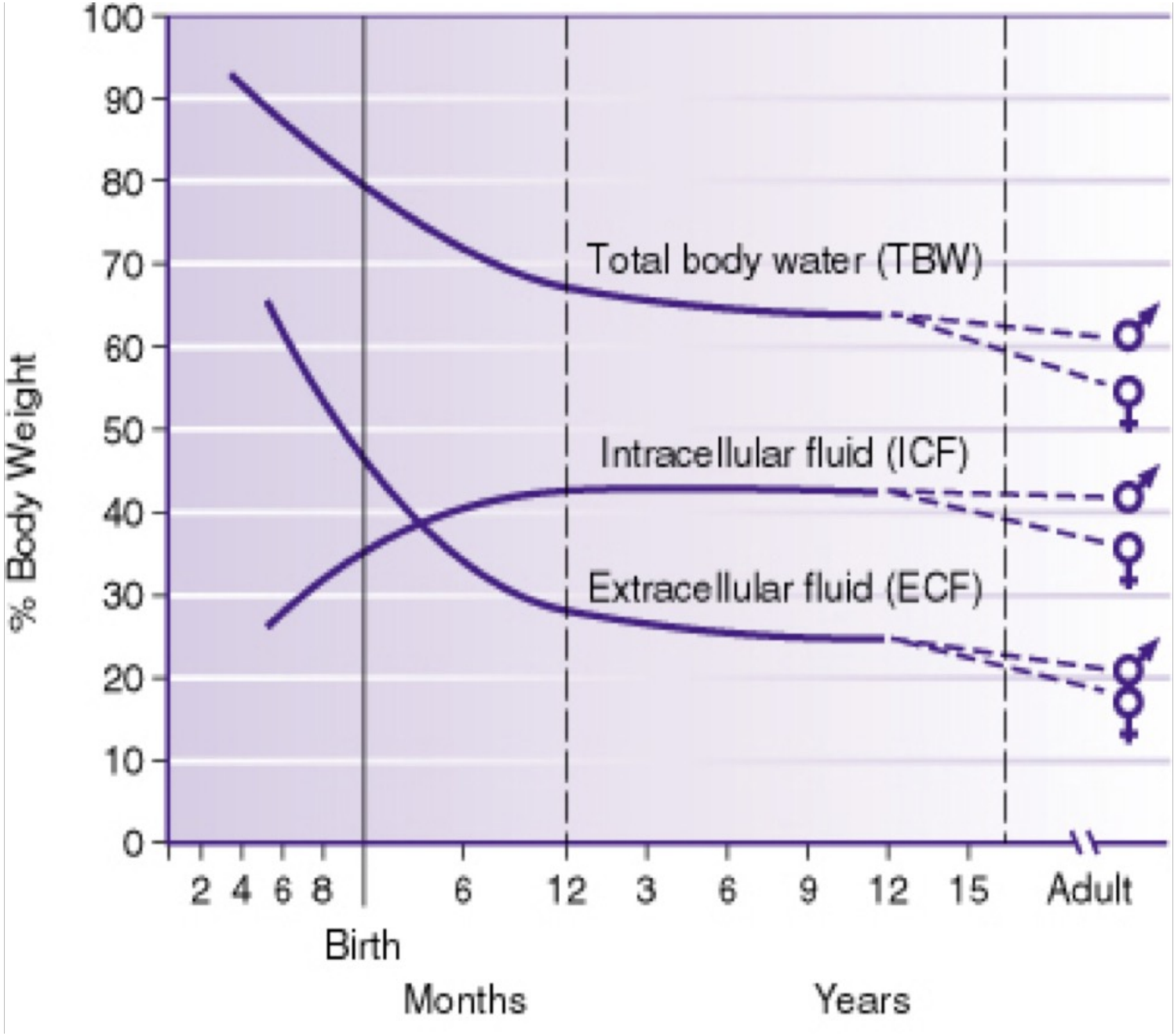
Fluid balance and nutrition in the PICU

Urban Fläring M.D. Ph.D. Associate Professor
Department of Pediatric Perioperative Medicine and Intensive Care
Astrid Lindgren Children's Hospital at Karolinska University Hospital
Stockholm
Sweden


100
90
80
70
60
50
40
30
20
10
0
% Body Weight
Total body water (TBW)
Intracellular fluid (ICF)
Extracellular fluid (ECF)
2 4 6 8
6
12
3
6
9
12
15
Adult
Birth
Months
Years

Första levnadsveckan:

Fysiologi skiljer sig från äldre barn

- Volym. Om endast intravenöst är möjligt: börja med 60-80 ml/kg/dygn. Öka under en vecka till max 120 ml/kg/dygn (givet att barnet är under återhämtning). Om enteral tillförsel är möjligt kan ev. större volym ges.

- **Natrium-**tillsats i glukosinfusion skall i normalfallet inte överstiga 40 mmol/1000 ml, oftast räcker 20.

Nyfödda tolererar under första levnadsveckan normalt endast låg natriumtillförsel och skall helst minska i vikt.

Fluid balance in PICU

Cumulative accumulation of fluid results in fluid overload and if severe, is likely to result in organ dysfunction.

Early achievement of negative fluid balance is associated with an increased survival.

Intensive Care Med (2015) 41:1445–1453
DOI 10.1007/s00134-015-3851-9

ORIGINAL

Priya Bhaskar
Archana V. Dhar
Marita Thompson
Raymond Quigley
Vinai Modem

Early fluid accumulation in children with shock and ICU mortality: a matched case–control study

Shock states (n=114). Median age 1.1 year. Total mortality 13%.

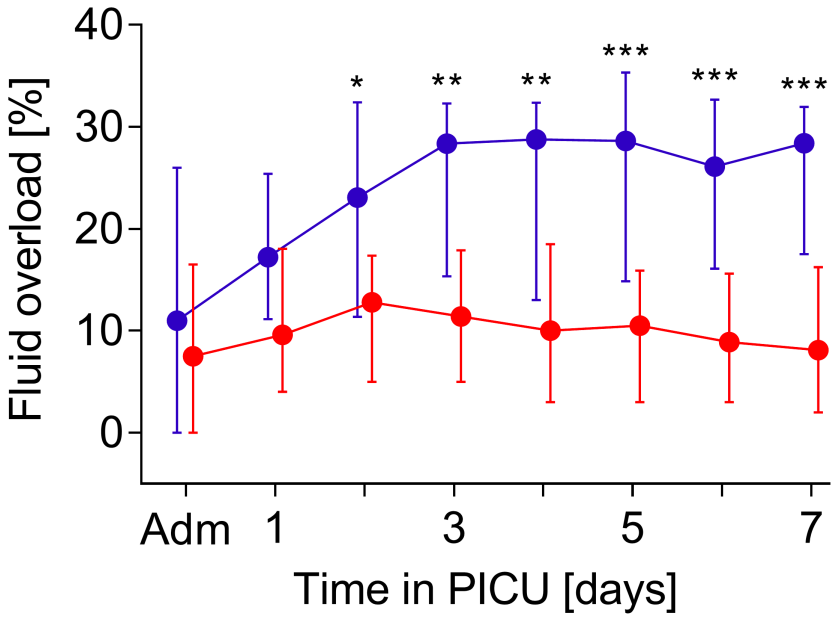
Early fluid overload (EFO) = ≥ 10% within 3 days

