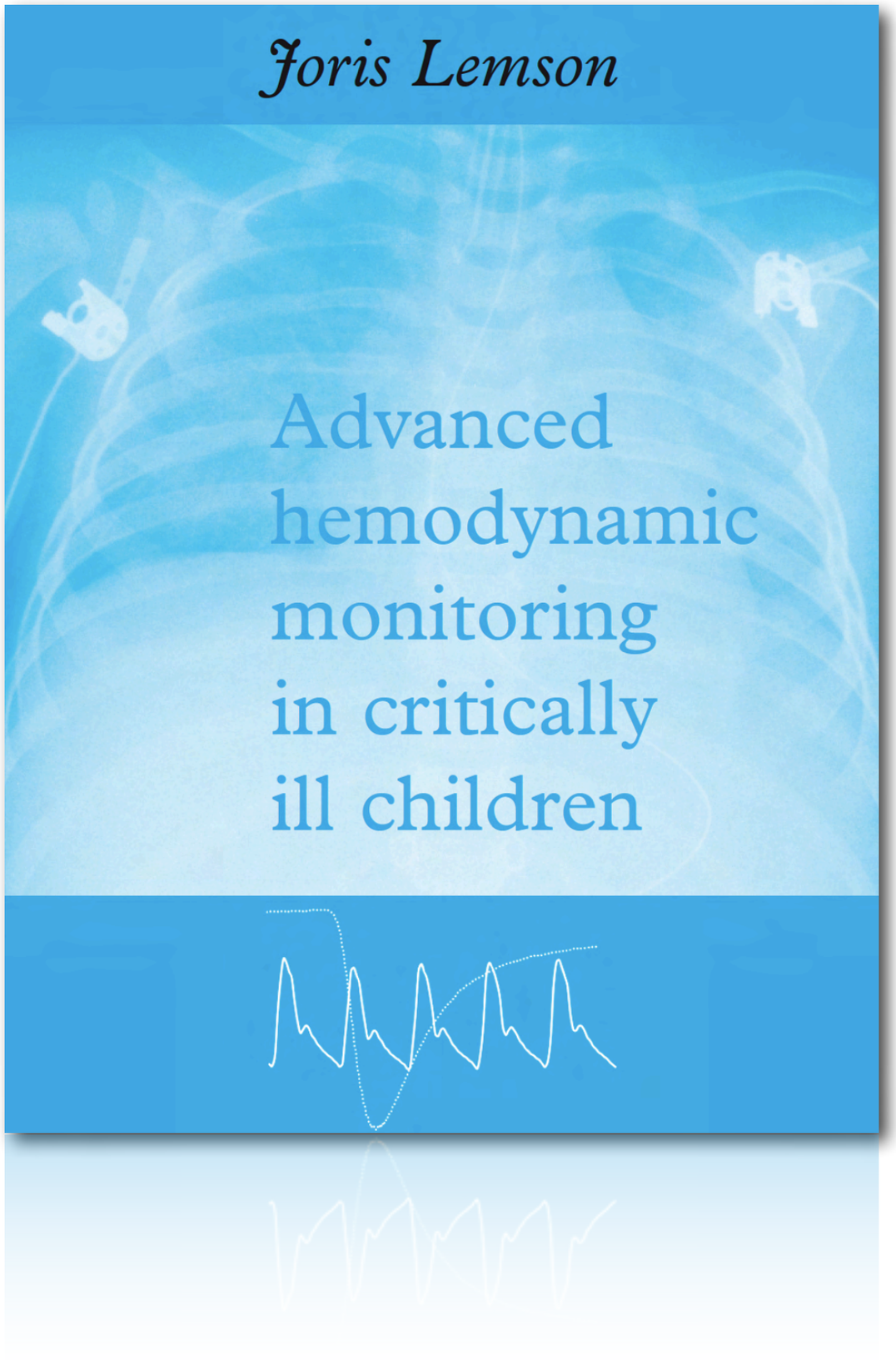
Geavanceerde hemodynamische monitoring bij kinderen

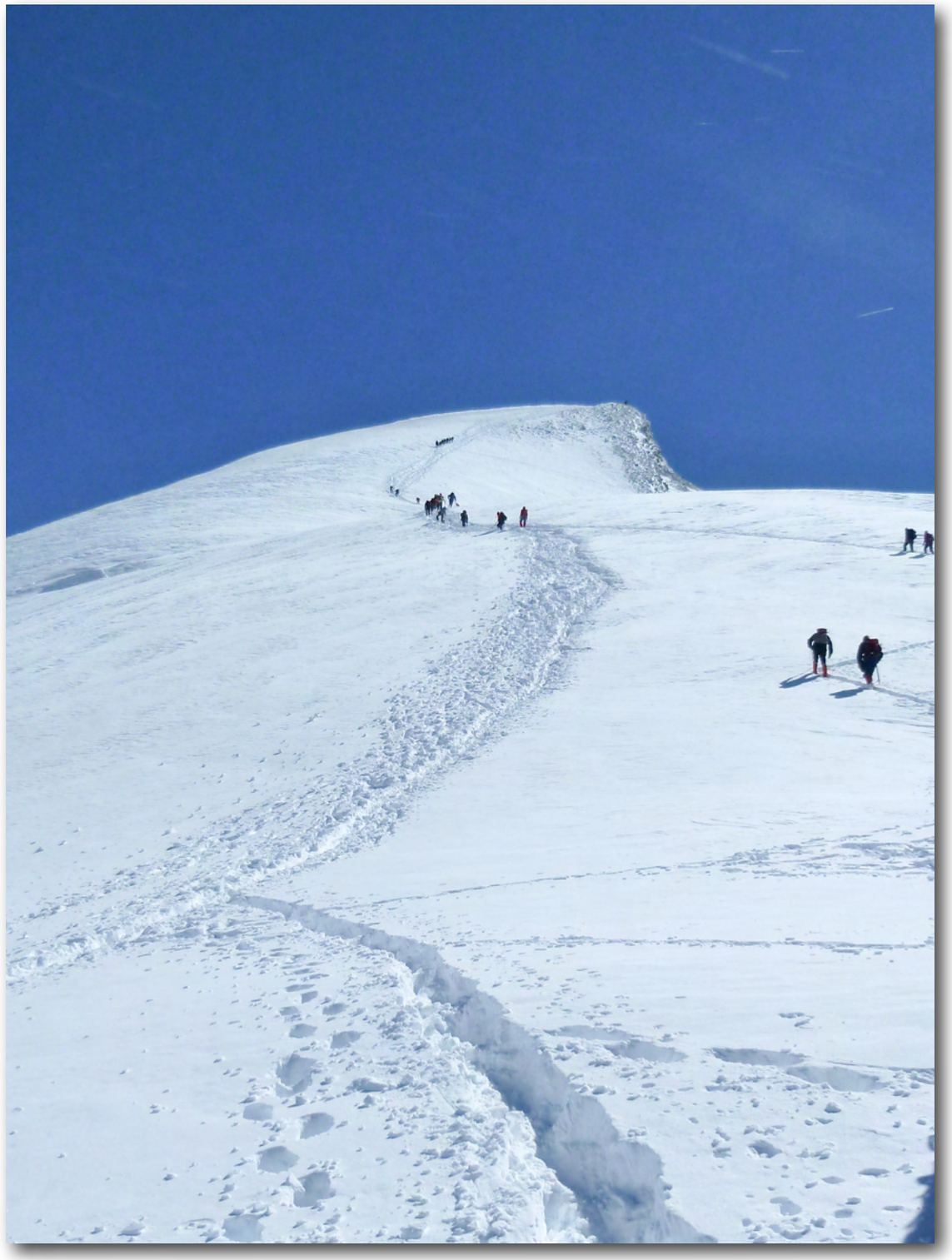
Wat is er mogelijk? is het anders dan bij volwassenen?

Joris Lemson

Symposium hemodynamiek bij volwassenen en kinderen

Vrijdag 15 oktober 2010

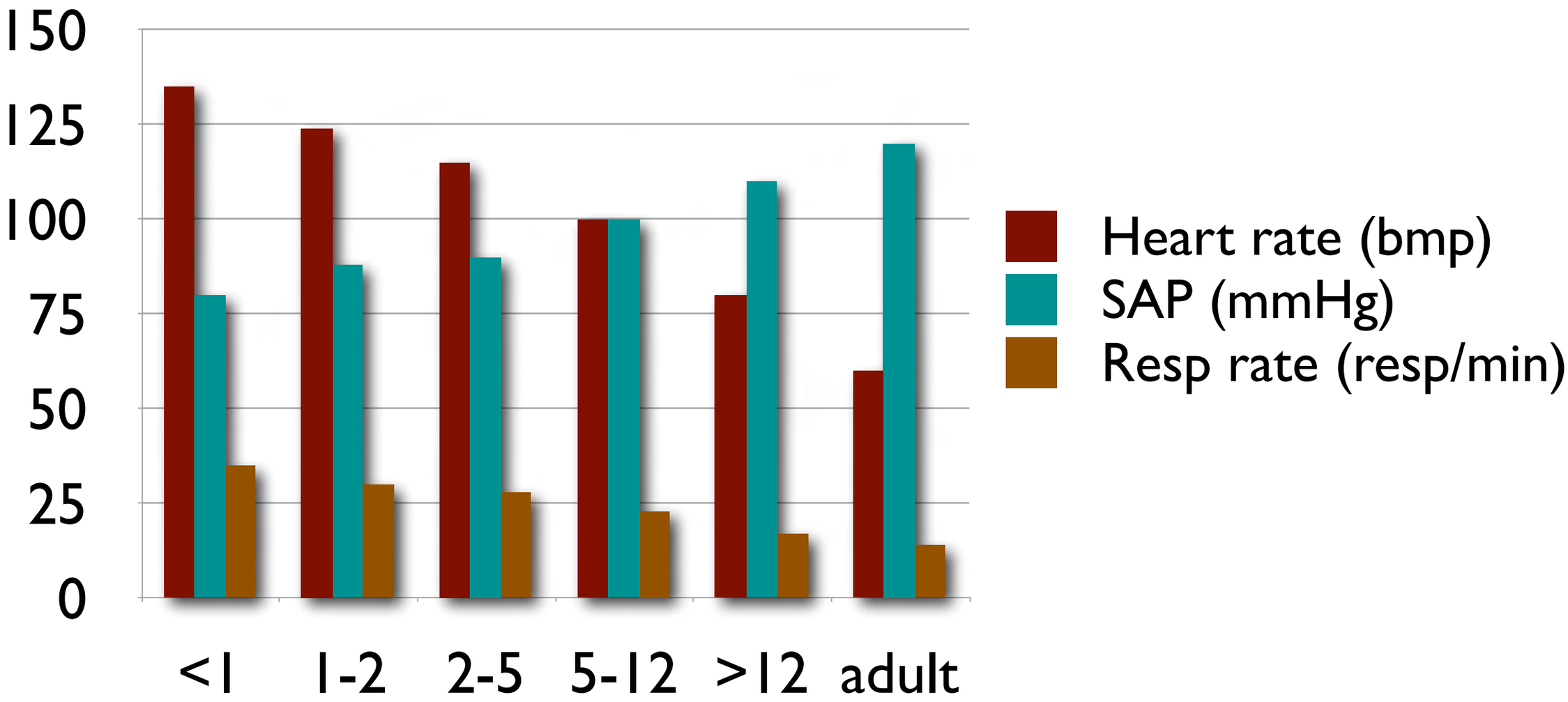

Joris Lemson
Advanced hemodynamic monitoring in critically ill children



Differences between children and adults

- Size / weight
- Hemodynamic physiology
- Congenital cardiac defects

Basic hemodynamic parameters and age



Young children

VO_2 ⇧

Cardiac output (CO) ⇧

Heart rate ⇧

Blood pressure ⇩

Systemic vascular resistance ⇩

Body water ⇧

SaO_2 =

SvO_2 =

CVP =

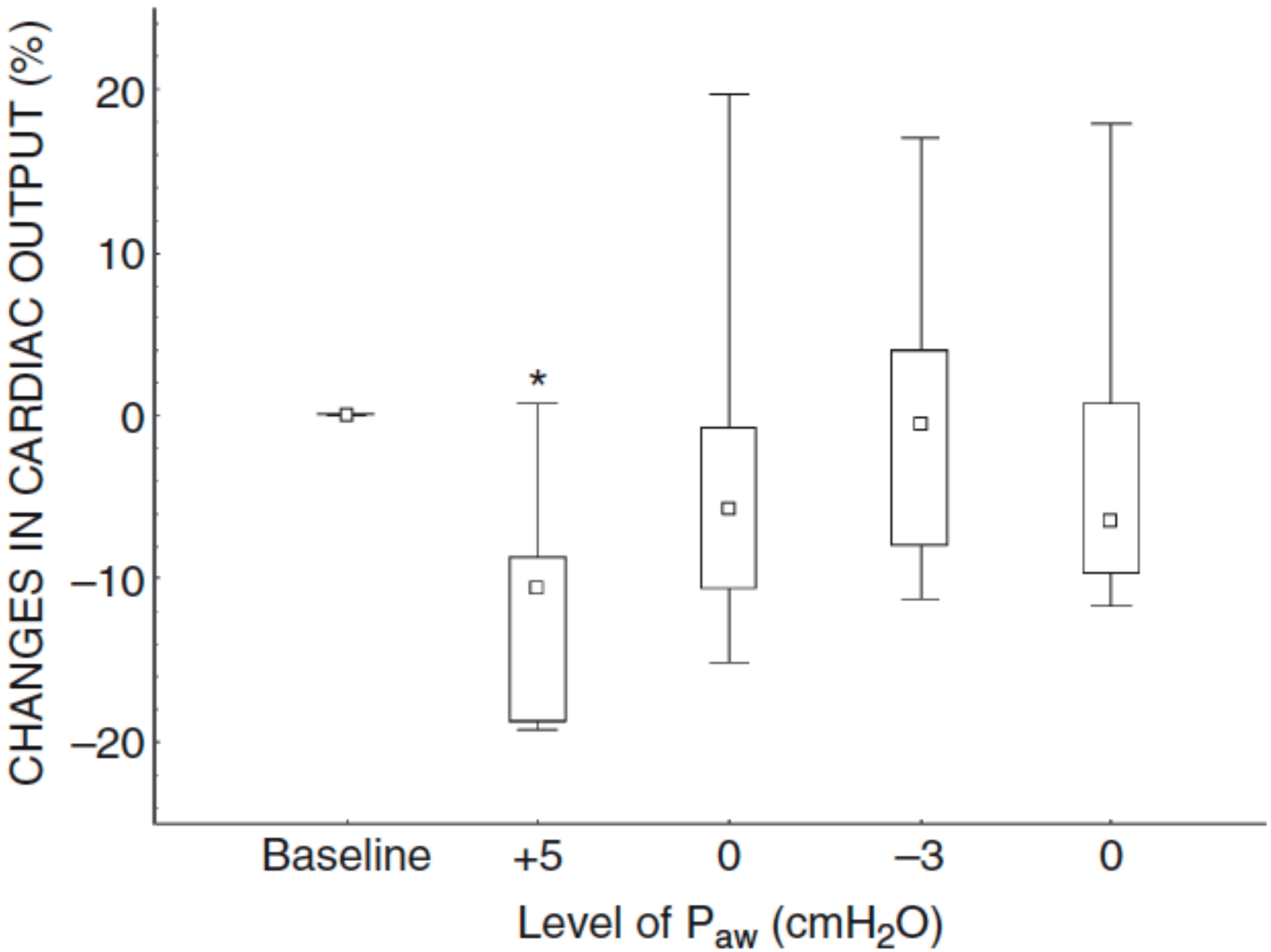
The heart in children

- Higher basal contractile state
- Higher O_2 consumption at high heart rate or high preload
- Greater sensitivity to increase in afterload
- Are children heart frequency dependent? => no

