LÉKAŘSKÁ FAKULTA
MASARYKOVY UNIVERZITY
A FAKULTNÍ NEMOCNICE BRNO

KLINIKA DĚTSKÉ
ANESTEZIOLOGIE
A RESUSCITACE

Šok u dětí.

Milan Kratochvíl

UNIVERSITAS MASARYKIANA BRUNENSIS

UNIVERSITAS MASARYKIANA BRUNENSIS FACULTAS MEDICA

FAKULTNÍ NEMOCNICE BRNO

Definice

- **Cirkulační šok** je definovaný jako život ohrožující generalizovaná forma **oběhového selhání**, vedoucí ke **tkáňové hypoperfúzi** a k neadekvátnímu využití kyslíku buňkami. Je to stav nepoměru dodávky kyslíku do tkání a jeho spotřeby. Výsledek je buněčná dysoxie, s anaerobním metabolismem a orgánovou dysfunkcí.

Intensive Care Med (2014) 40:1795–1815

Hemodynamic Support in Fluid-refractory Pediatric Septic Shock

Gary Ceneviva, J. Alan Paschall, Frank Maffei and Joseph A. Carcillo

Pediatrics 1998;102:e19

Teplý šok

Studený šok

TABLE 3. CI (L/min/m^2) and SVRI (dyne/sec/cm^5) in Groups I, II, and III After Fluid Resuscitation, Initial Therapy Adjustment, and 48 Hours

	After Fluid Resuscitation	After Initial Therapy Adjustment	48 Hours
Group I (n = 29)			
CI	3.06 ± .26	3.3 ± .16*	4.0 ± .2**
SVRI	1794 ± 176	1758 ± 158*	1178 ± 65**
Group II (n = 10)			
CI	8.51 ± 1.1	6.3 ± .75	5.06 ± .41**
SVRI	622 ± 184	919 ± 99	1090 ± 91**
Group III (n = 11)			
CI	3.93 ± .28	4.37 ± .26	5.07 ± .29**
SVRI	922 ± 87	904 ± 65	1089 ± 92

58%

in children.[4] As a result, many paediatric clinicians in intensive care units rely on indirect variables of cardiac performance (heart rate, blood pressure, pulse volume, central venous pressure) and organ perfusion (urine output, capillary refill, core-peripheral temperature difference, mental state, serum lactate concentration, and base excess) when manipulating treatment regimens.

