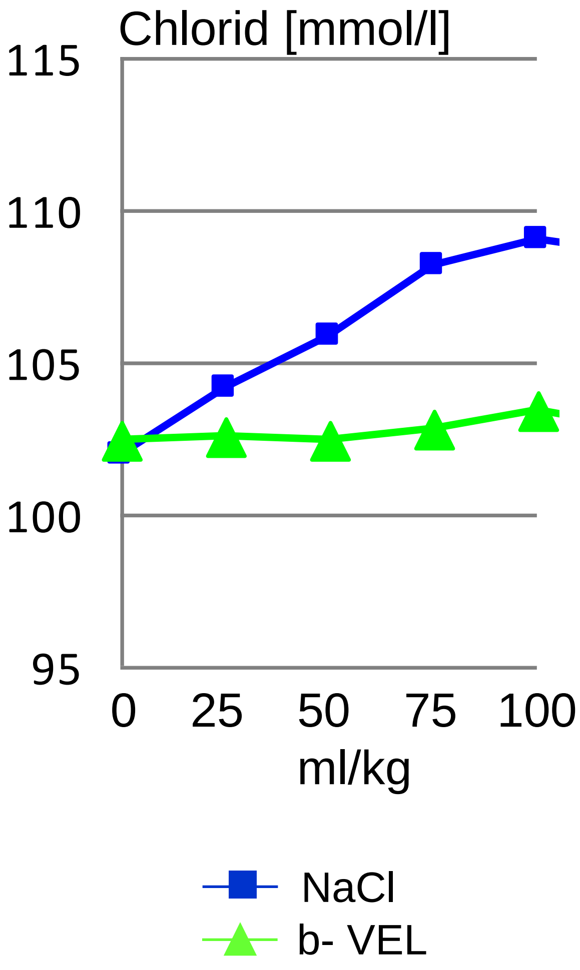
⇒

pH ↓

= Dilutionsazidose

*b-VEL- balancierte Vollelektrolyt- Lösung
Witt L et al. Pediatr Anesth 2010; 20: 734

Hyperchlorämische Azidose



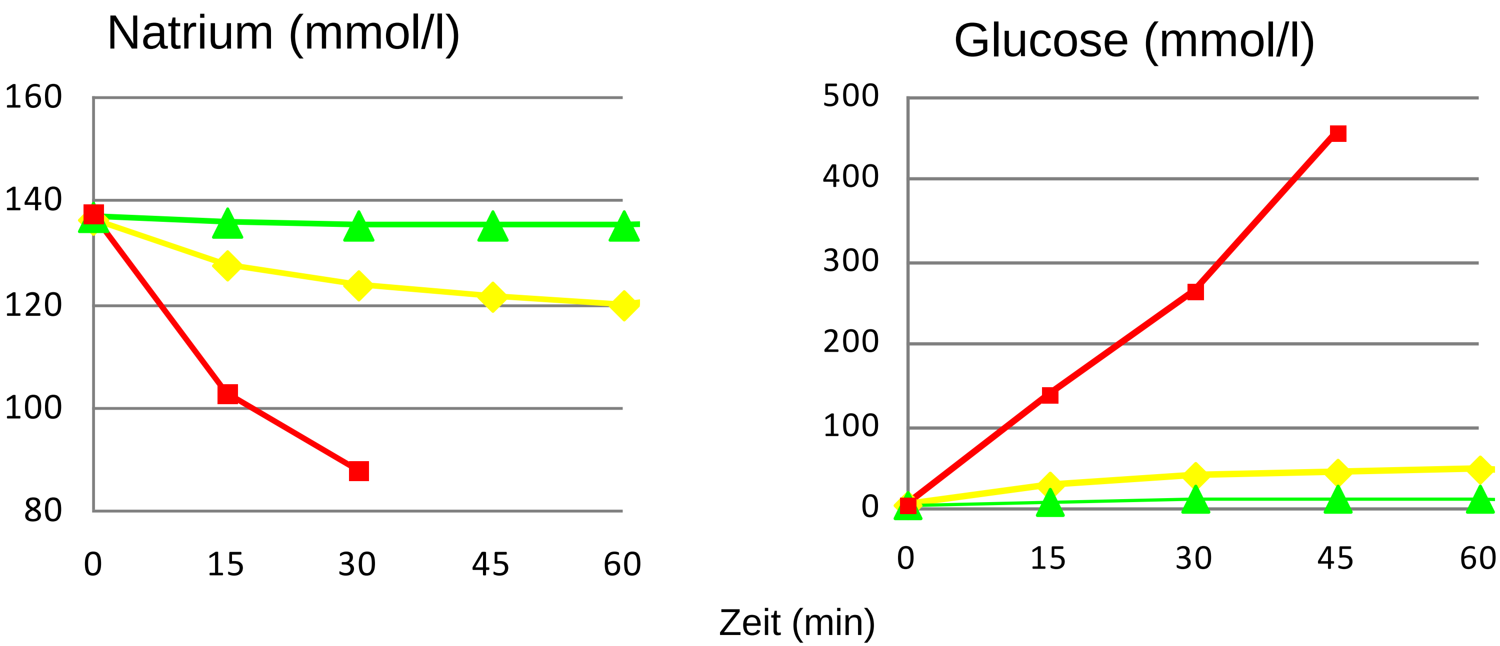
- renaler Gefäßwiderstand ↑
- GFR ↓
- Plasma-Renin-Aktivität ↓
- Diurese ↓
- Kaliumverschiebung ↑
- Blutgerinnung ↓
- Übelkeit, Erbrechen↑