Newborn lamb and fluid resuscitation

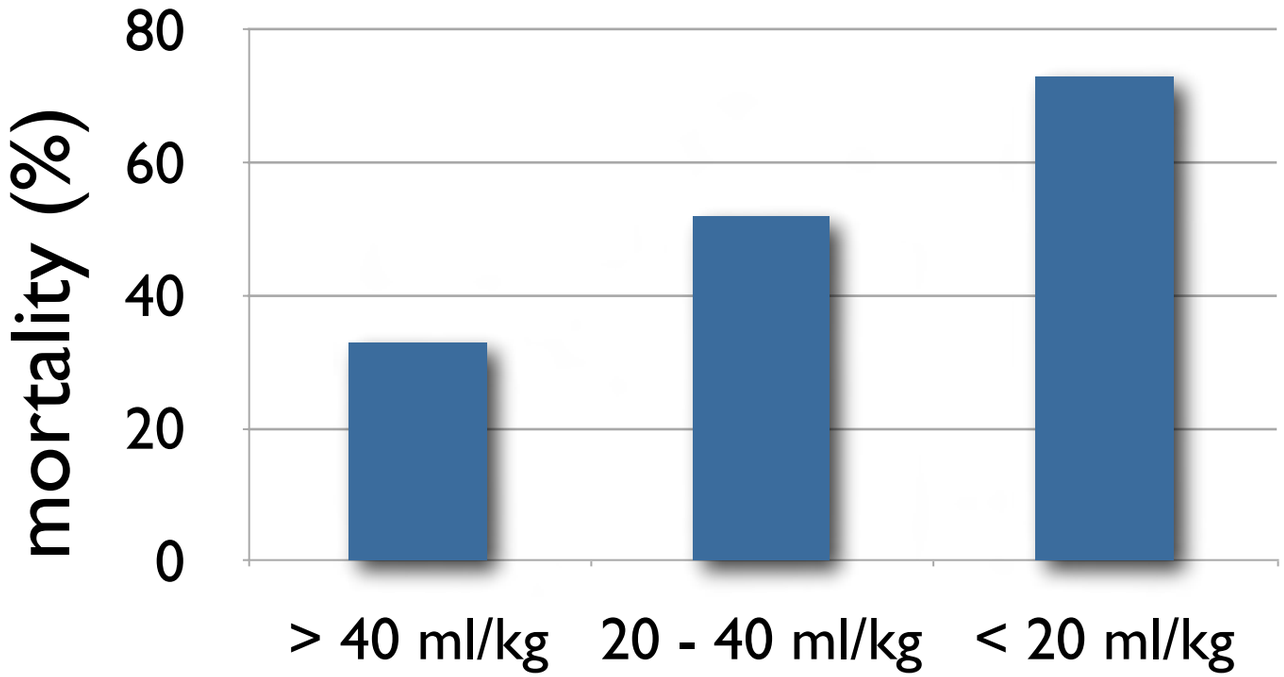
n = 11 (4.2 - 12.5 kg)

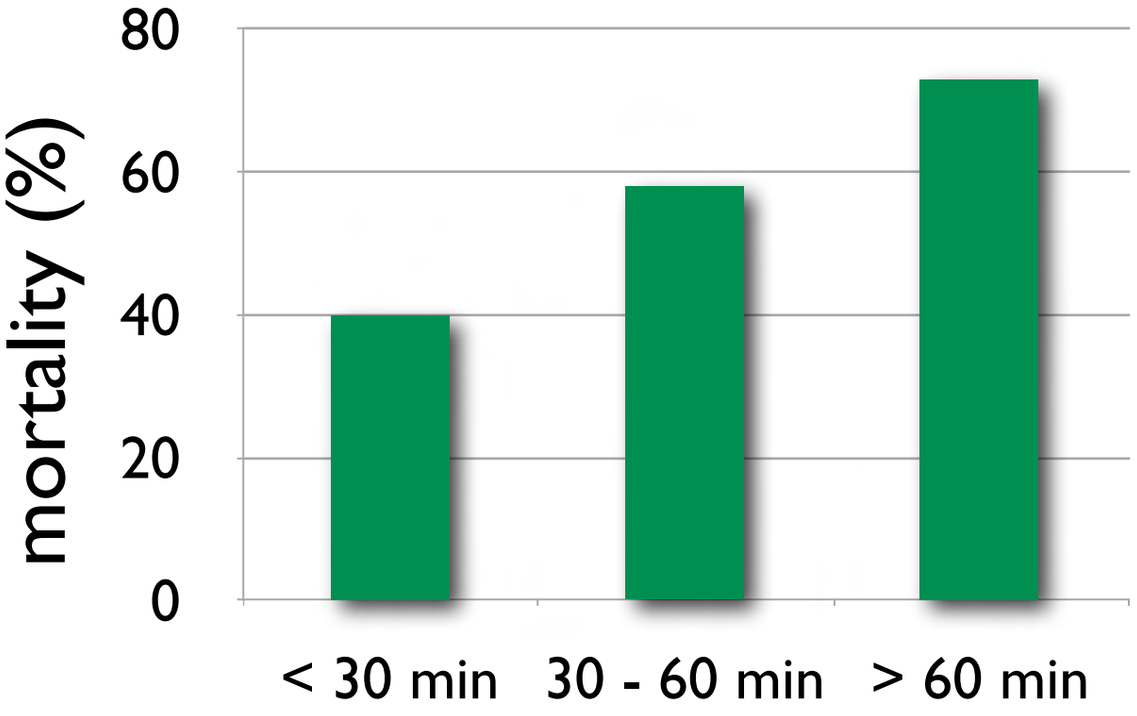
HFOV and CO in newborns



Acta Anaesthesiol Scand 2004; 48: 218—223

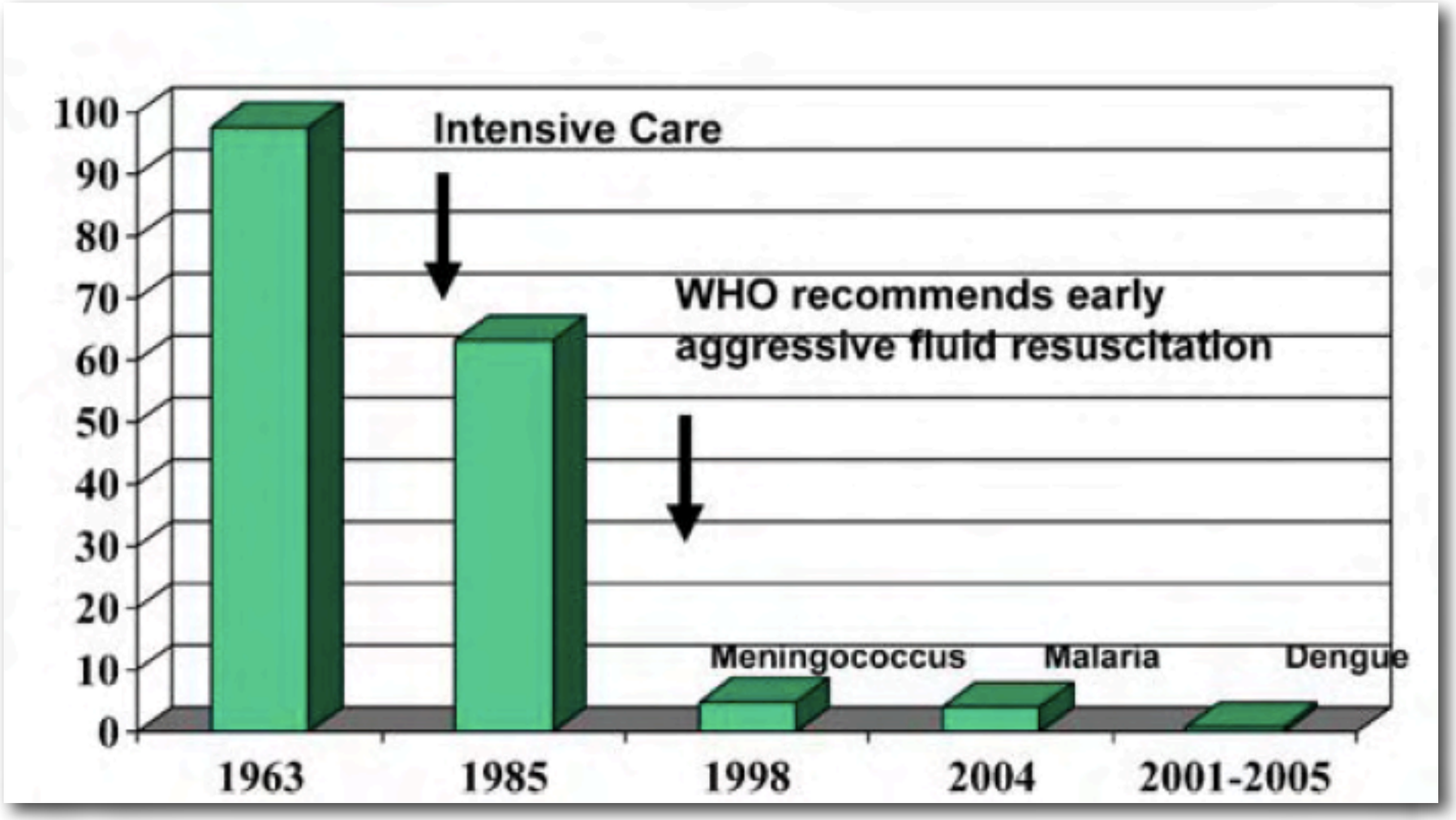
Early fluids; quantity and timing





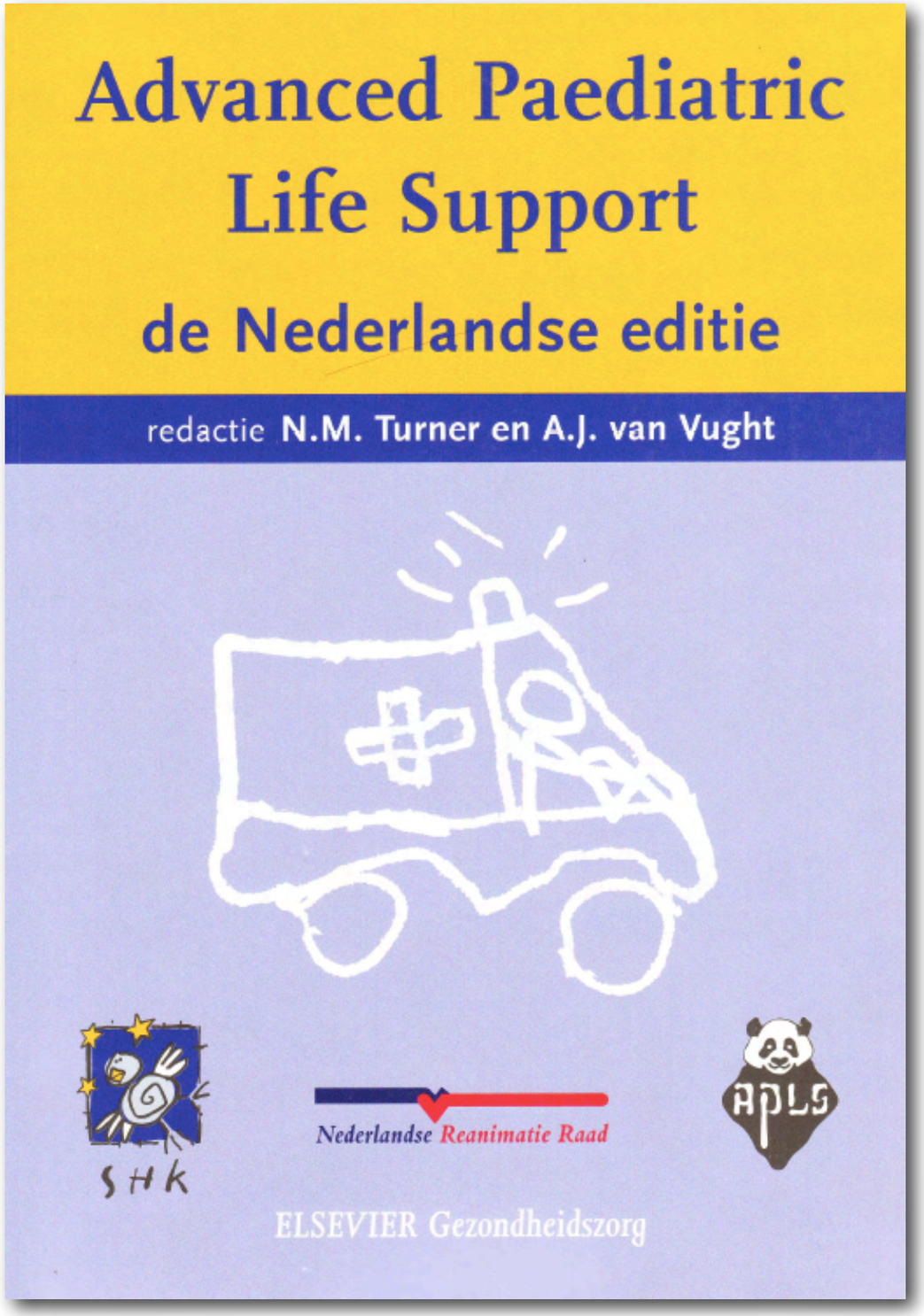
Pediatric Emergency Care 2008;24:810-815

Decrease in mortality of shock



Intensive Care Med 2006;32:958–961

First hour


Advanced Paediatric Life Support
de Nederlandse editie
redactie N.M. Turner en A.J. van Vught
SHK
Nederlandse Reanimatie Raad
APLS
ELSEVIER Gezondheidszorg


SHK

Archives of Disease in Childhood 1997;77:516–518

Clinicians' abilities to estimate cardiac index in ventilated children and infants