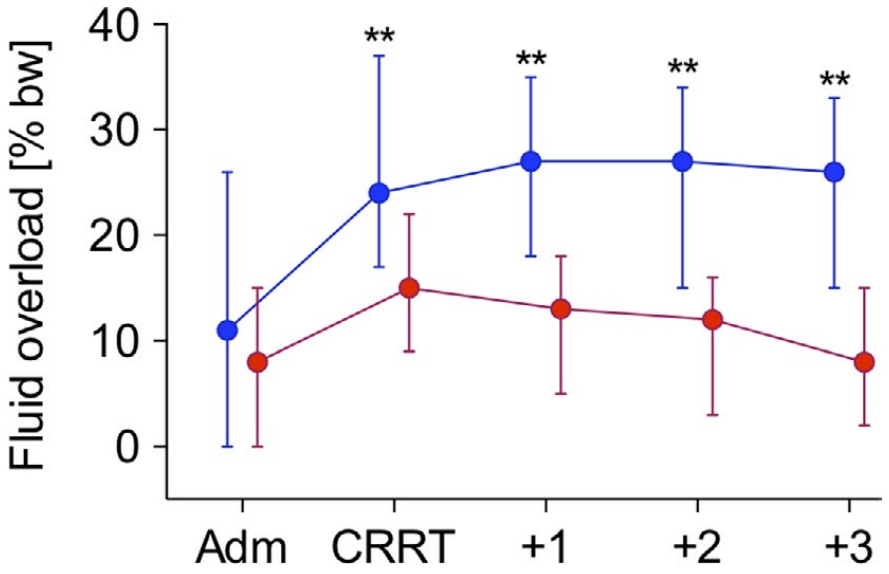
Mortality EFO 26 % vs non-EFO 6 %. (p=0.003)

Predictor variable[a]	Univariable OR (95 % CI)	Multivariable OR[b] (95 % CI)
Early peak cumulative fluid accumulation (initial 3 days)	1.10 (1.05, 1.17)	1.11 (1.05, 1.19)
Peak cumulative fluid accumulation (initial 7 days)	1.09 (1.05, 1.14)	1.13 (1.07, 1.23)
Presence of early fluid overload	6.03 (1.90, 23.16)	9.17 (2.22, 55.57)
Duration of fluid overload	1.49 (1.19, 1.91)	1.61 (1.21, 2.28)

Fluid balance after continuous renal replacement therapy initiation and outcome in paediatric multiple organ failure

Andreas Andersson[1,2] | Åke Norberg[3,4] | Lars Mikael Broman[1,2] | Johan Mårtensson[2] | Urban Fläring[1,2]





JAMA Pediatrics | Original Investigation

Association Between Fluid Balance and Outcomes in Critically Ill Children

A Systematic Review and Meta-analysis

Rashid Alobaidi, MD; Catherine Morgan, MD, MSc; Rajit K. Basu, MD; Erin Stenson, MD; Robin Featherstone, MLIS; Sumit R. Majumdar, MD, MPH; Sean M. Bagshaw, MD, MSc

17 studies. (n=2853)

Fluid overload was associated with increased in-hospital mortality.
OR 4.34 (3.01-6.26)

After adjustment of illness severity: 6% increase in odds of mortality for every 1% increase in fluid overload.
OR 1.06 (1.03-1.10)

Maintenance fluid therapy and fluid creep impose more significant fluid, sodium, and chloride burdens than resuscitation fluids in critically ill patients: a retrospective study in a tertiary mixed ICU population

Niels Van Regenmortel[1,2*], Walter Verbrugghe[1], Ella Roelant[3], Tim Van den Wyngaert[4,5] and Philippe G. Jorens[1,5]

Fluid creep = A hidden and unintentional volume as a vechle for medication and/or electrolytes.

n=14654

All fluid sources in the ICU were quantified, including fluid creep. The volume, sodium and chloride burdens were characterised.

Maintenance fluid 24,7%, Resuscitation fluid 6,5%, Fluid creep 32,6%

Intensive Care Med (2018) 44:409–417

Största volyms-, natrium- och kloridbelastningen kommer från underhållsvätska och Fluid creep