Literatur (Tierexperimente + Probanden):

Kotchen TA et al.: Ann Intern Med 1983; 98: 817-822; Wilcox CS: J Clin Invest 1983; 71: 726-735; Wilcox CS et al.: Am J Physiol 1987; 253: F734-F741; Quilley CP et al.: Br J Pharmacol 1993; 108: 106-110; Kellum JA: Crit Care Med 2002;30:259-261; Reid F et al.: Clin Sci 2003; 104: 17-24;
Roche AM et al.: Anesth Analg 2006;102: 1274

*b- VEL- balancierte Vollelektrolyt- Lösung
Witt L et al. Pediatr Anesth 2010; 20: 734

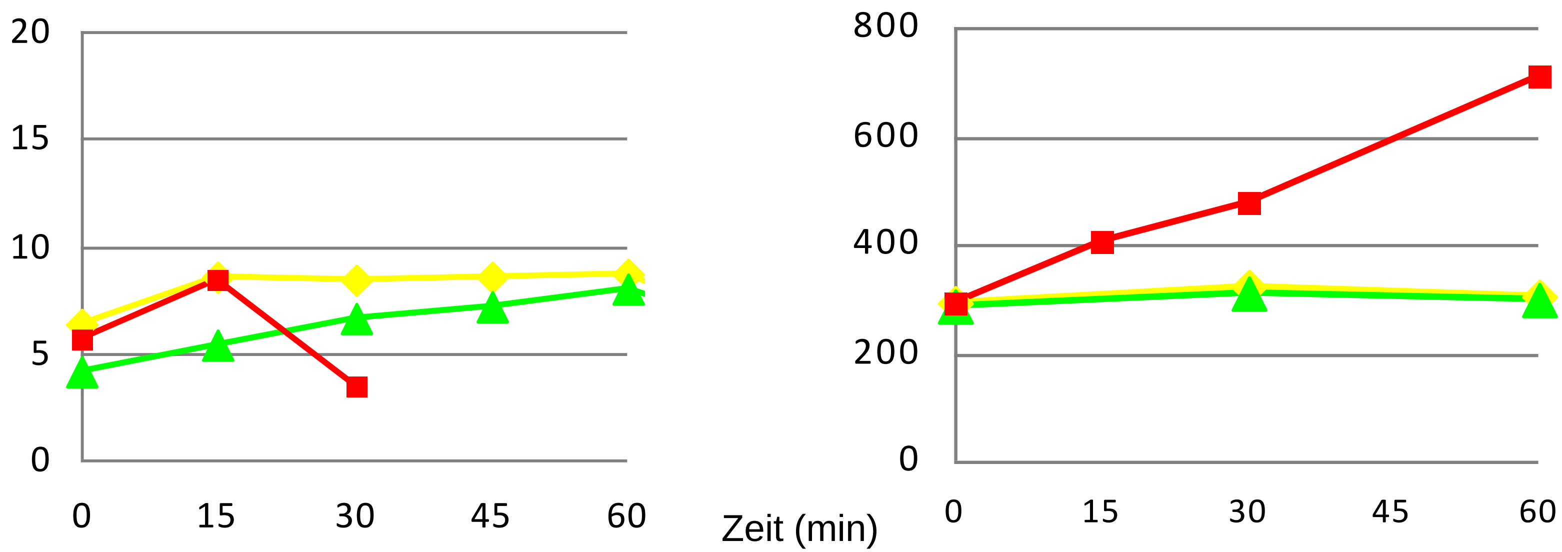
Infusionsversuch Glucose



- b- VEL- Glc 1% → Natrium + Glucose stabil
- ½ EL- Glc 5% → Natrium↓ + Glucose↑
- Glucose 40% → Natrium↓↓↓ + Glucose↑↑↑