Shane M Tibby, Mark Hatherill, Michael J Marsh, Ian A Murdoch

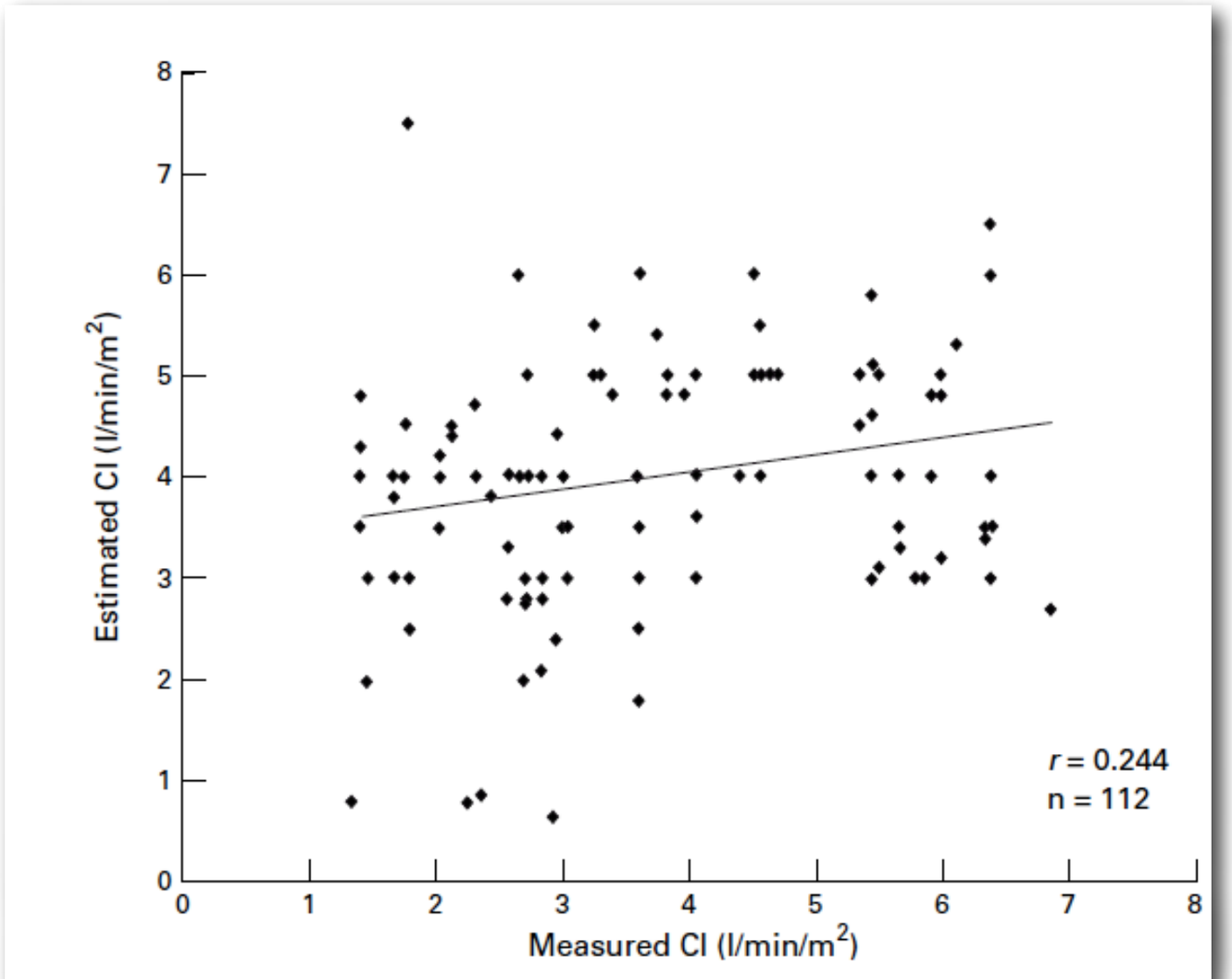


Figure 1 *Estimated v measured cardiac index (CI) from all grades.*

The pulmonary artery catheter in children

The use of balloon-tipped pulmonary artery catheters in children undergoing cardiac surgery

J. Damen and J. E. A. T. Wever

Department of Cardiac Anaesthesia, University Hospital and University Children's Hospital, University of Utrecht, Utrecht, The Netherlands

Intensive Care Med 1987;13:266-272

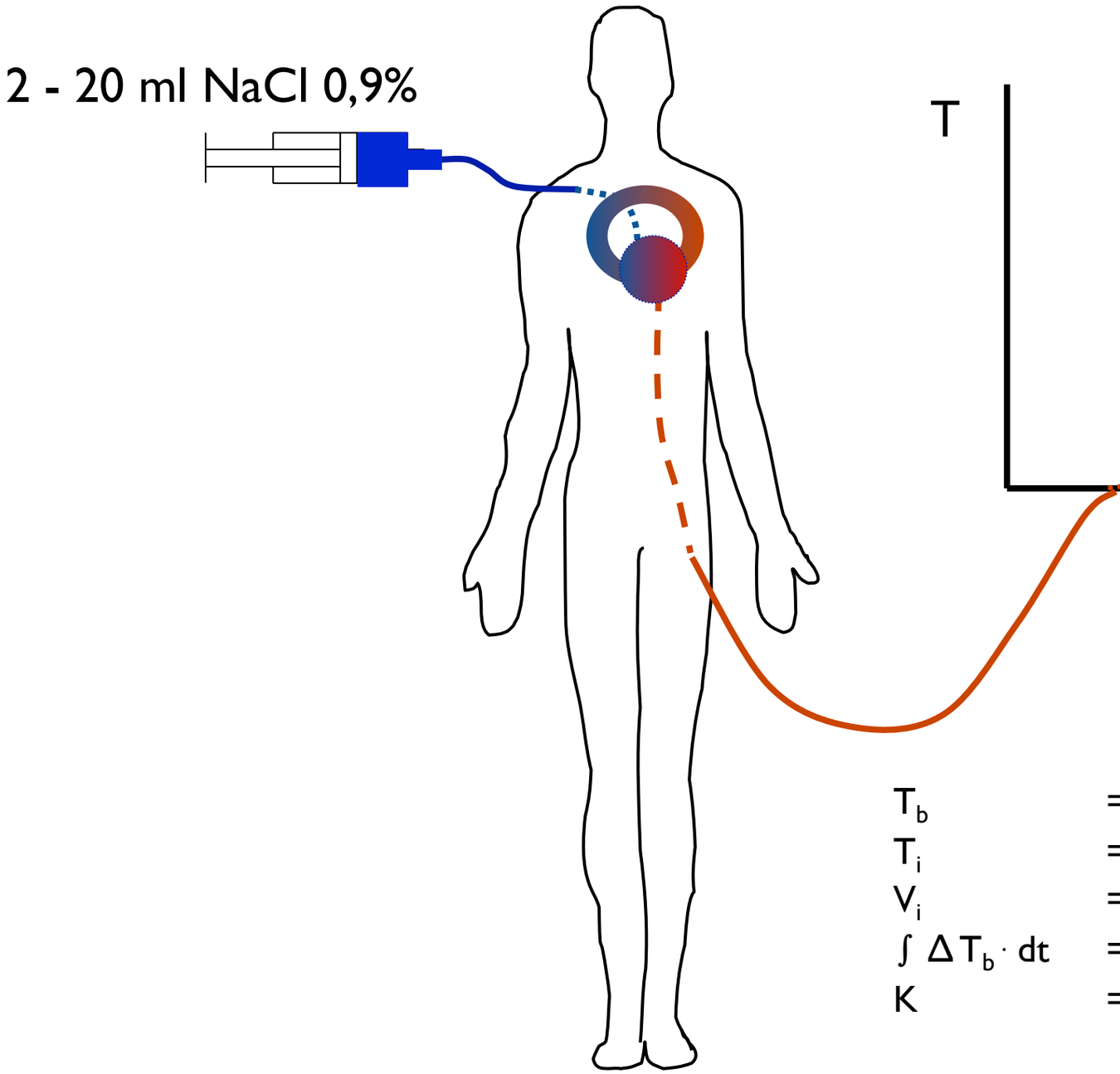
- Size
- Lack of efficacy in adults
- Better alternatives

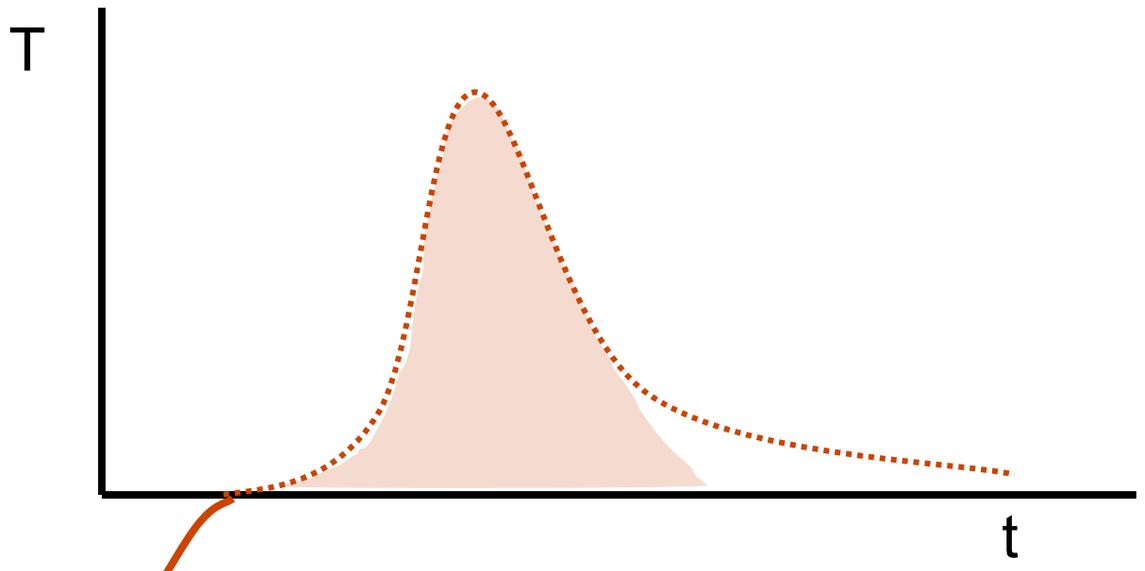
picture: Jeroen Verwiel

Hemodynamic monitoring in children

- $ScvO_2$ often not measured
- Continuous $ScvO_2$ (pediasat) introduced in 2006
- Introduction of PiCCO in 1997
- Pediatric arterial 3 Fr 7 cm catheter in 2004
- Oesophageal doppler in children from 2004
- Utrageluid dilutie (COstatus) 2010

Transpulmonary thermodilution (TPTD)