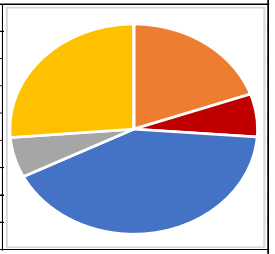
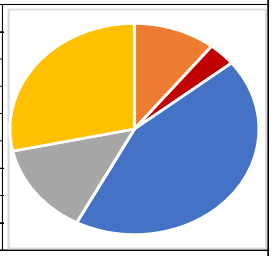
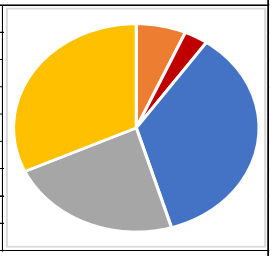
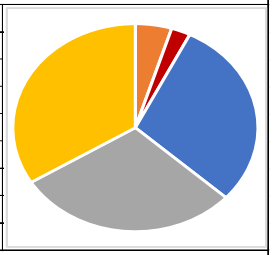
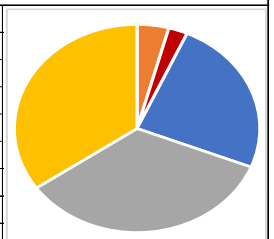
	Medical	Elective Surgery	Emergency Surgery & Trauma	Whole cohort	
First day of admission	n = 7,052	n = 4,396	n = 3,206	n = 14,654	
Resuscitation fluids	21.1%	16.4%	20.6%	19.6%	
Blood products	8.1%	2.8%	8.7%	6.6%	
Maintenance/Replacemen	37.0%	48.9%	40.1%	41.3%	
Nutrition and Oral fluids	7.7%	4.4%	5.4%	6.2%	
Fluid creep	26.0%	27.4%	25.2%	26.3%	
Total mean daily fluid volume	1,682 ± 1,365	1,771 ± 849	1,824 ± 1,544	1,739 ± 1,280	
Mean cumulative fluid balance	437 ± 1,524	219 ± 1,035	520 ± 1,531	390 ± 1,402	
Mean duration of ICU-day[a]	14.3 ± 5.3	16.6 ± 3.2	13.4 ± 5.3	14.8 ± 4.9	
Second day of admission	n = 6,834	n = 4,290	n = 3,130	n = 14,254	
Resuscitation fluids	10.7%	10.7%	10.5%	10.6%	
Blood products	4.2%	1.9%	4.2%	3.6%	
Maintenance/Replacemen	38.8%	49.9%	46.4%	43.4%	
Nutrition and Oral fluids	16.2%	12.2%	11.2%	14,0%	
Fluid creep	30.0%	25.3%	27.7%	28.3%	
Total mean daily fluid volume	2,274 ± 1,504	1,650 ± 1,385	2,628 ± 1,639	2,164 ± 1,544	
Mean cumulative fluid balance	1,020 ± 2,618	758 ± 1,720	1,391 ± 2,412	1,022 ± 2,346	
Mean duration of ICU-day[a]	20.3 ± 7.2	14.4 ± 9.6	20.1 ± 7.4	18.5 ± 8.5	
Third day of admission	n = 5,336	n = 2,106	n = 2,435	n = 9,877	
Resuscitation fluids	6.5%	6.4%	6.8%	6.5%	
Blood products	3.4%	2.4%	3.0%	3.1%	
Maintenance/Replacemen	31.4%	41.1%	40.5%	35.7%	
Nutrition and Oral fluids	25.4%	21.0%	18.8%	22.8%	
Fluid creep	33.4%	29.1%	30.8%	31.9%	
Total mean daily fluid volume	2,172 ± 1,338	1,788 ± 1,311	2,501 ± 1,568	2,171 ± 1,414	
Mean cumulative fluid balance	1,517 ± 3,590	1,709 ± 2,607	2,223 ± 3,310	1,732 ± 3,346	
Mean duration of ICU-day[a]	20.2 ± 7.4	16.5 ± 9.1	20.0 ± 7.4	19.4 ± 7.9	
Fourth day of admission	n = 4,153	n = 1,247	n = 1,878	n = 7,278	
Resuscitation fluids	4.5%	5.3%	5.0%	4.8%	
Blood products	2.8%	2.0%	2.2%	2.5%	
Maintenance/Replacemen	25.9%	32.6%	34.5%	29.4%	
Nutrition and Oral fluids	31.7%	27.9%	25.9%	29.4%	
Fluid creep	32.8%	31.7%	32.4%	33.8%	
Total mean daily fluid volume	2,201 ± 1,256	1,761 ± 1,257	2,536 ± 1,412	2,212 ± 1,322	
Mean cumulative fluid balance	1,922 ± 4,430	2,326 ± 3,395	2,961 ± 4,076	2,259 ± 4,200	
Mean duration of ICU-day[a]	20.8 ± 6.9	16.8 ± 9.1	20.7 ± 7.0	20.1 ± 7.5	
Fifth day of admission	n = 3,368	n = 755	n = 1,520	n = 5,643	
Resuscitation fluids	4.1%	4.3%	4.2%	4.2%	
Blood products	2.9%	1.8%	2.0%	2.5%	
Maintenance/Replacemen	21.2%	26.9%	29.6%	24.4%	
Nutrition and Oral fluids	36.1%	33.5%	30.9%	34.3%	
Fluid creep	35.7%	33.4%	33.3%	34.7%	
Total mean daily fluid volume	2,224 ± 1,222	1,935 ± 1,314	2,563 ± 1,364	2,277 ± 1,289	
Mean cumulative fluid balance	2,216 ± 5,111	2,834 ± 4,147	3,404 ± 4,613	2,619 ± 4,887	
Mean duration of ICU-day[a]	21.1 ± 6.7	18.1 ± 8.6	20.9 ± 6.7	20.6 ± 7.0	

Fig. 2 Day-per-day proportions of the mean volumes of the different fluid types, administered during the first 5 days of ICU stay. [a]First day of admission runs from time of admission until 8:00 AM; day of discharge runs from 8:01 AM until time of discharge

Fluid therapy in mechanically ventilated critically ill children: the sodium, chloride and water burden of fluid creep

Thomas Langer[1,2,3*], Veronica D'Oria[2], Giulia C. I. Spolidoro[4], Giovanna Chidini[2], Stefano Scalia Catenacci[2], Tiziana Marchesi[2], Marta Guerrini[2], Andrea Cislaghi[2], Carlo Agostoni[4,5], Antonio Pesenti[3,6] and Edoardo Calderini[2]

n=43.

Age: ≤ 3 years

Invasively ventilated ≥ 48h.

High sodium and chloride dose (14 mmol/kg/day)