Infusionsversuch Glucose

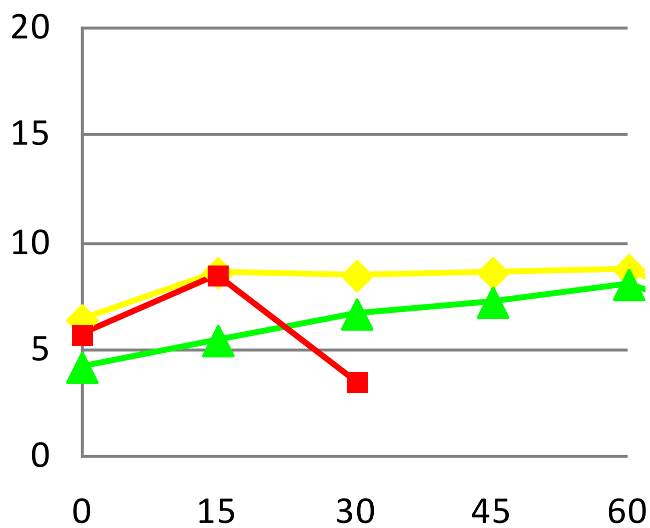
intrakranieller Druck (mmHg)   Osmolarität (mosmol/kg H_2O)



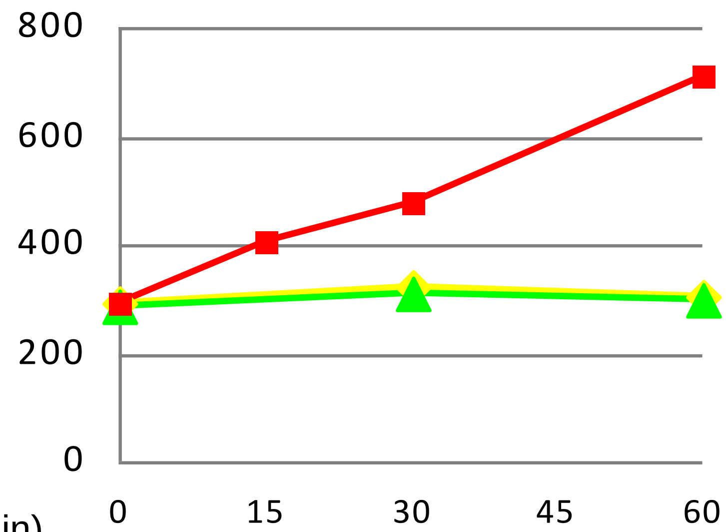
- VEL- Glc 1% → ICP + Osmolarität stabil
- ½ EL- Glc 5% → ICP + Osmolarität stabil
- Glucose 40% → ICP↓ + Osmolarität↑↑↑

Infusionsversuch Glucose

intrakranieller Druck (mmHg)



Osmolarität (mosmol/kg H_2O)



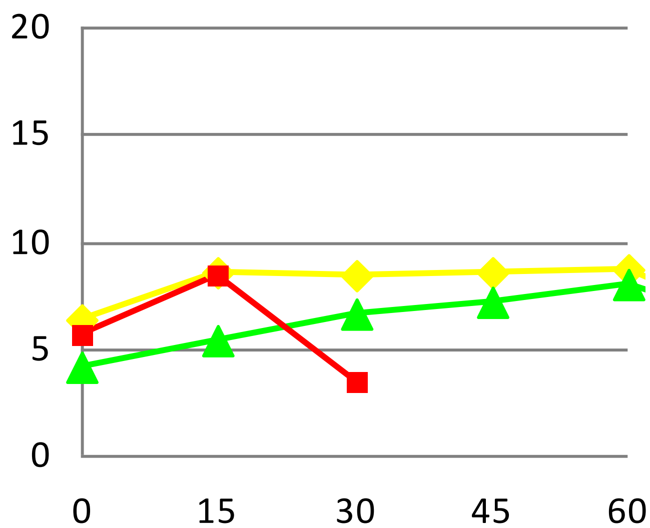
Zeit (min)