$$CO_{TDa} = \frac{(T_b - T_i) \times V_i \times K}{\int \Delta T_b \times dt}$$

T_b = Blood temperature

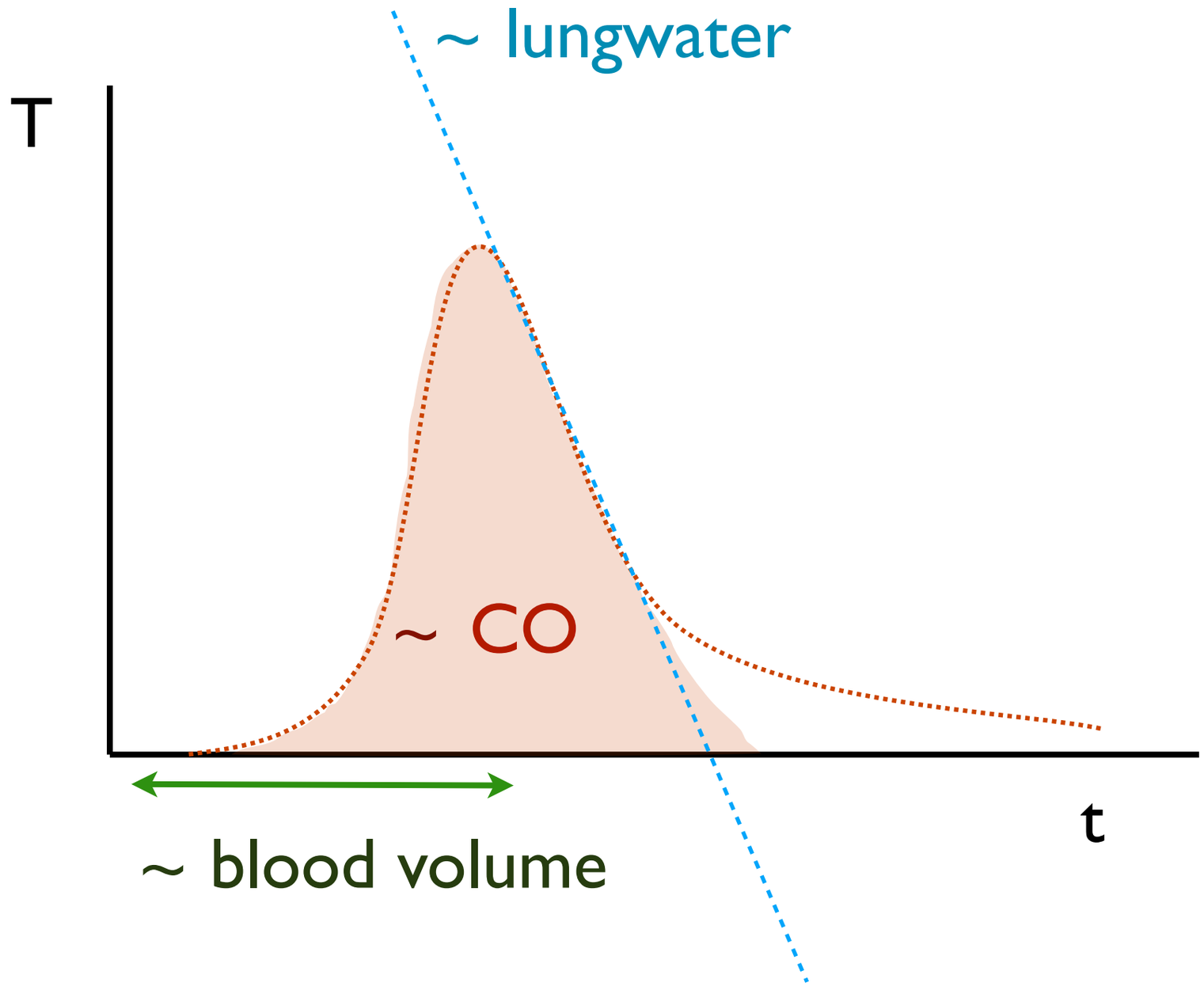
T_i = Injectate temperature

V_i = Injectate volume

$\int \Delta T_b \cdot dt$ = Area under the thermodilution curve

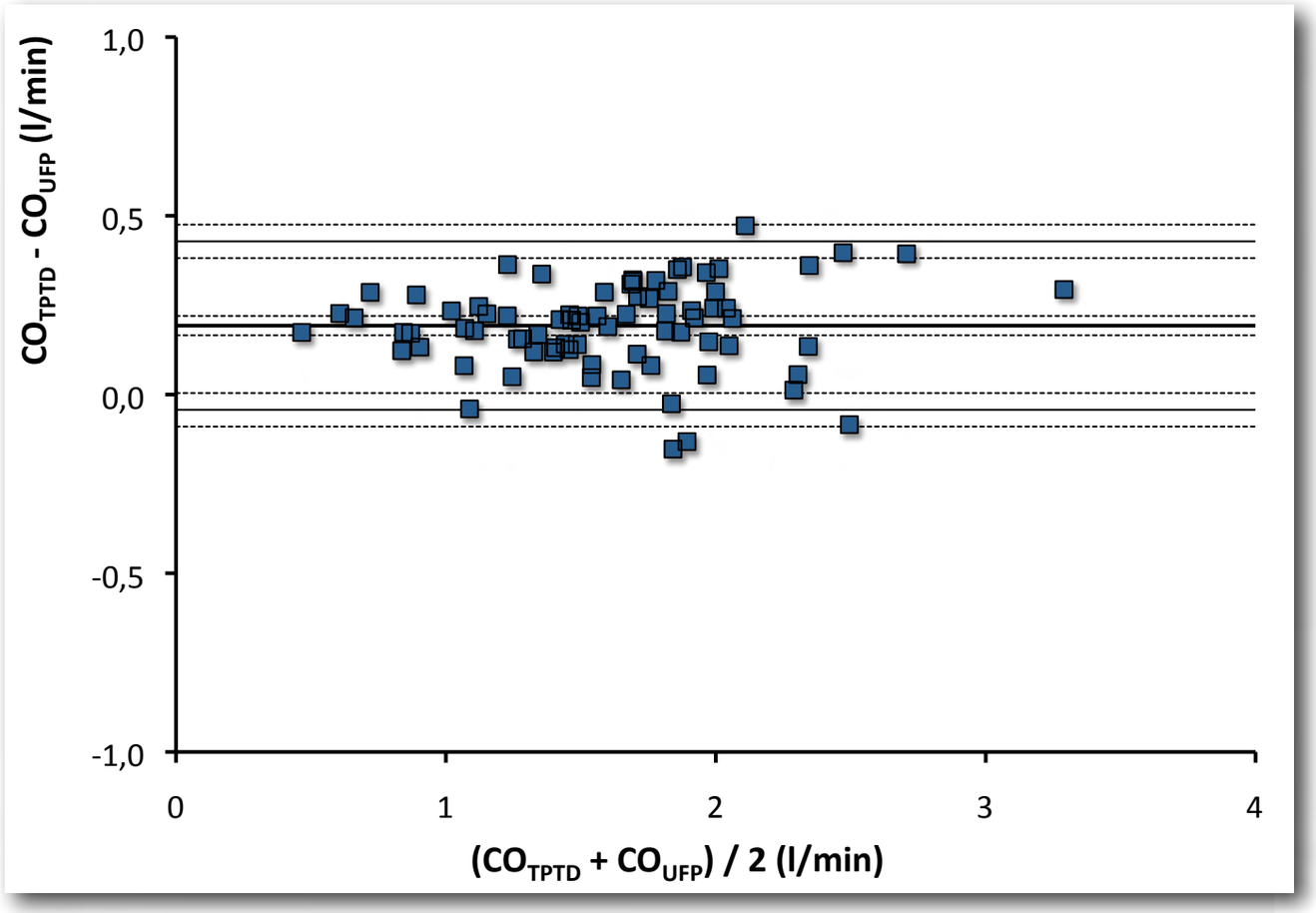
K = Correction constant, made up of specific weight and specific heat of blood and injectate

The TPTD curve



Reliability of CO measurement withTPTD

- 11 lambs
- Gold standard = flow probe
- Percentage error = 14%



Ped Crit Care Med 2008;9:313-319

CO measurement in children

- Reliable when measured invasively
  - thermodilution (PiCCO)
  - ultrasound dilution (COstatus)

- Less reliable when measured with echo

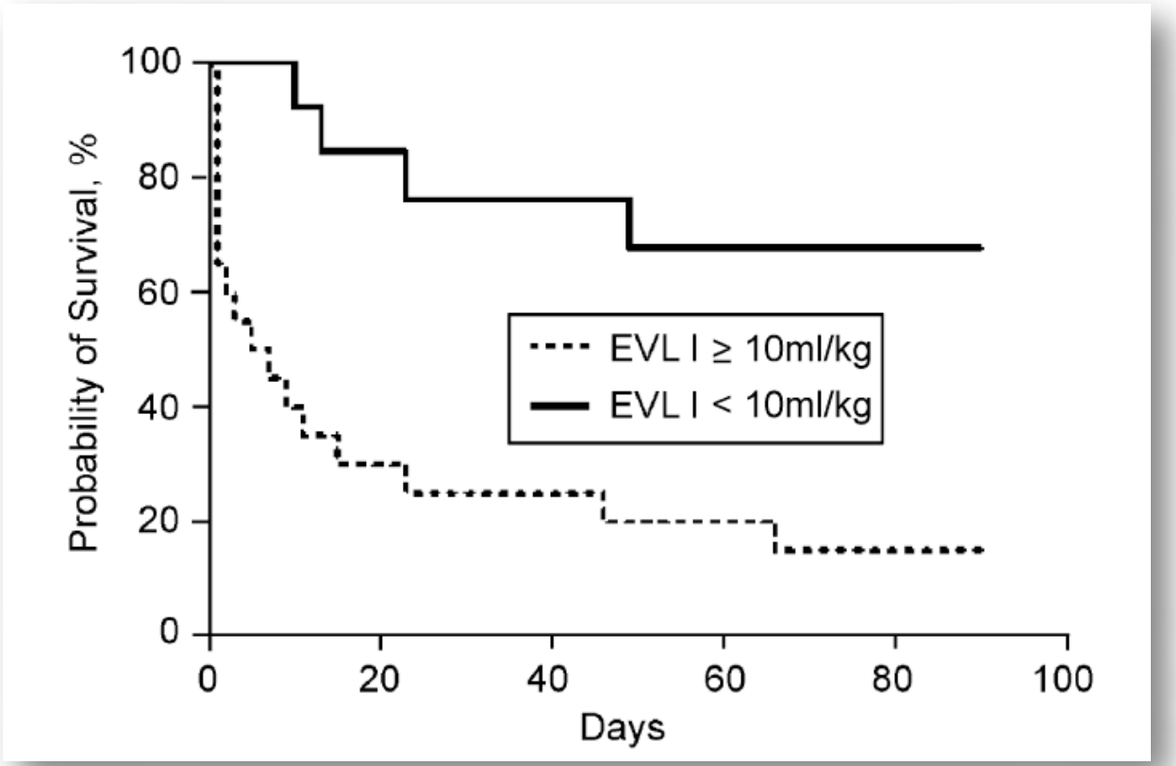
- Arterial pressure wave CO measurement???

- Bioimpedance????

Expert Rev Med Devices 2010;7:503–517

Extravascular lung water

- Prediction of mortality
- Indicator of severity of illness
- Discrimination between increased capillary permeability and increased hydrostatic pressure
- Possible therapeutic approach
- Research



Respiratory Medicine (2008) 102, 956–961

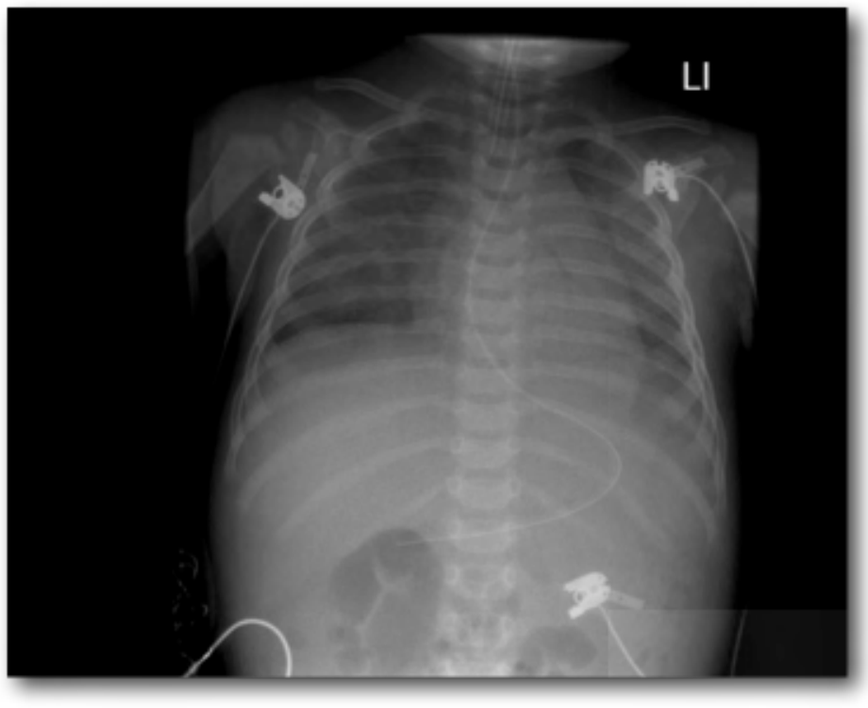
Lung water in children

Reliable?

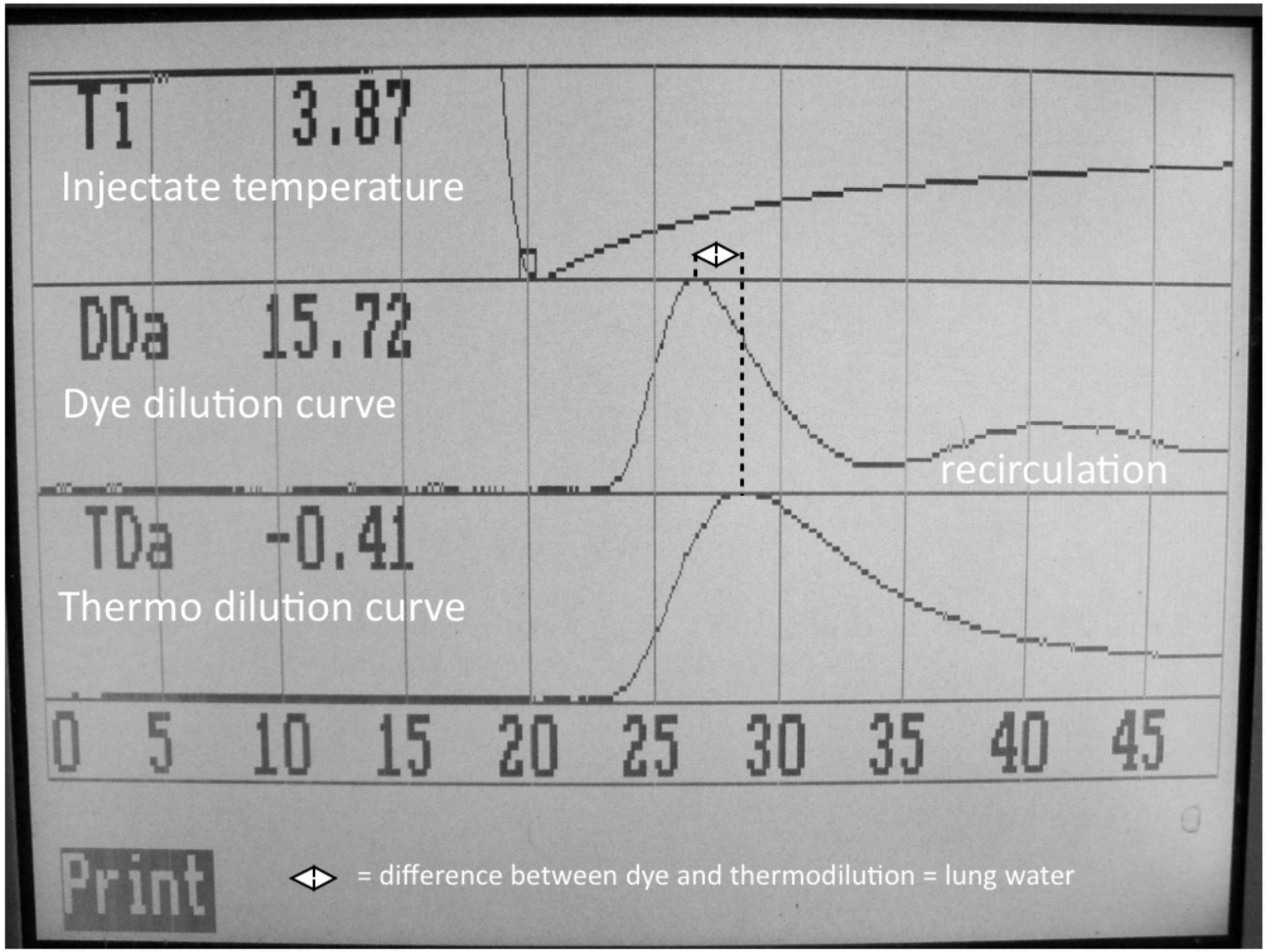
Is it higher compared to adults?

Pediatrics International (2009) 51, 59–65
Journal of Cardiothoracic and Vascular Anesthesia, Vol 16, No 5 (October), 2002: pp 592-597
Pediatric Anesthesia 2006 16: 635–640
Crit Care 2010;14:R105

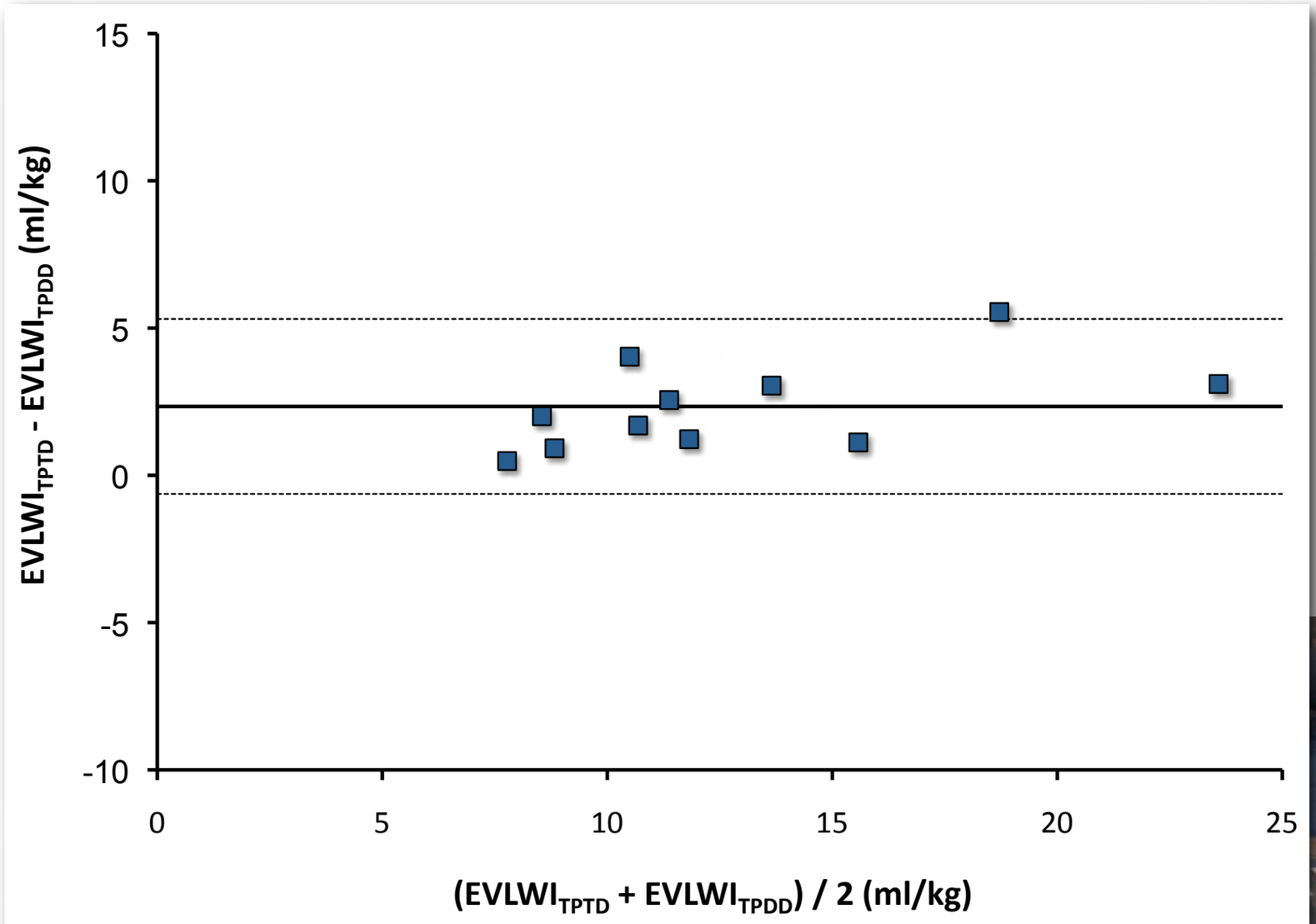
=> yes, but why?