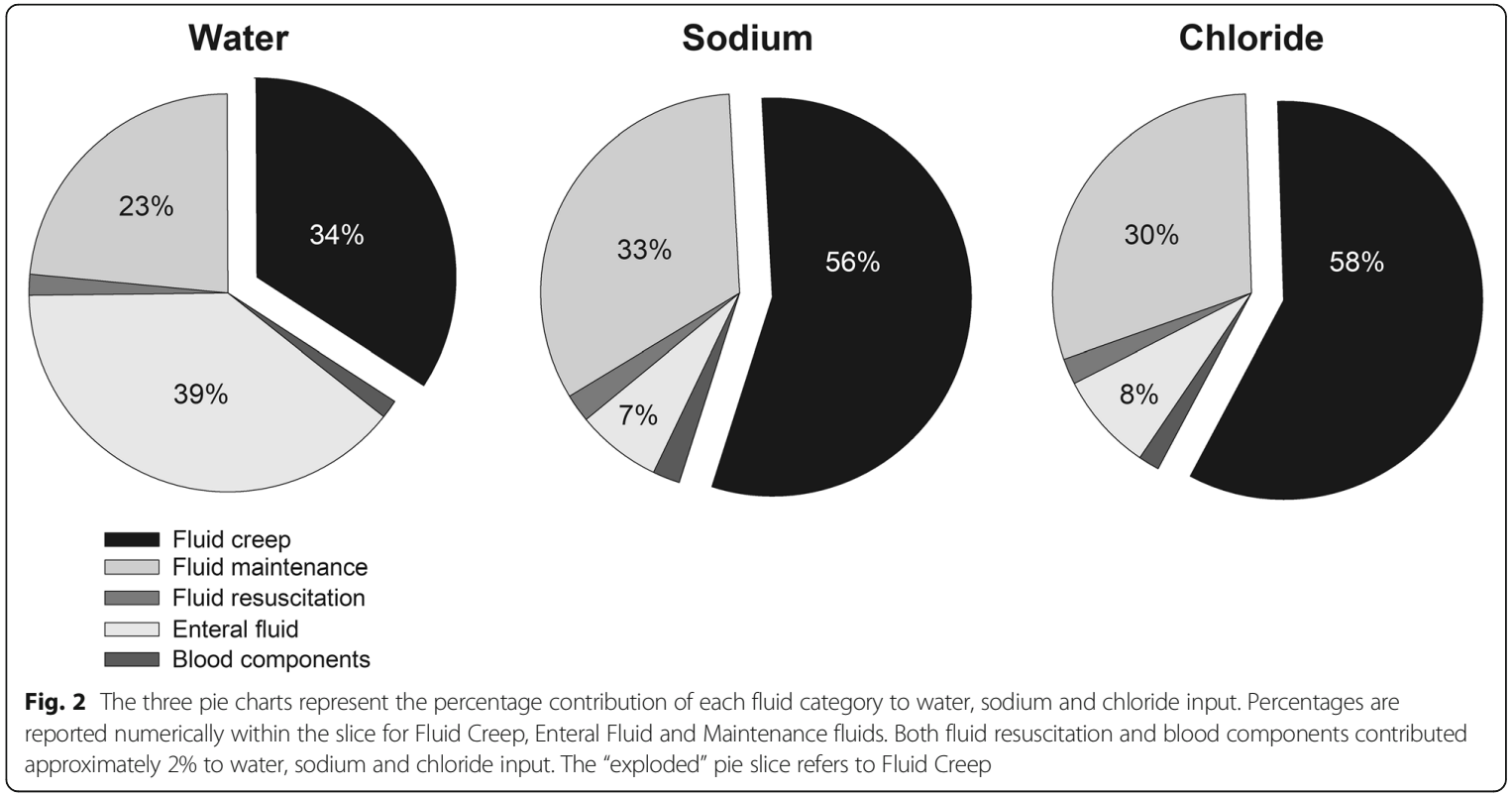


Fig. 2 The three pie charts represent the percentage contribution of each fluid category to water, sodium and chloride input. Percentages are reported numerically within the slice for Fluid Creep, Enteral Fluid and Maintenance fluids. Both fluid resuscitation and blood components contributed approximately 2% to water, sodium and chloride input. The "exploded" pie slice refers to Fluid Creep

Basalt vätskebehov

Vikt	Vätska per dygn	Vätska per timma
2-10 kg	100 ml/kg	4 ml/kg
10-20 kg	1000 ml + 50 ml för varje kg över 10	3-4 ml/kg
> 20 kg	1500 ml + 20 ml/kg för varje kg över 20.	2-3 ml/kg

Spädbarn (0-1 år upp till 10 kg) postoperativt och/eller med invasiv ventilation får oftast 80-100 ml/kg/dygn i total vätska.

Spädbarn i stabil/återhämtningsfas som huvudsakligen försörjs enteralt/peroralt får ca 150 ml/kg/dygn.

Barn> 1år/10 kg får postoperativt eller under intensivvård i den akuta fasen ca 60-70 % av volymerna ovan. När patienterna stabiliseras ökas till ca 85%.

Fluid requirement

Fluid for maintenance/nutrition

Fluid for ongoing losses (1%-rule).

Fluid for resuscitation

Blood products

Fluid creep (fluid for drug dilution – injection/infusion, flush)
Dissolve drugs in smaller volumes, use glucose 5% instead of NaCl, switch to orally administered drugs whenever possible.

Normala vätskeförluster

(per timma)

	Prematur	Spädbarn	Vuxen
Perspiratio insensibilis	2-3 ml/kg	1 ml/kg	0,5 ml/kg
Diures	2-3 ml/kg	2 ml/kg	1 ml/kg