Therapeutische Breite:

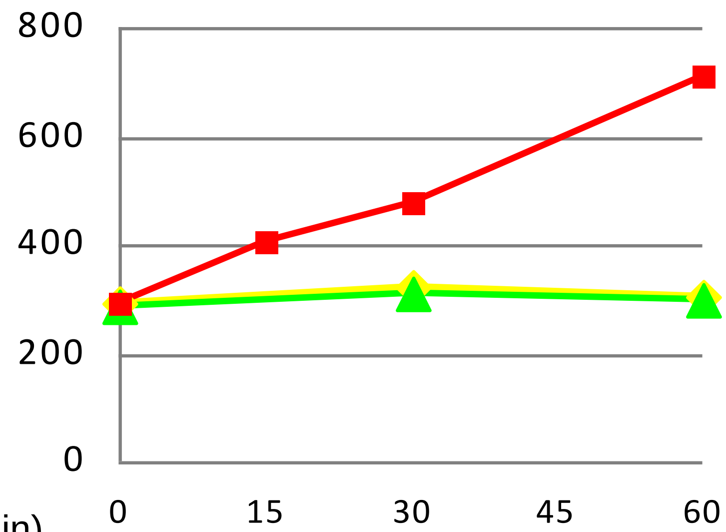
1. b- VEL- Glc 1%
2. ½ EL- Glc 5%
3. Glucose 40%

Infusionsversuch Glucose

intrakranieller Druck (mmHg)



Osmolarität (mosmol/kg H_2O)



Zeit (min)