Transpulmonary double indicator dilution



Lung water in children



Ped Crit Care Med 2009;10:227-233

Calculation of lungwater

<u>TPDD (COLD)</u>

Measured: ITTV and ITBV

EVLW = ITTV - ITBV

<u>TPTD (PiCCO)</u>

Measured: ITTV and PTV

GEDV = ITTV - PTV

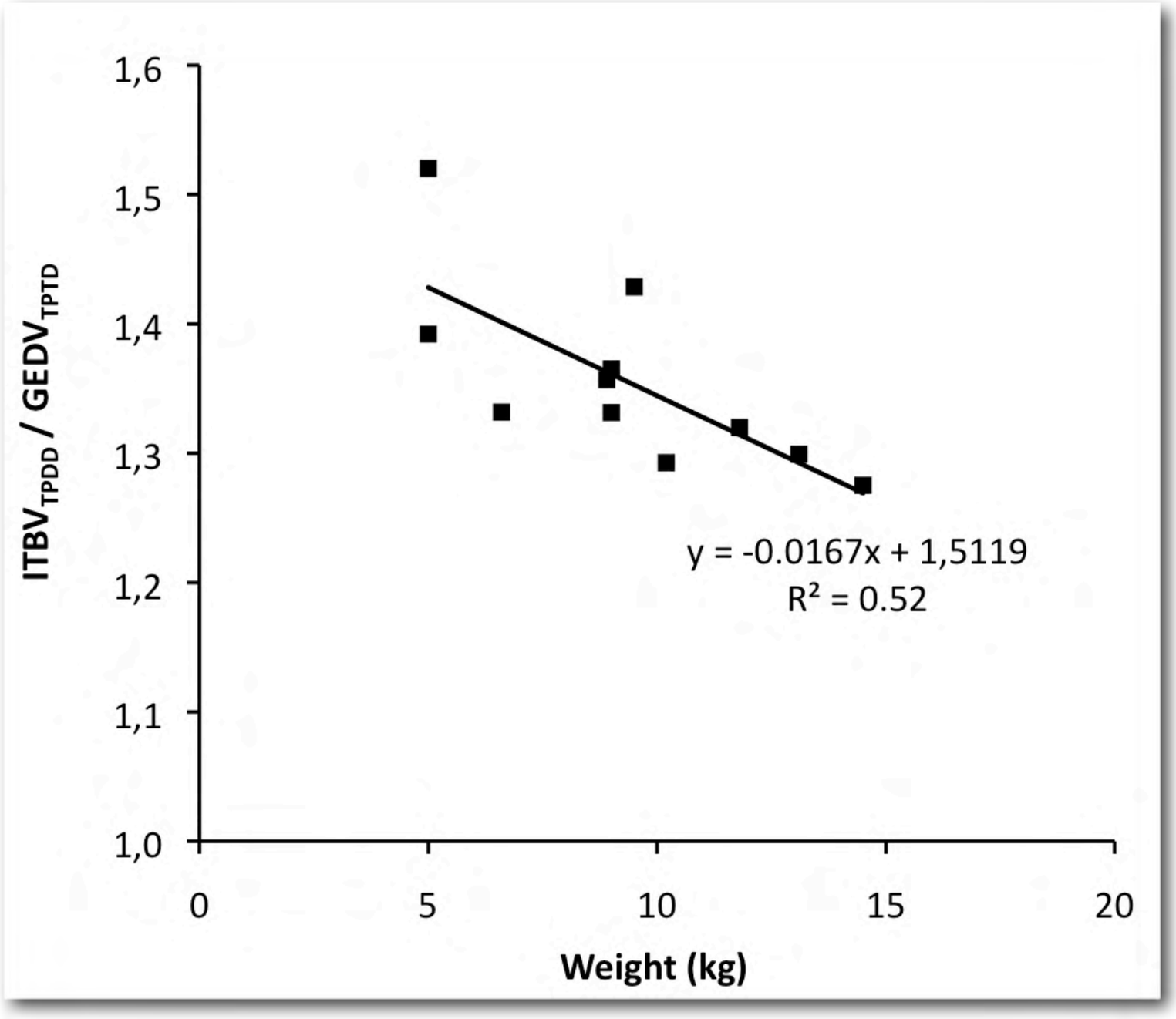
ITBV = GEDV **x 1,25**

EVLW = ITTV - ITBV

(ITBV - GEDV = PBV)

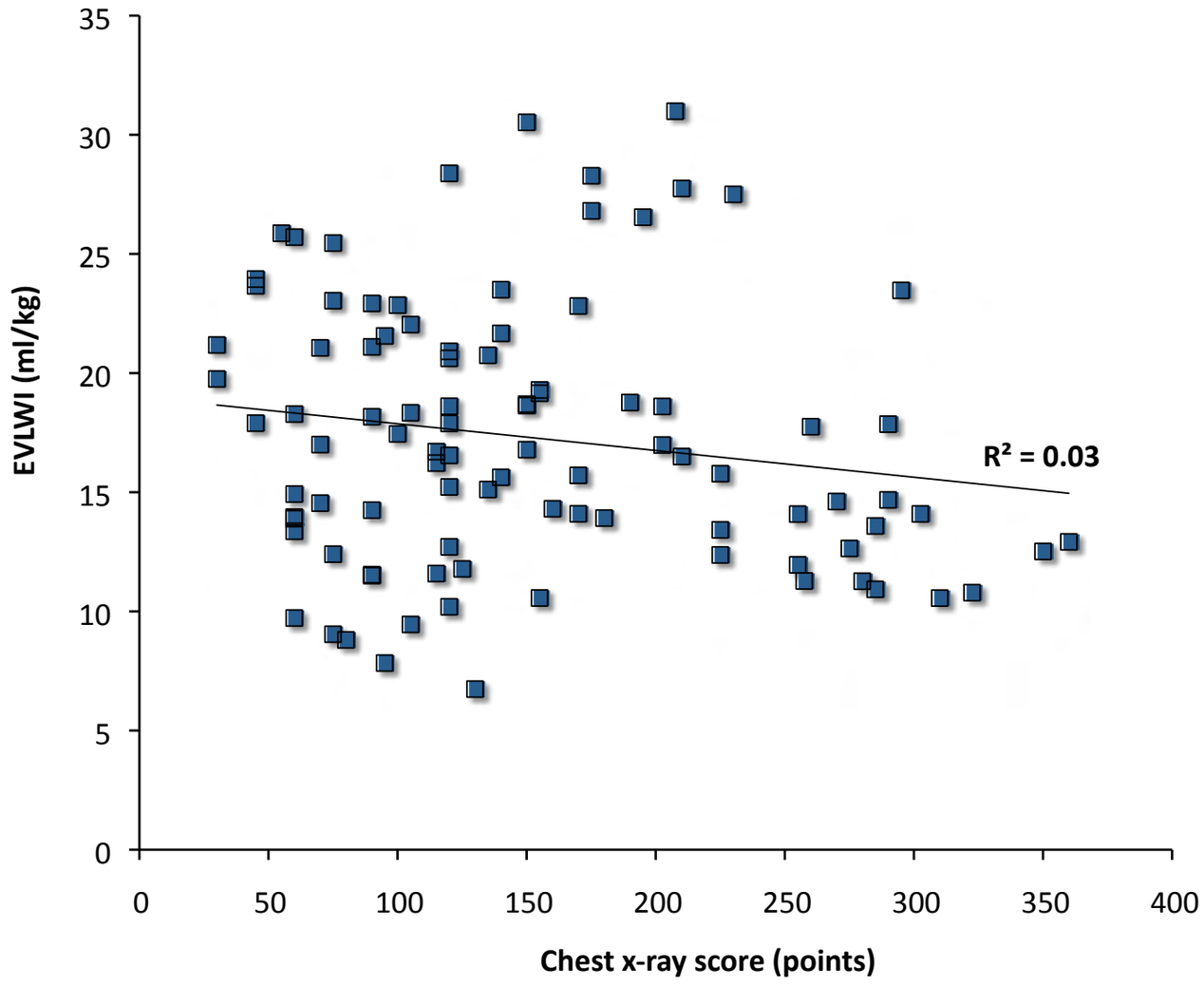
Ped Crit Care Med 2009;10:227-233

Calculation of ITBV



Ped Crit Care Med 2009;10:227-233

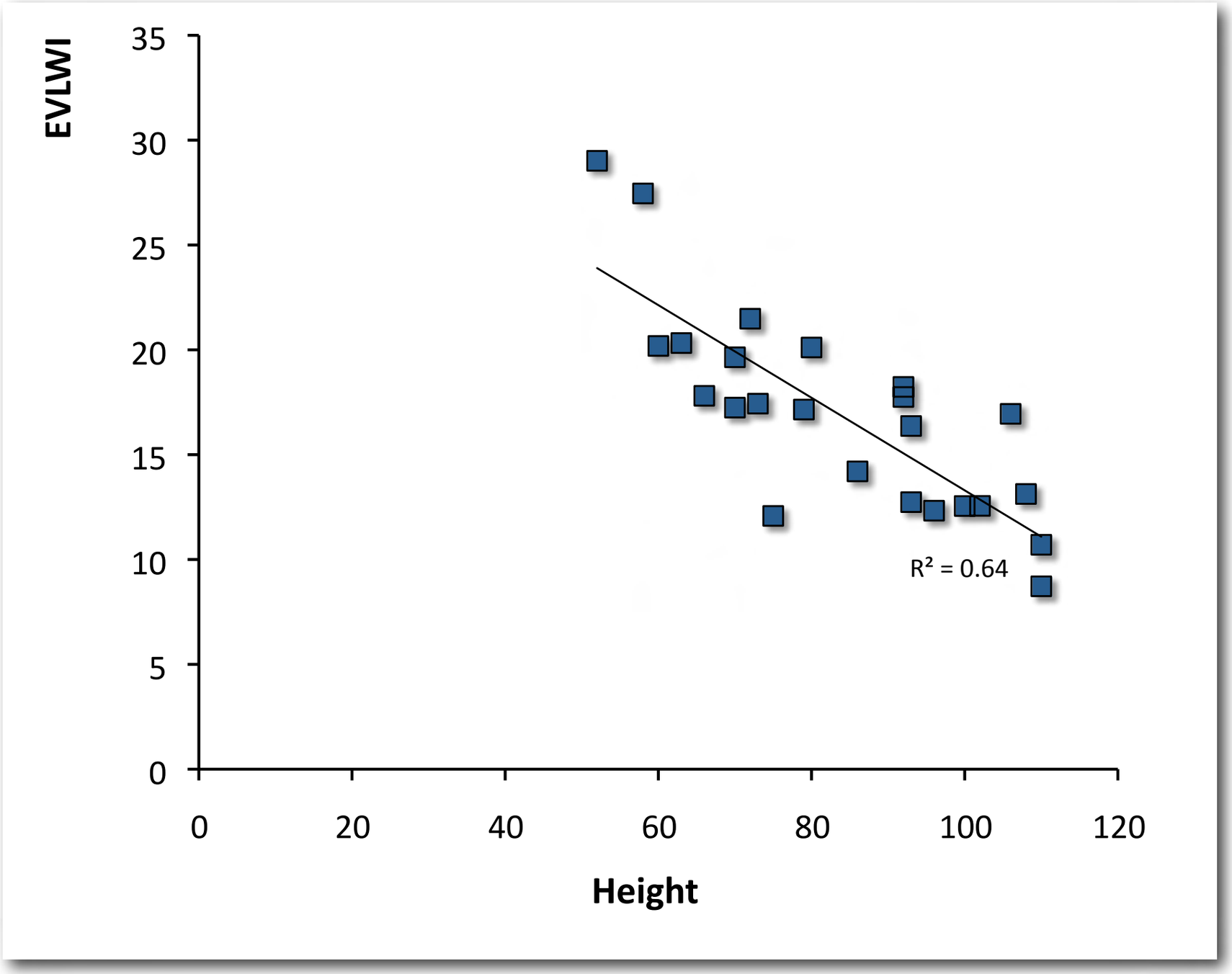
Lung water in critically ill children



EVLWI and chest x-ray score both no relation with outcome or oxygenation

Crit Care 2010;14:R105

Lung water in relation to height



Crit Care 2010;14:R105

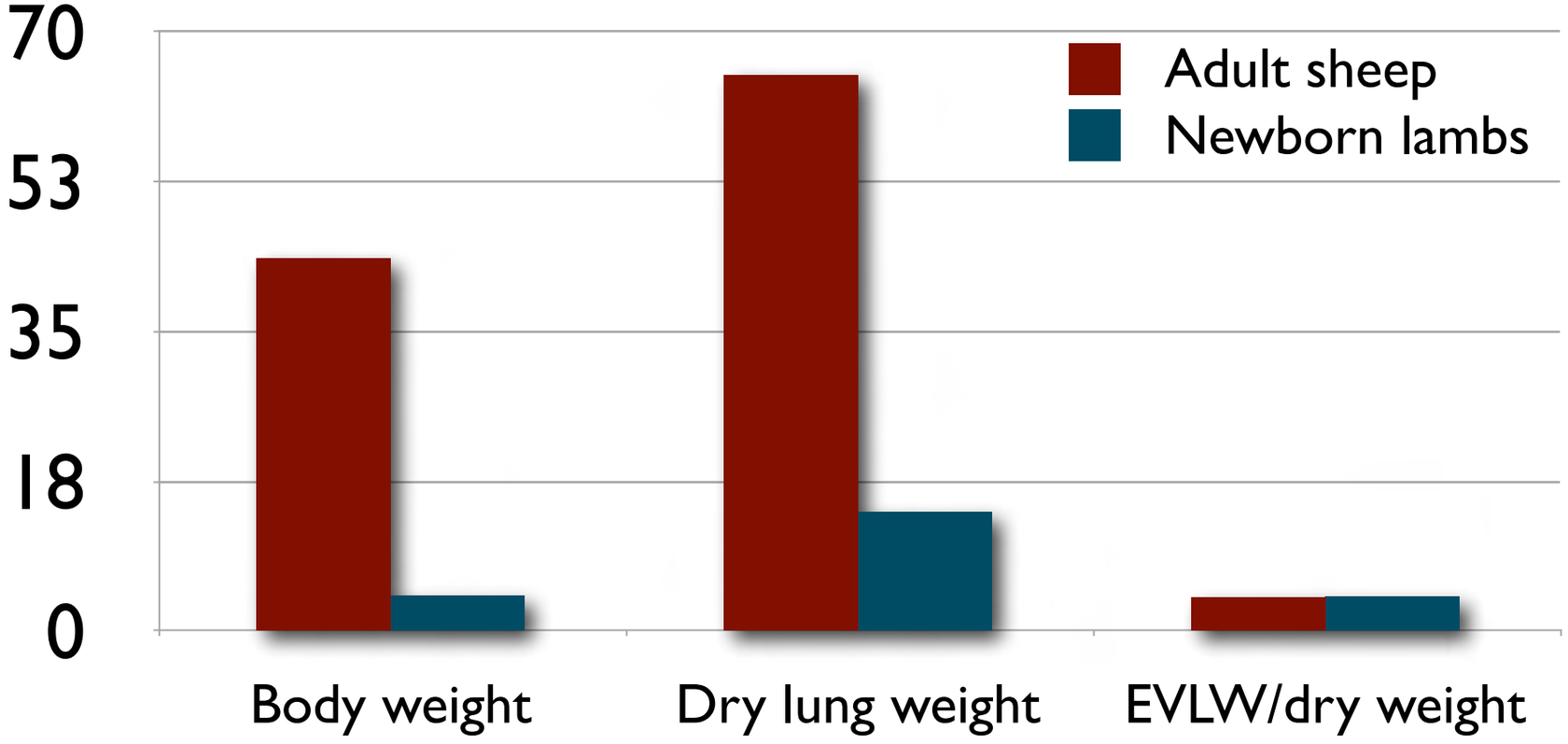
Lung water in children

- Normal lung water in young children up to 20 ml/kg? (normal adult values 3 - 7 ml/kg)
- Can we explain this phenomenon?