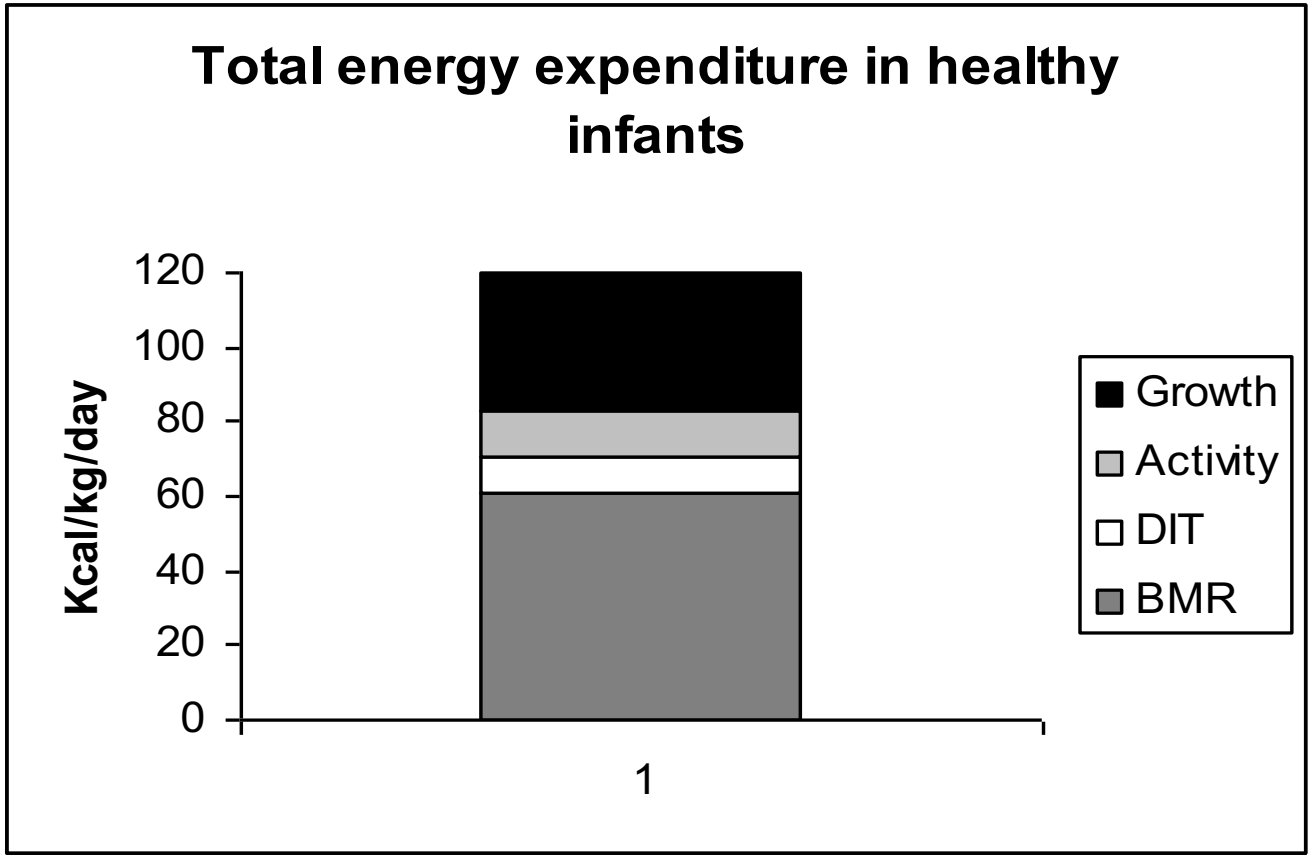
Fluid for nutrition

Holliday-Segar equation

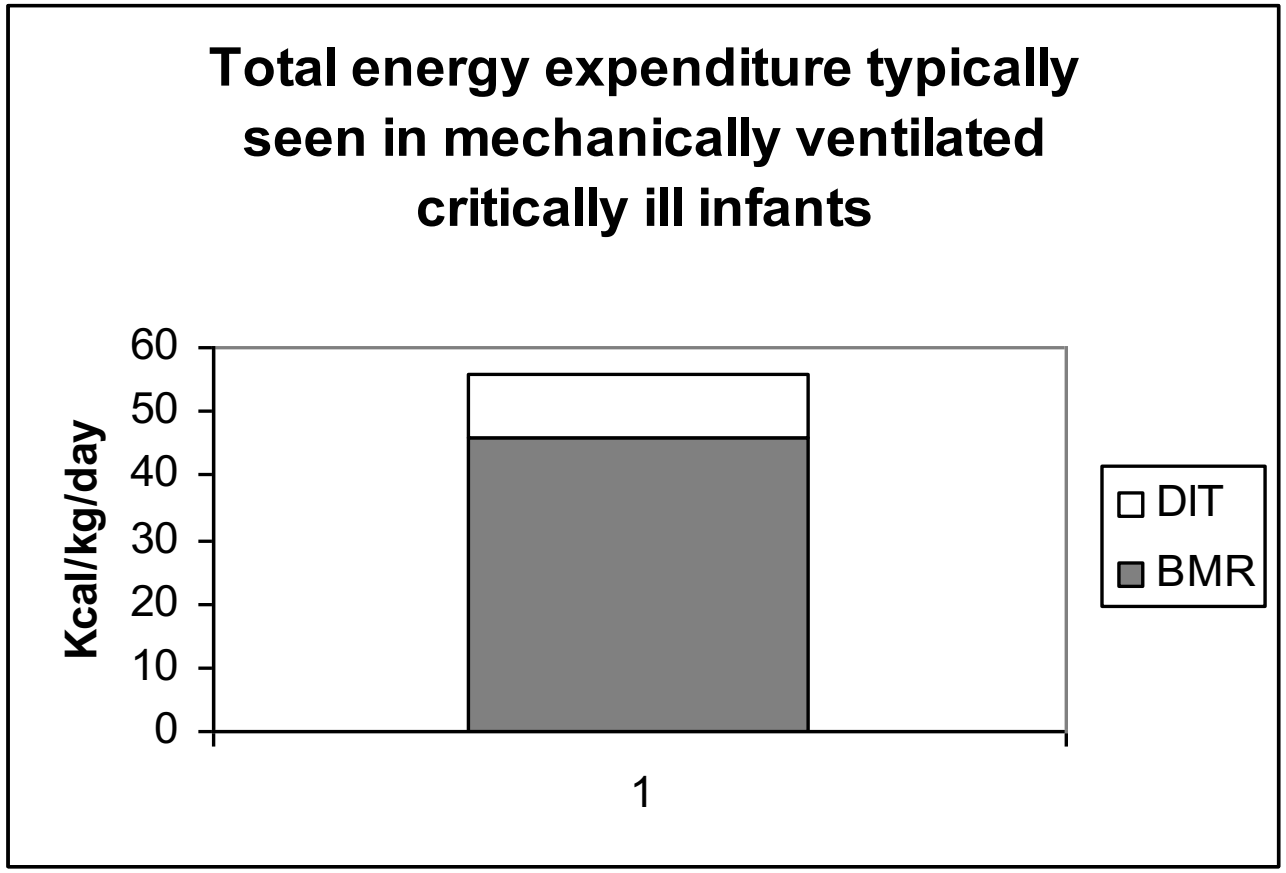
- Requirements of electrolyte free water (EFW) is based upon metabolic rate, equating 1 ml if water with a fixed consumption of 1 kcal.

- Due to low nutritional requirements during the acute phase of critical illness, the fluid volume can often be reduced by as much as 40-50 %.