Therapeutische Breite: 1. b- VEL- Glc 1%

~~2. ½ EL- Glc 5%~~

~~3. Glucose 40%~~

Viewpoint

THE LANCET

Intravenous fluids for seriously ill children: time to reconsider

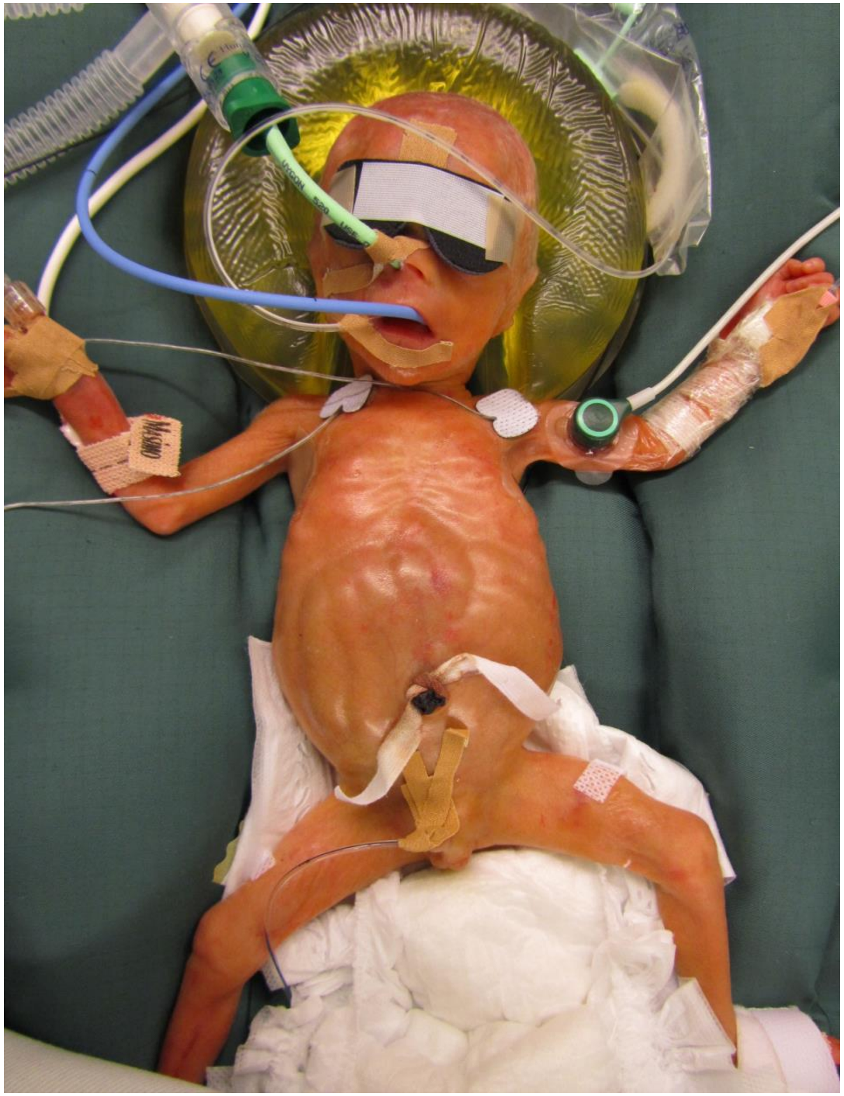
Trevor Duke
Elizabeth M Molyneux

Fluid	Volume (mL/kg/day)	Volume per day (mL)	Urine output (mL)	Insensible losses (mL)	Total output (mL)	Total net water added (ICF/ECF) (mL)	Na+ added (mmol)	24-h serum [Na]*
0·18% saline	100	600	210	180	390	210 (84/126)	7·2	130·6
0·9% saline	75	450	210	180	390	60 (0/60)	13·5	137·5

Total body water=70% of bodyweight (35% ECF, 35% ICF. ICF=intracellular fluid. ECF=extracellular fluid. Free-water excretion reduced by 50% normal (urine volume from 70–35 mL/kg/day) due to increased activity antidiuretic hormone. Starting serum [Na] 135 mmoL/L; total ECF Na=0·35×6×135=283·5 mmol.
*24-h serum [Na]=(pre-existing ECF [Na]+[Na] added)/(pre-existing ECF+ECF added).

„Isotonic saline results in a lower frequency of adverse neurological events than do hypotonic solutions.“

FG, 800 g, Ileus, NaCl 0,9%



SAEURE-BASE	37.0	°C
pH	7.260↓	
pCO_2	28.7↓	mmHg
pO_2	70.5↓	mmHg
HCO_3^-act	12.6	mmol/L
HCO_3^-std	14.4	mmol/L
BE(B)	-13.0	mmol/L
BE(ecf)	-14.5	mmol/L
$ctCO_2$	13.5	mmol/L
CO-OXYMETRIE		
Hct	37	%
tHb	12.7	g/dL
sO_2	97.6	%
FO_2Hb	96.7	%
FCOHb	0.3↓	%
FMetHb	0.6	%
FHHb	2.4	%
SAUERSTOFFSTATUS	37.0	°C
BO_2	17.5	mL/dL
O_2CT	16.5	mL/dL
ELEKTROLYTE		
Na^+	147.5	mmol/L
K^+	3.34↓	mmol/L
Ca^{++}	1.22	mmol/L
Cl^-	128↑	mmol/L
AnGap	10.3	mmol/L
METABOLITE		
Glu	10.8↑	mmol/L
Lac	3.60↑	mmol/L

SPECIAL ARTICLE

European consensus statement for intraoperative fluid therapy in children

Robert Sümpelmann, Karin Becke, Peter Crean, Martin Jöhr, Per-Arne Lönnqvist, Jochen M. Strauss and Francis Veyckemans

Balancierte Lösungen in der Kinderanästhesie:

- physiologische Osmolarität + Natrium Konzentration
  - ⇒ Hyponatriämie↓
- Metabolische Anionen (Azetat, Laktat, Malat)
  - ⇒ Stabilität Säure- Basen- Haushalt↑
- Zusatz von 1- 2.5% Glucose
  - ⇒ Hypoglykämie↓, Lipolyse↓, Hyperglykämie↓

List of consensus supporters:

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Postop: Isotone Lösungen mit Glucose 5%

	Plasma	Ionosteril® D5	E153® G5	Sterofundin® VG-5
Kationen				
Na^+	142	137	140	140
K^+	4,5	4	5	4
Ca^{2+}	2,5	1,65	2,5	2,5
Mg^{2+}	1,25	1,25	1,5	1,0
Anionen				
Cl^-	103	147	103	141
HCO_3^-	24			
Laktat	1,5			
Acetat	-		50	
Malat	-			10
Gluconat	-			
Proteinat	20			
Glucose	2,78- 5	277,5	277,5	277,5

Neville KA et al. J Pediatr 2010; 156: 313
Rote Liste 2010