Lung Water and Vascular Permeability in Sheep

Newborns Compared with Adults

KENNETH L. BRIGHAM, HAKAN SUNDELL, THOMAS R. HARRIS, ZAK CATTERTON, ILLYA KOVAR, AND MILDRED STAHLMAN



Circ Res 1978;42;851-855

Age and body weight, height and lung weight

J Crit Care; 2010; submitted

Lung weight / body weight in relation to age

J Crit Care; 2010; submitted

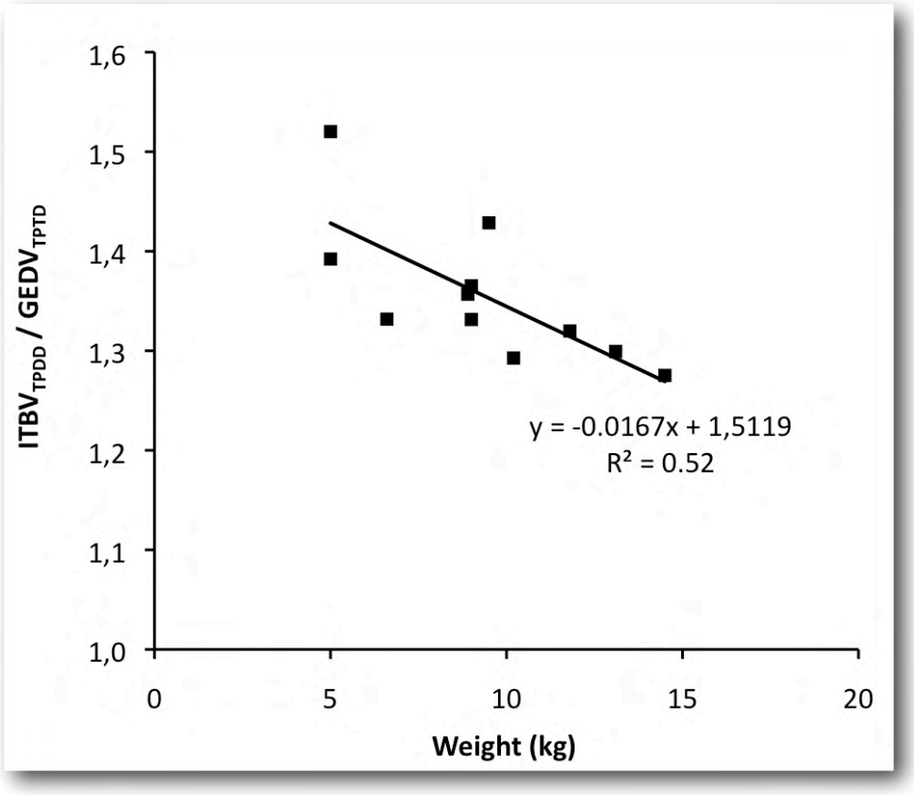
Lung water in children

- Young children have a higher lung mass
- A higher lung mass => more lung water
- A higher lung mass => higher pulmonary blood volume

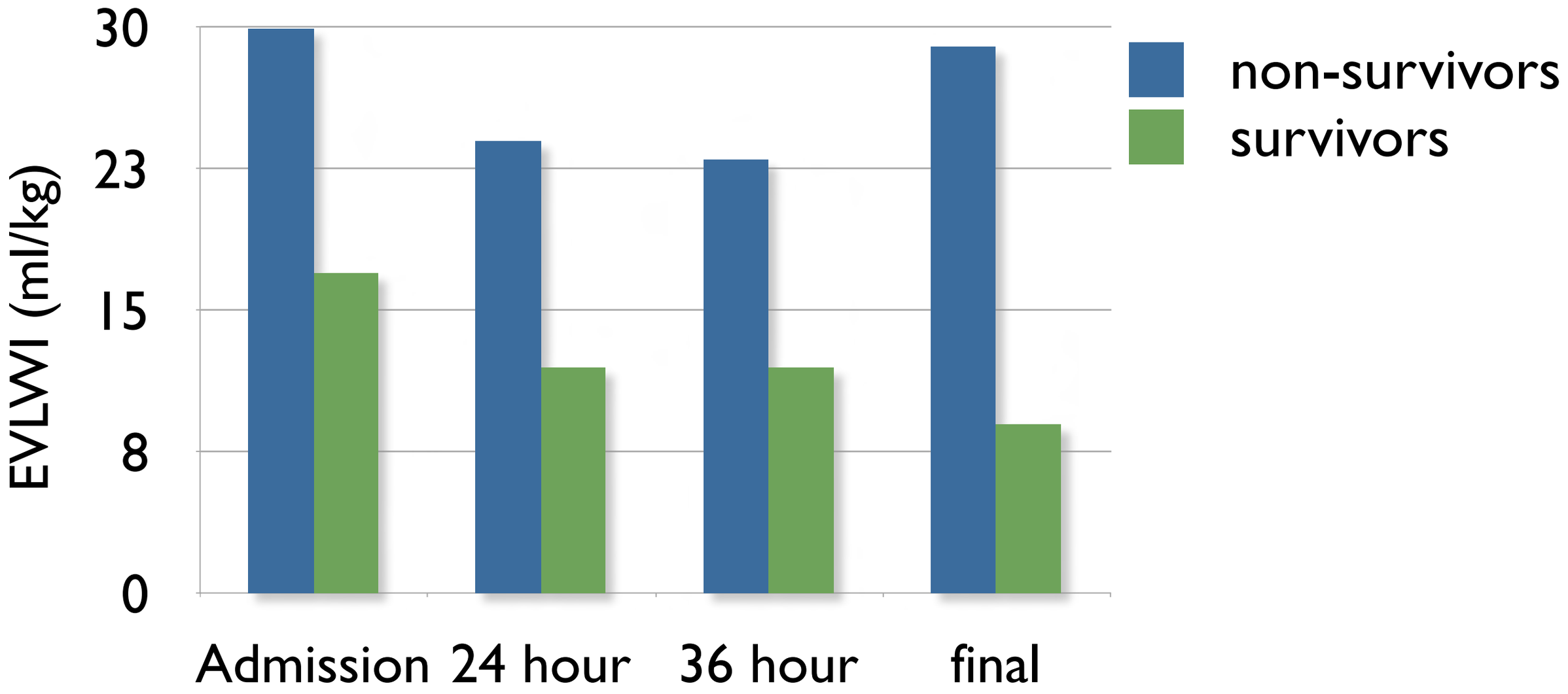
(children have higher body water content)

Solution

1. Develop age related normal values
2. Develop a correcting algorithm



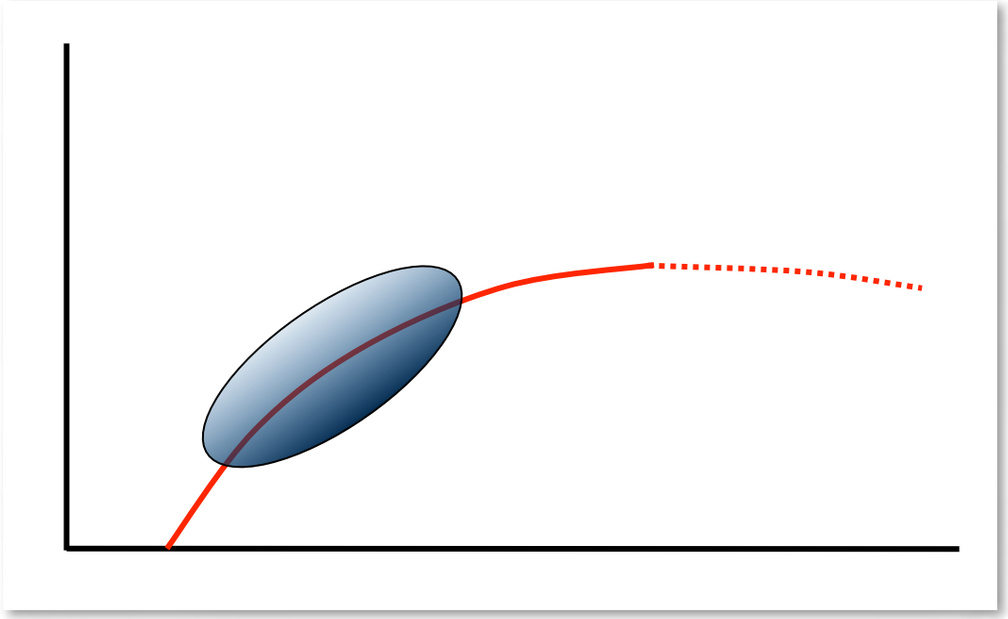
27 children with ALI/ARDS



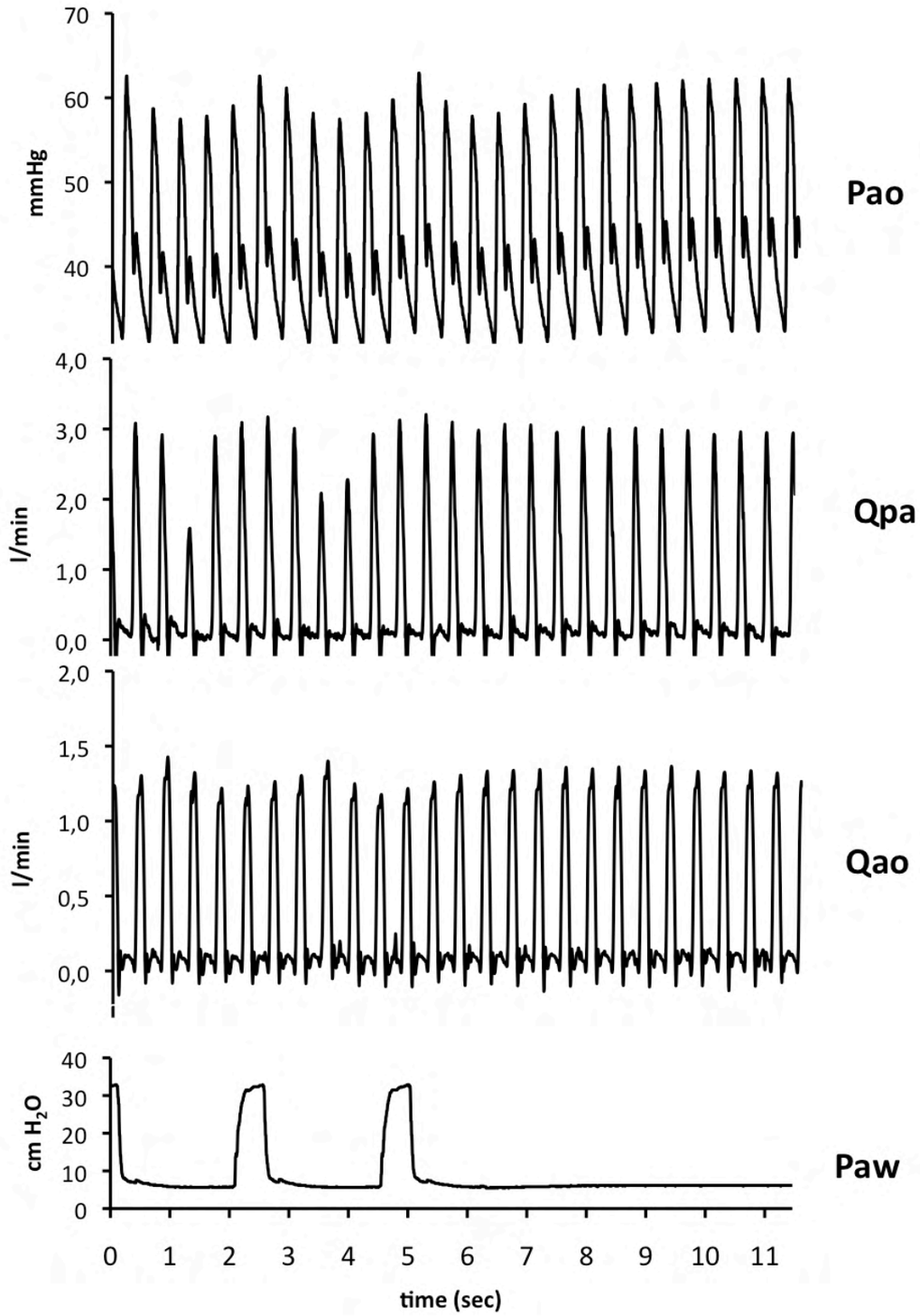
Intensive Care Med 2010 DOI 10.1007/s00134-010-2047-6