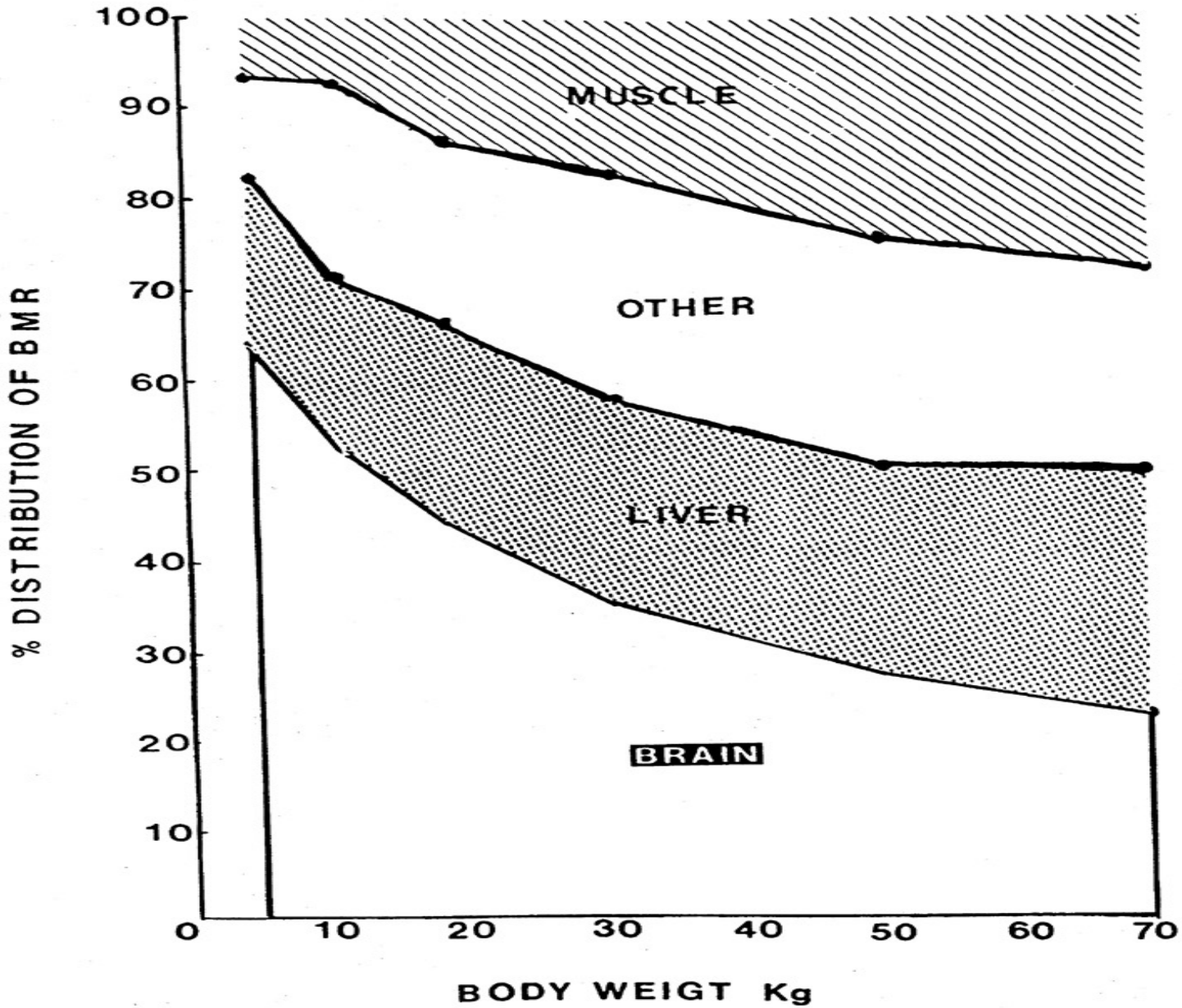
Total energy expenditure healthy infant



Total energy expenditure in critically ill infant



Fläring U, Pediatric Anesthesia 2009 19: 300–312


100
90
80
70
60
50
40
30
20
10
0
% DISTRIBUTION OF BMR
MUSCLE
OTHER
LIVER
BRAIN
10
20
30
40
50
60
70
BODY WEIGT Kg

Ongoing fluid losses

In general, replace losses >1% with albumin 5% or balanced solutions, (Plasmalyte may be used to reduce chloride load).

Pyloric stenosis

Fluid for resuscitation

In septic shock, try not to exceed 30 (60) ml/kg during the first hour.

Consider catecholamine infusion early.

Echocardiography

Keep in mind other possible diagnosis such as ductus dependent heart malformations and metabolic diseases (hyperammonemia).

Sammanfattning vätskebalans

Sträva efter att undvika vätskeöverskott som överskrider 10 %.

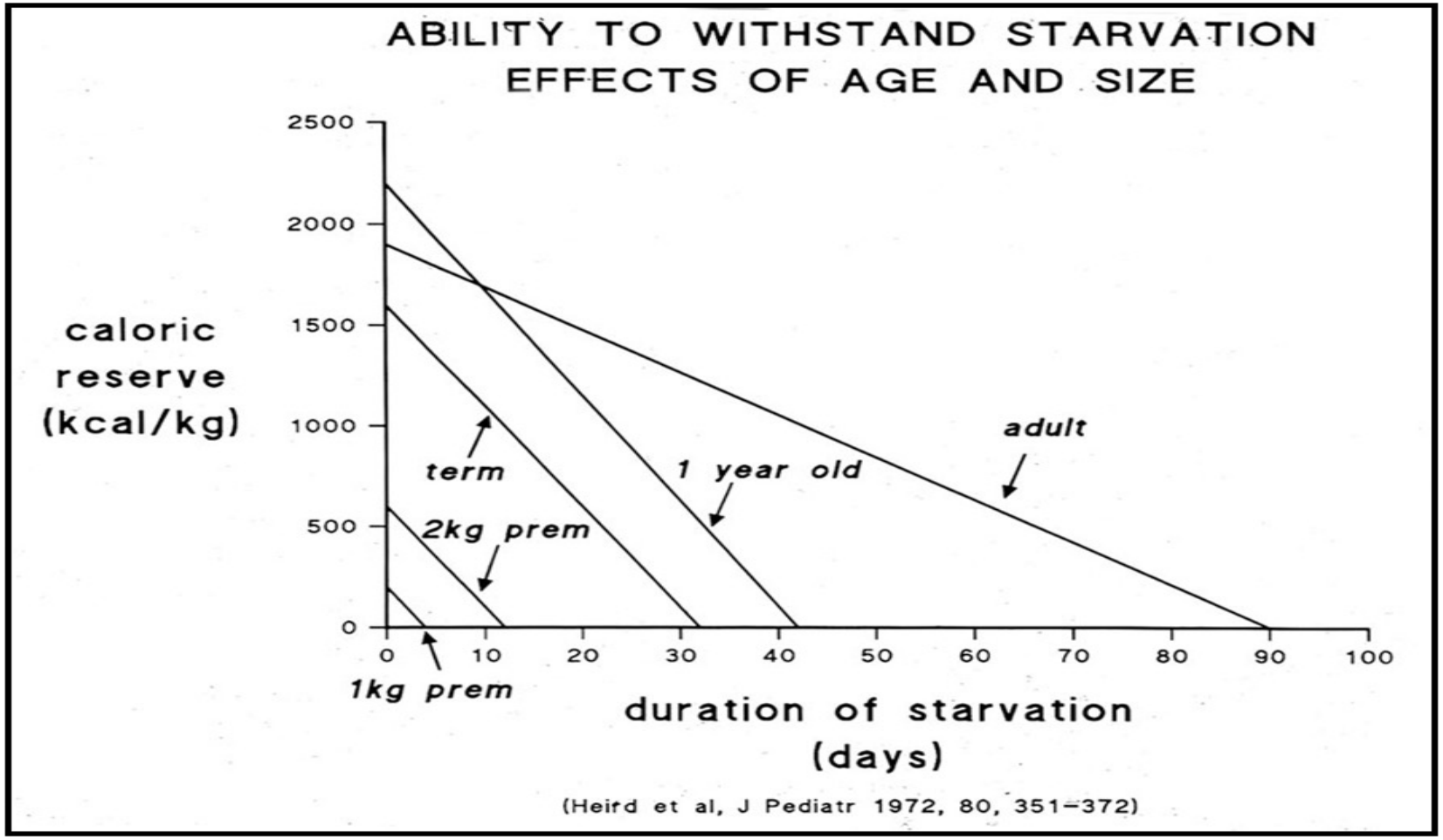
1. **Vätskerestriktion**.
2. **Koncentrera läkemedel** vb, ev. späda med Glukos
3. **Diuretika** - för att undvika diuretikaresistens:

- Starta tidigt kontinuerlig infusion furix om dåligt svar på bolus.
- Teofyllamin o/e hANP samt addera ev tiazid.
- Undvik nefrotoxiska läkemedel (Gentamycin).

4. **Lätt ökat MAP** (pressure natriuresis)
5. Undvik metabol acidos (hyperkloremi).
6. Starta CRRT vid 15% övervätskning om kumulativ negativ vätskebalans inte uppnås med maximal diuretikabehandling.
7. Räkna in all vätska i vätskebalans, inklusive flush på spädbarn.