Fluid responsiveness in children

- Arterial pressure variations
- Passive leg raising test

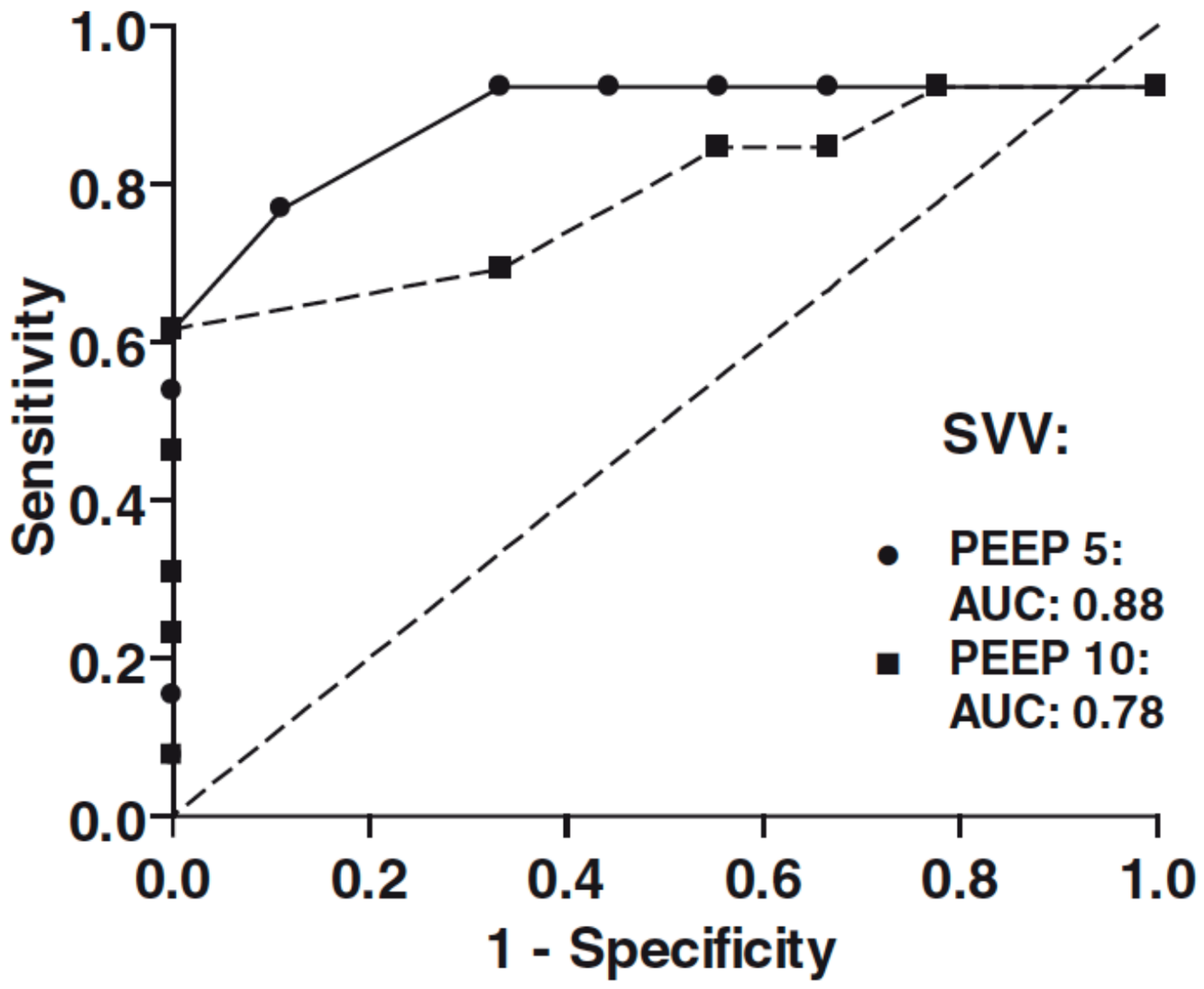


Arterial pressure variations



Lamb of 7 kg

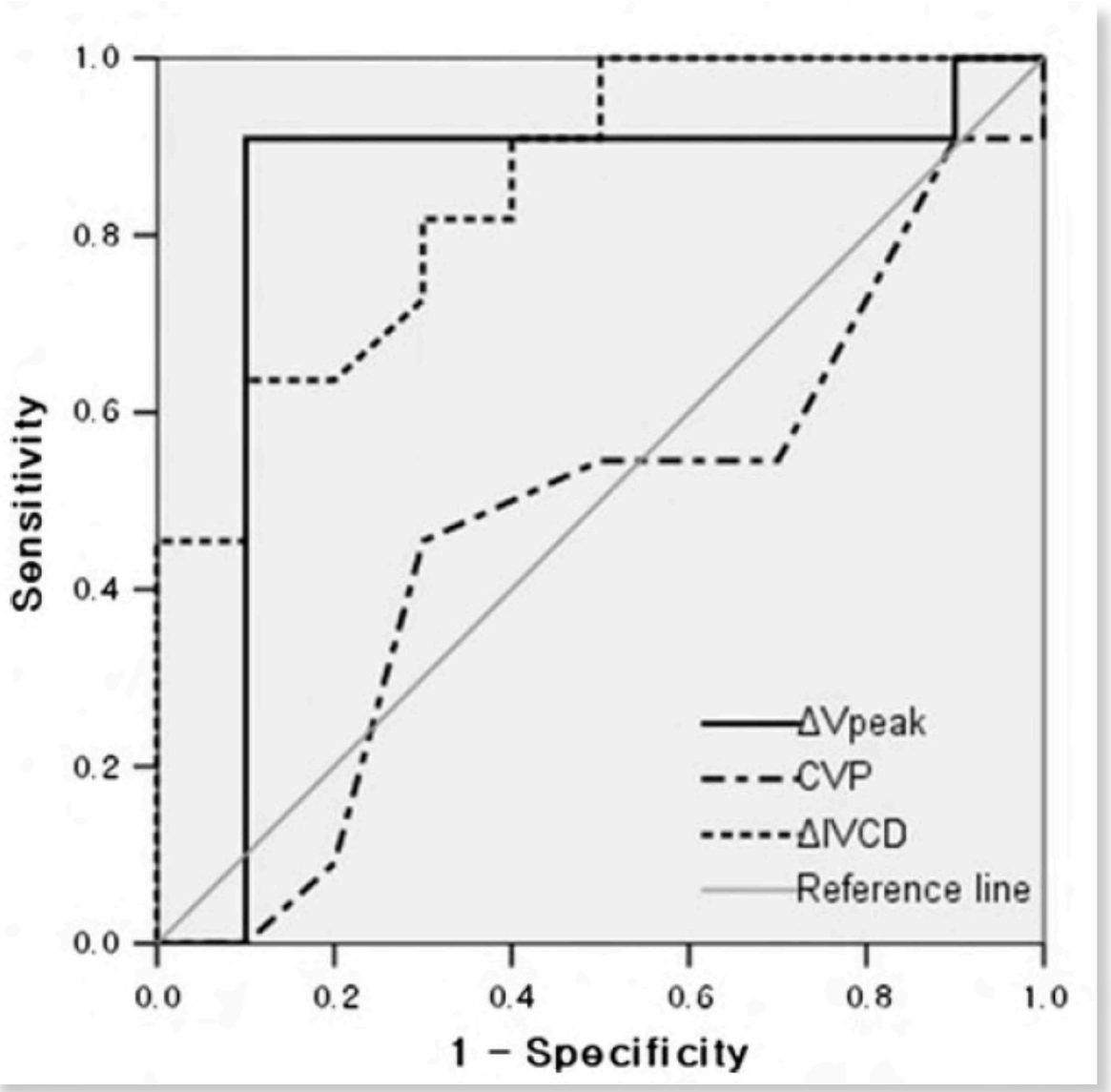
SVV in hypovolemic piglets



22 anesthetized piglets (8 kg)

Pediatric Anesthesia 2008;18:1170–1177

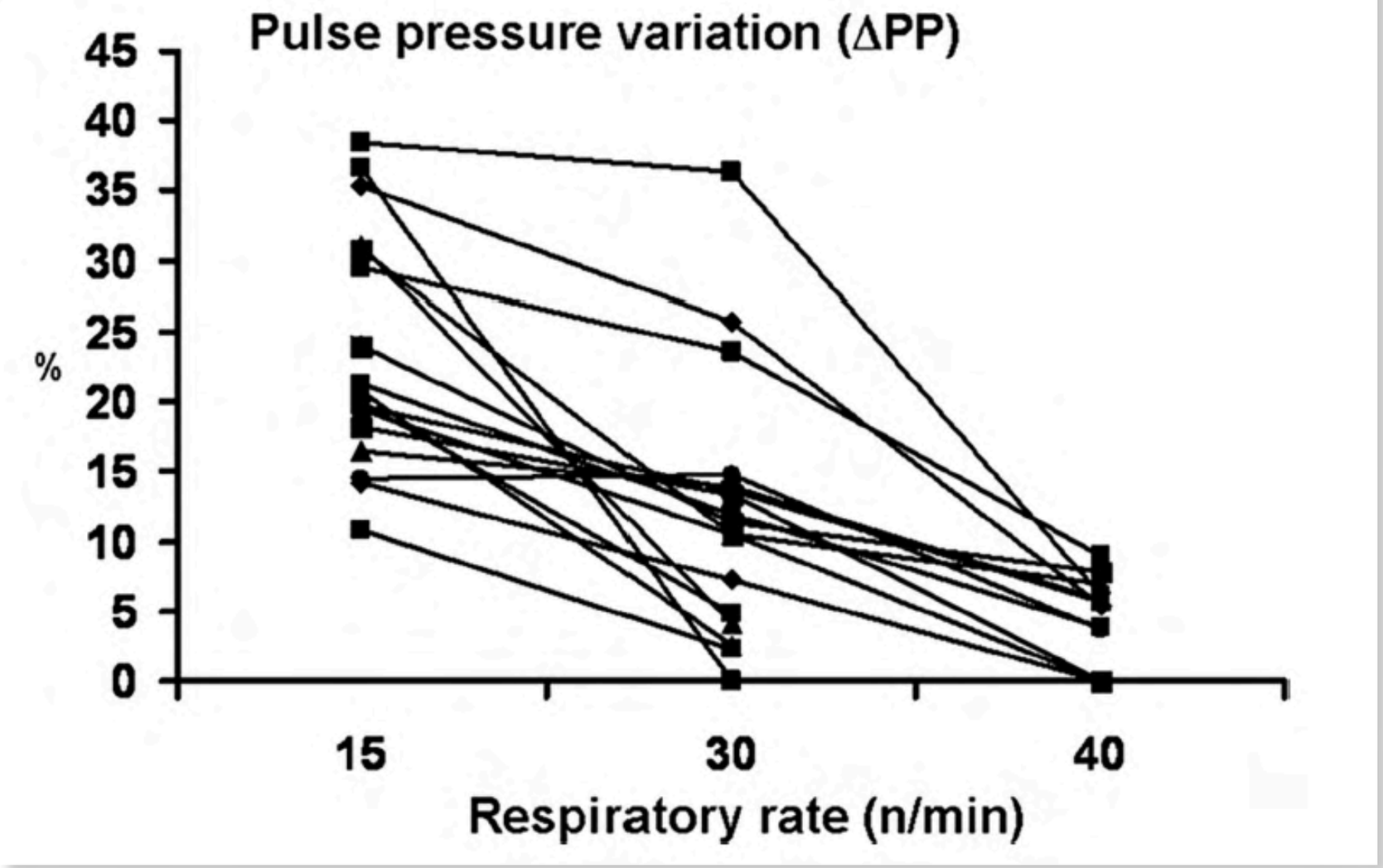
Variation of aortic blood flow velocity



21 ventilated children after closure of VSD

Pediatr Cardiol 2010; DOI: 10.1007/s00246-010-9776-8

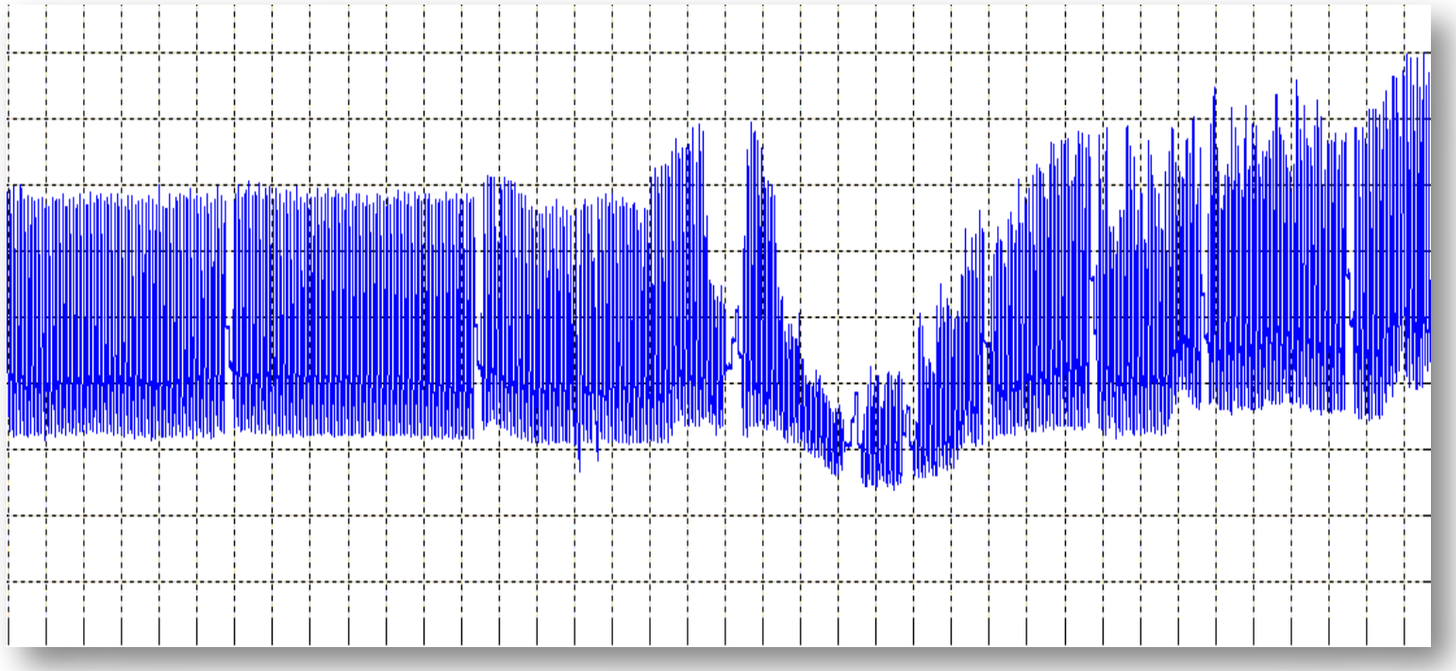
PPV and the HR/RR ratio



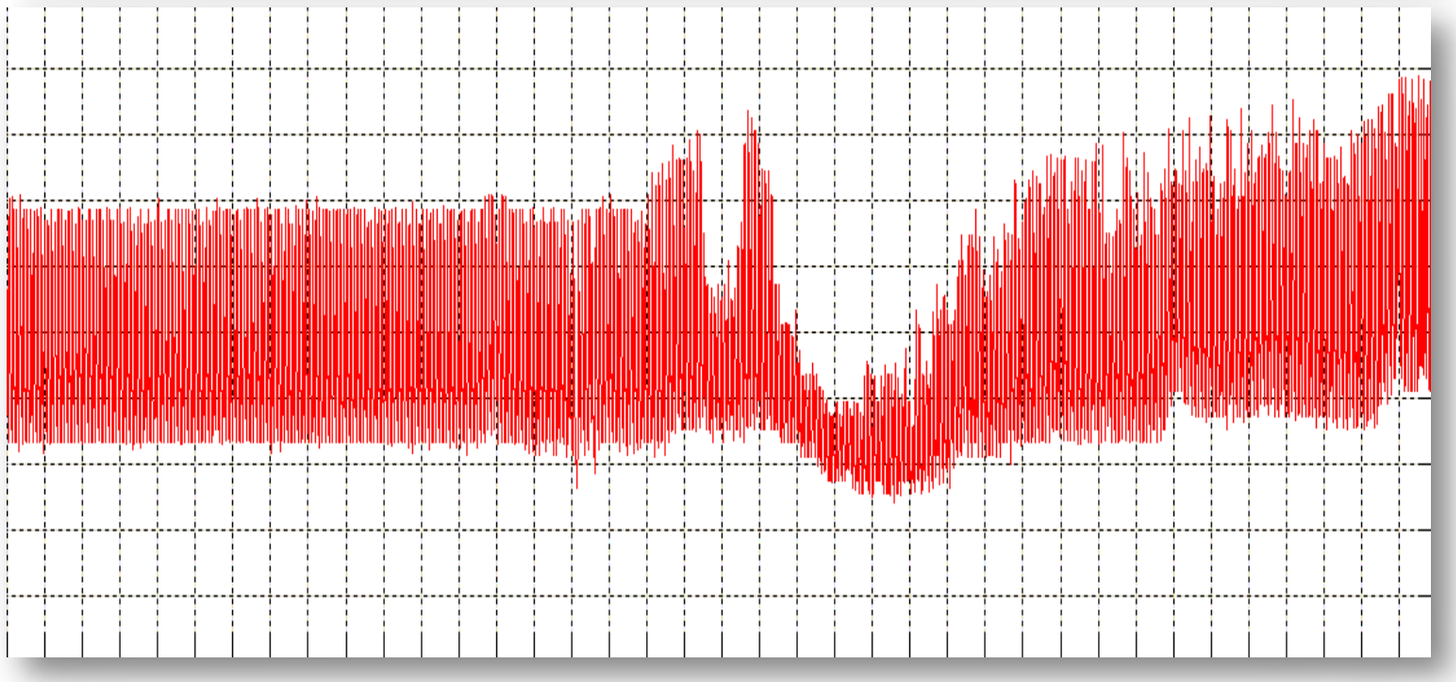
HR/RR ratio must be > 3.6

Anesthesiology 2009; 110:1092–7

Nexfin-pediatric



finger arterial pressure



intra arterial pressure

Conclusions

1. Advanced hemodynamic monitoring in children is feasible and reliable

2. Many basic values and principles are similar to adults

3. There are certain important physiological differences between young children and adults

Wise words

"No monitoring device, no matter how simple or sophisticated, will improve patient-centered outcomes unless coupled with a treatment that, itself, improves outcome……"

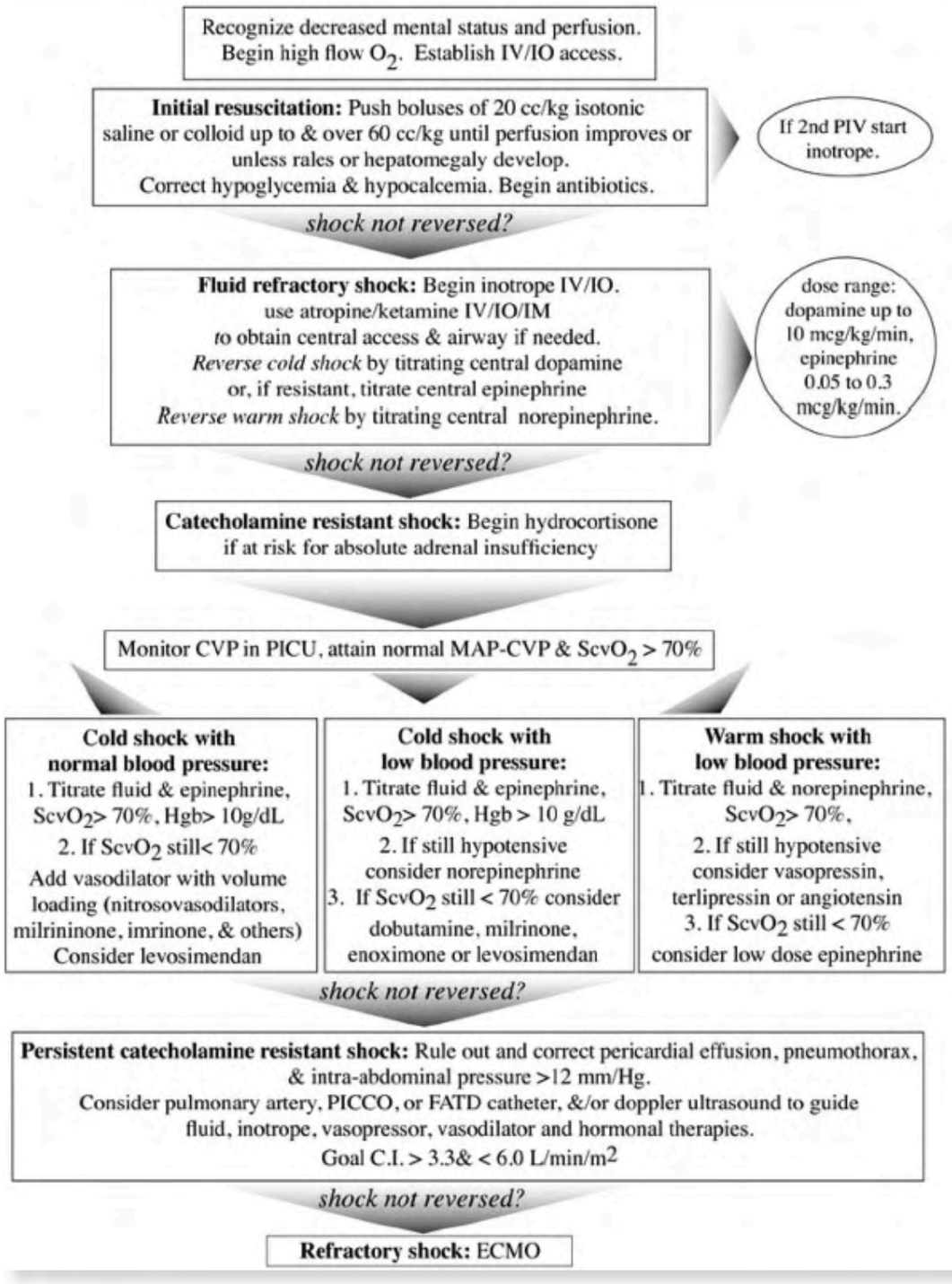
Pinsky & Vincent *Crit Care Med 2005;33:1119-1122*

Questions?

Future perspectives

- CO validation = done (non-invasive techniques excluded)
- Lung water = validation almost done
- Clinical value of lung water => not completed
- Hemodynamic treatment strategies should be tested

Surviving sepsis in children



Lots of fluids

Inotropes

CVP / $ScvO_2$

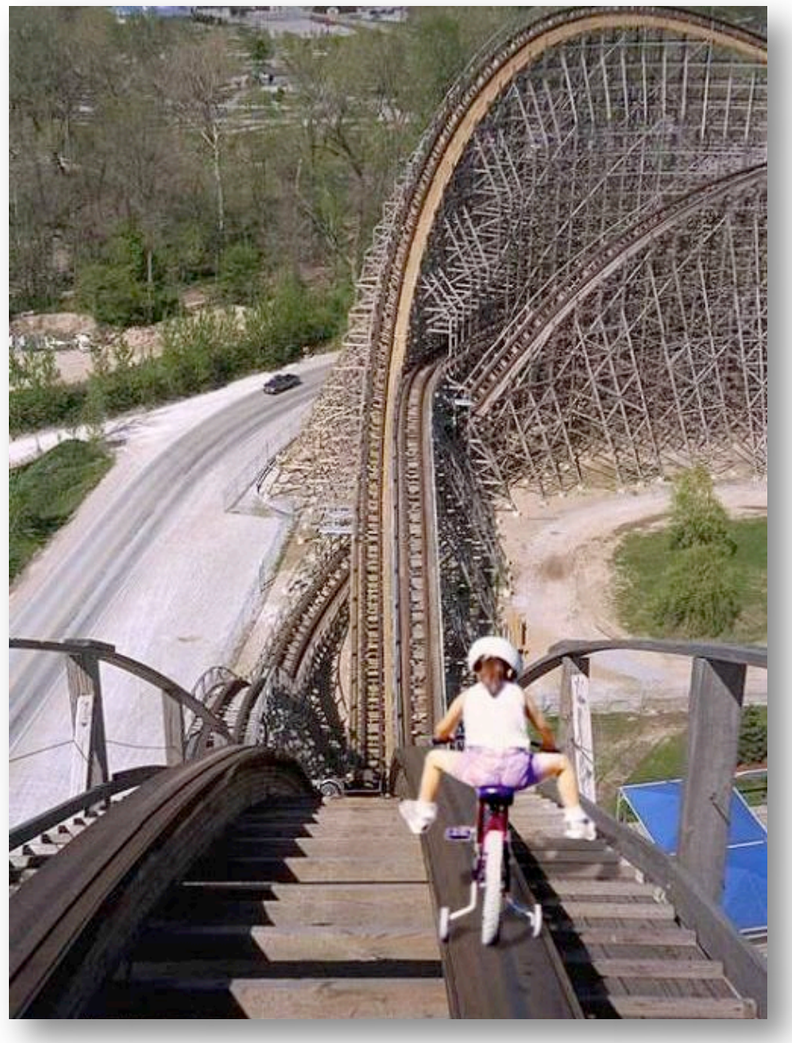
More inotropes/vasopressors
More fluids

Cardiac output
ECMO

Crit Care Med 2009; 37:666–688

PICU in the Netherlands

- 8 PICU's in The Netherlands
- 4800 admissions each year (0 to 16 year)
- Mortality 3 - 4%
- 20% of admissions: circulatory insufficiently



The New England Journal of Medicine

EARLY GOAL-DIRECTED THERAPY IN THE TREATMENT OF SEVERE SEPSIS AND SEPTIC SHOCK

EMANUEL RIVERS, M.D., M.P.H., BRYANT NGUYEN, M.D., SUZANNE HAVSTAD, M.A., JULIE RESSLER, B.S., ALEXANDRIA MUZZIN, B.S., BERNHARD KNOBLICH, M.D., EDWARD PETERSON, PH.D., AND MICHAEL TOMLANOVICH, M.D., FOR THE EARLY GOAL-DIRECTED THERAPY COLLABORATIVE GROUP*

"early goal directed therapy"

N Engl J Med 2001; 345: 1368-1377

EGDT in children

Intensive Care Med (2008) 34:1065–1075
DOI 10.1007/s00134-008-1085-9

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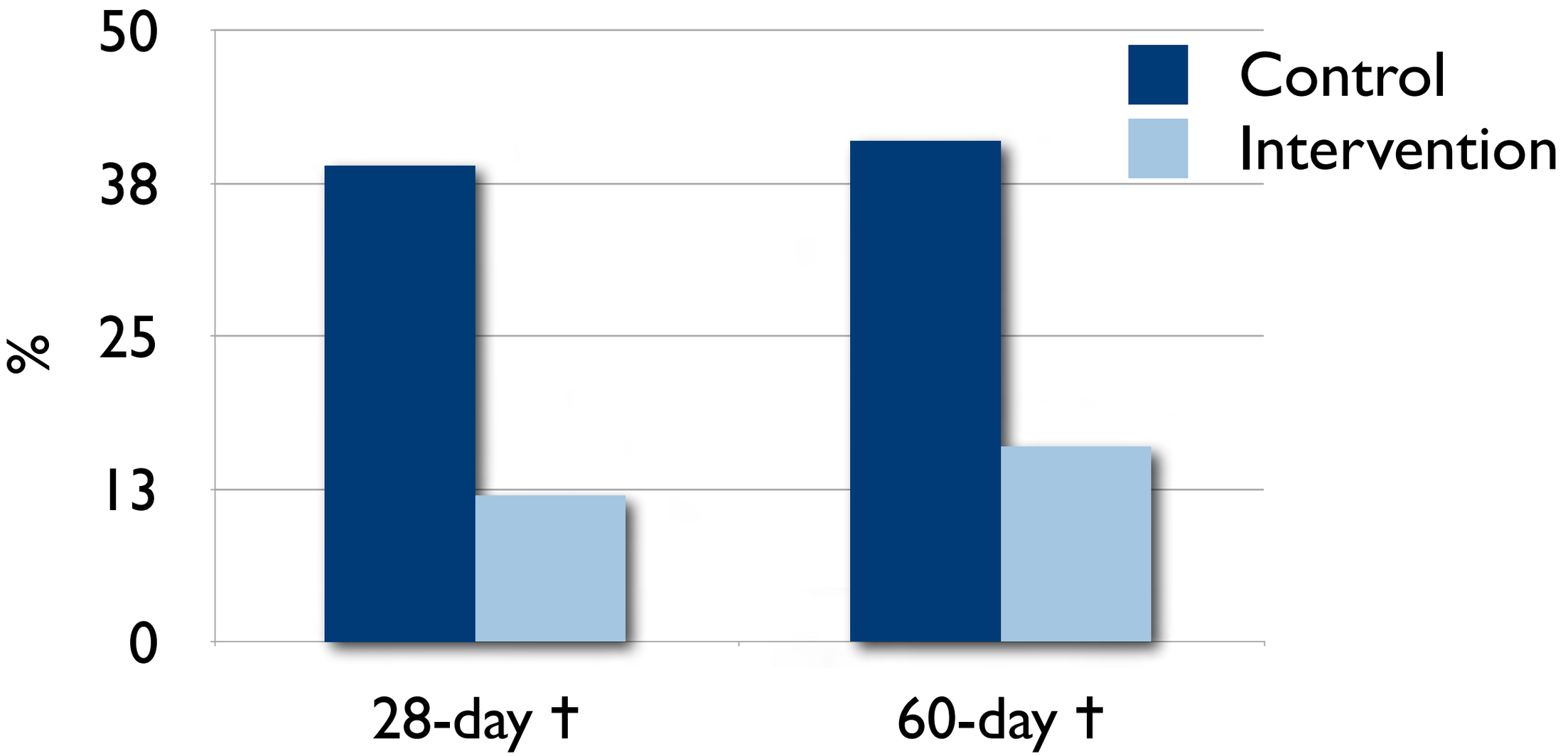
ACCM/PALS haemodynamic support guidelines for paediatric septic shock: an outcomes comparison with and without monitoring central venous oxygen saturation

$ScvO_2$ in septic children



Intensive Care Med 2008;34:1065–1075

$ScvO_2$ in septic children

parameter	Control	Intervention
Fluids total (< 6 hours)	21 ml/kg	73 ml/kg
$ScvO_2$ (after 6 hours)	74%	78%
patients with $ScvO_2$ < 70% (baseline)	31%	21%
Lactate (baseline)	1,2 mmol/l	1,1 mmol/l

Intensive Care Med (2008) 34:1065–1075