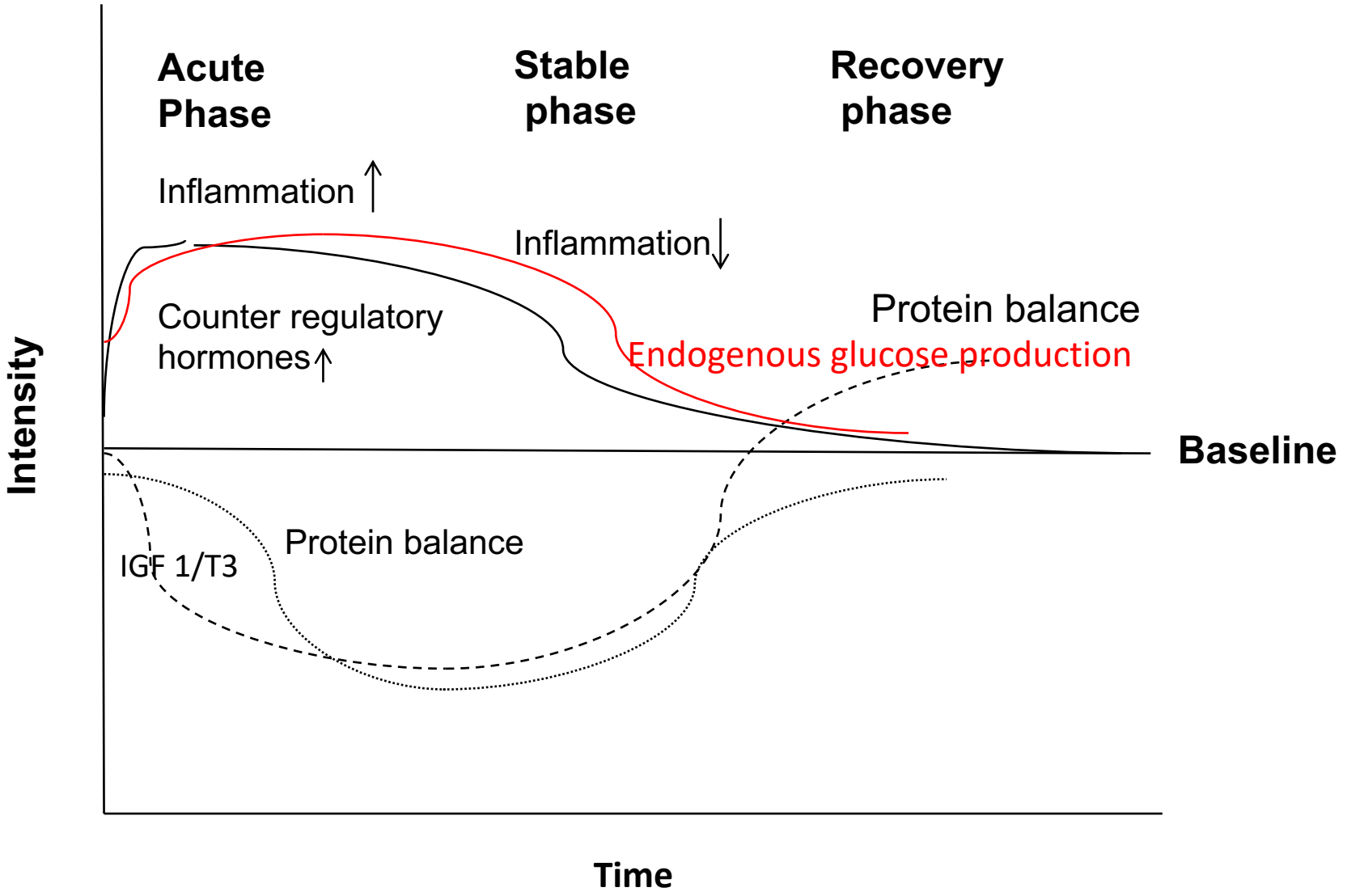
Nutrition in the PICU (including term newborns)

Energy reserves



Short- vs longstyers

- Median length of stay in the PICU 2 days
- In general, patients staying shorter than 4-5 days do not constitute a nutritional problem in the PICU
- Long-stayers are more prone to malnutrition and to suffer side-effects of under- or overfeeding.


Acute Phase
Stable phase
Recovery phase
Inflammation
Inflammation
Counter regulatory hormones
Protein balance
Endogenous glucose production
Baseline
Protein balance
IGF 1/T3
Intensity
Time

The NEW ENGLAND JOURNAL of MEDICINE

ORIGINAL ARTICLE

Early versus Late Parenteral Nutrition in Critically Ill Children

RCT. 3 sites. Early (within 24 hours) initiation (n=723) of PN vs late (day 8) initiation (n=717) was compared. Term newborns – 17 years

Primary outcomes

Fewer new infections (mainly bloodstream or airway) 10,7 in late compared to 18,5 % in early . OR:0.48 (0.35-0.66).

-Beneficial for malnourished patients. Similar effects in neonates and older children OR in neonates 0,47.

-Shorter PICU-stay: 2,7 days. (95% CI, 1.3 to 4.3).

Secondary outcomes

-Less time on mechanical ventilation,

-Less kidney failure,

-Increased likelihood of earlier live discharge from PICU and hospital.

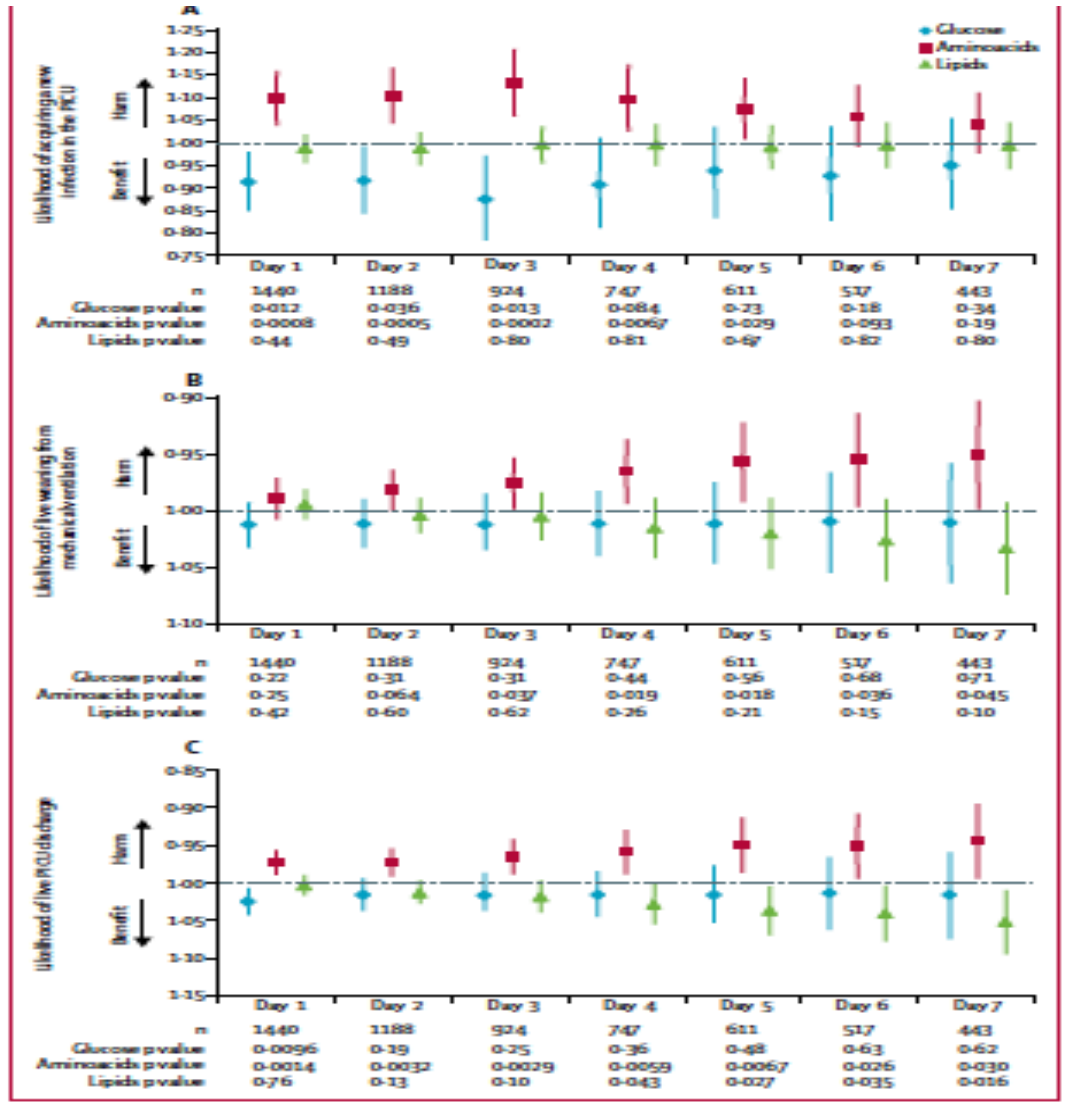
Predefined posthoc study

Average intake of glucose, lipids and amino acids was investigated with possible associations with:

- Likelihood of acquiring a new infection in the PICU
- Likelihood of earlier weaning from mechanical ventilation
- Likelihood of earlier alive discharge

Effect of early supplemental parenteral nutrition in the paediatric ICU: a preplanned observational study of post-randomisation treatments in the PEPaNIC trial

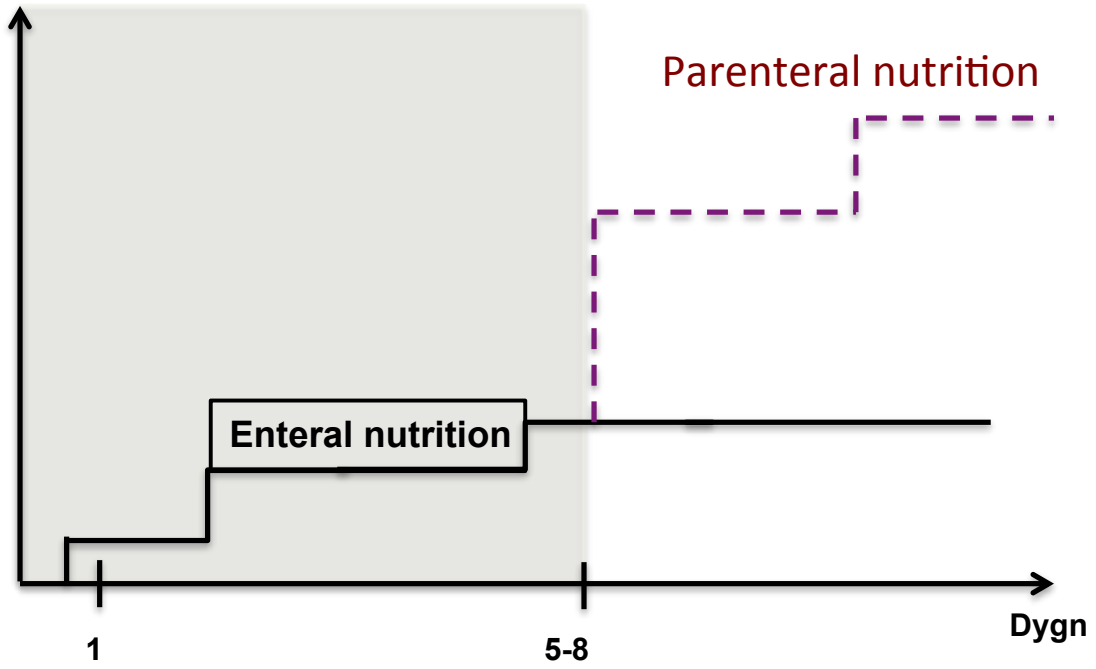
Ilse Vanhorebeek, Sascha Verbruggen, Michaël P Casaer, Jan Gunst, Pieter J Wouters, Jan Hanot, Gonzalo García Guerra, Dirk Vlasselaers, Koen Joosten, Greet Van den Berghe



Hög risk för övernutrition

Risk för undernutrition

Proteintillförsel sannolikt ogynnsamt



Iv glukos+vitaminer +spårämnen	**Ev. komplettering med parenteral nutrition**

Early enteral feeding

Original Communication

aspen

Journal of Parenteral and Enteral Nutrition
Volume 38 Number 4
May 2014 459–466

DOI: 10.1177/0148607113517903
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Early Enteral Nutrition Is Associated With Lower Mortality in Critically Ill Children

Theresa A. Mikhailov, MD, PhD[1,2]; Evelyn M. Kuhn, PhD[2]; Jennifer Manzi, CPNP-AC/PC[2,3]; Melissa Christensen, BS[4]; Maureen Collins, MS, RD[2]; Ann-Marie Brown, MSN, CPNP-AC/PC, CCRN, FCCM[5]; Ronald Dechert, RRT, DPH[6]; Matthew C. Scanlon, MD[1,2]; Martin K. Wakeham, MD[1,2]; Praveen S. Goday, MBBS, CNSC[7]

Guidelines for the Provision and Assessment of Nutrition Support Therapy in the Pediatric Critically Ill Patient: Society of Critical Care Medicine and American Society for Parenteral and Enteral Nutrition

Nilesh M. Mehta, MD[1]; Heather E. Skillman, MS, RD, CSP, CNSC[2]; Sharon Y. Irving, PhD, CRNP, FCCM, FAAN[3]; Jorge A. Coss-Bu, MD[4]; Sarah Vermilyea, MS, RD, CSP, LD, CNSC[5]; Elizabeth Anne Farrington, PharmD, FCCP, FCCM, FPPAG, BCPS[6]; Liam McKeever, MS, RDN[7]; Amber M. Hall, MS[8]; Praveen S. Goday, MBBS, CNSC[9]; Carol Braunschweig, PhD, RD[10]

Tips enteral nutrition

Undvik tillsatser tillsdess att patienten är uppe i fulla mål (osmolaritet och hög proteintillförsel medför långsam ventrikeltömning.

Starta med kontinuerlig tillförsel första dagarna.

Naloxone enteralt om behandling med opiat, ev tillägg av Erytromycin.

Movicol/ev klyx.

Postpylorisk sond.

Tack för uppmärksamheten