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

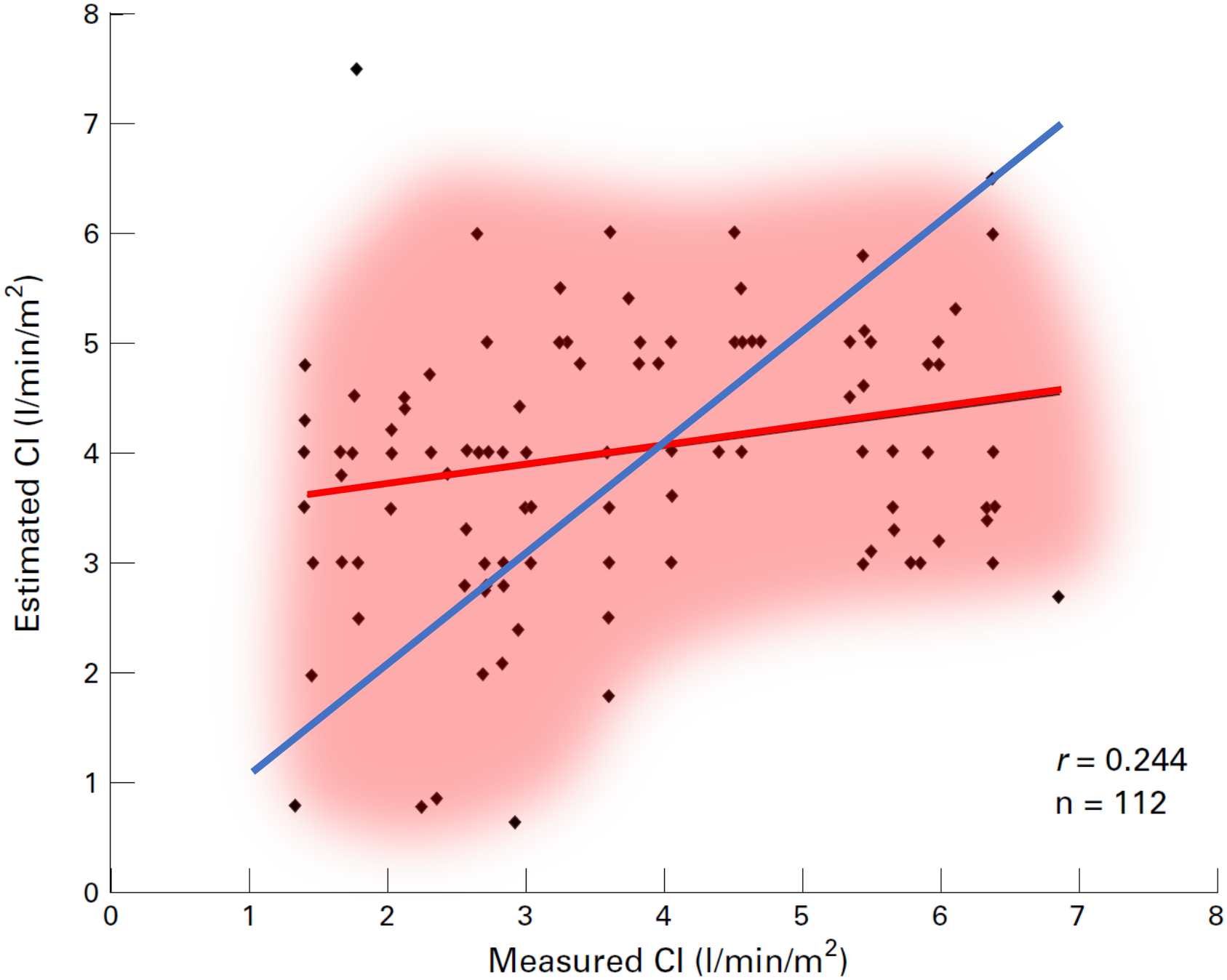
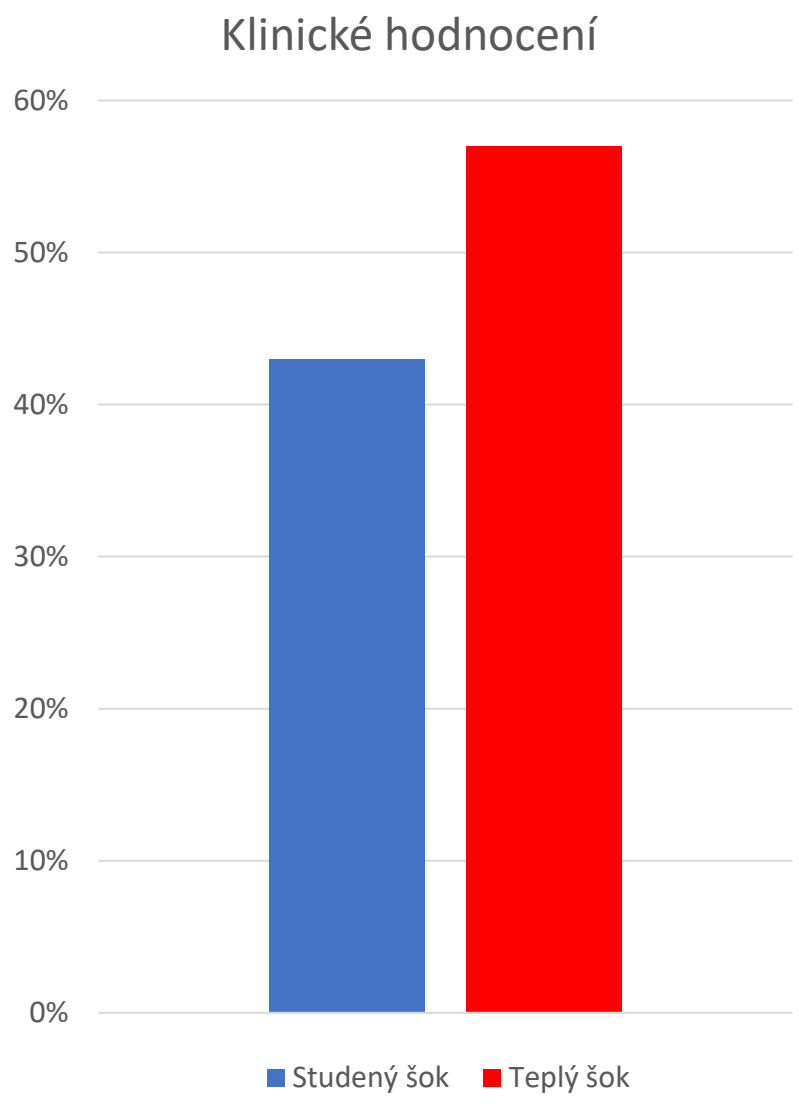
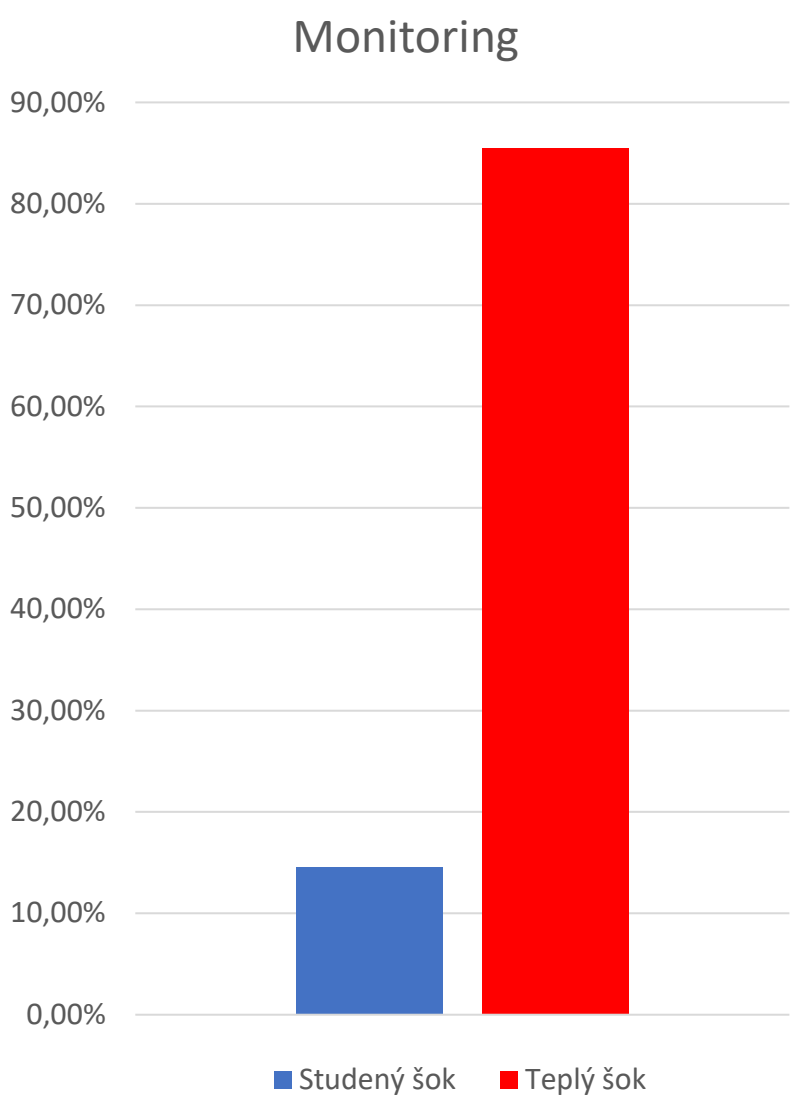


Figure 1 *Estimated v measured cardiac index (CI) from all grades.* *Archives of Disease in Childhood* 1997;77:516–518





(*Pediatr Crit Care Med* 2014; 15:e17–e26)

Singh *et al. Critical Care* (2020) 24:620
https://doi.org/10.1186/s13054-020-03326-2

Critical Care

RESEARCH

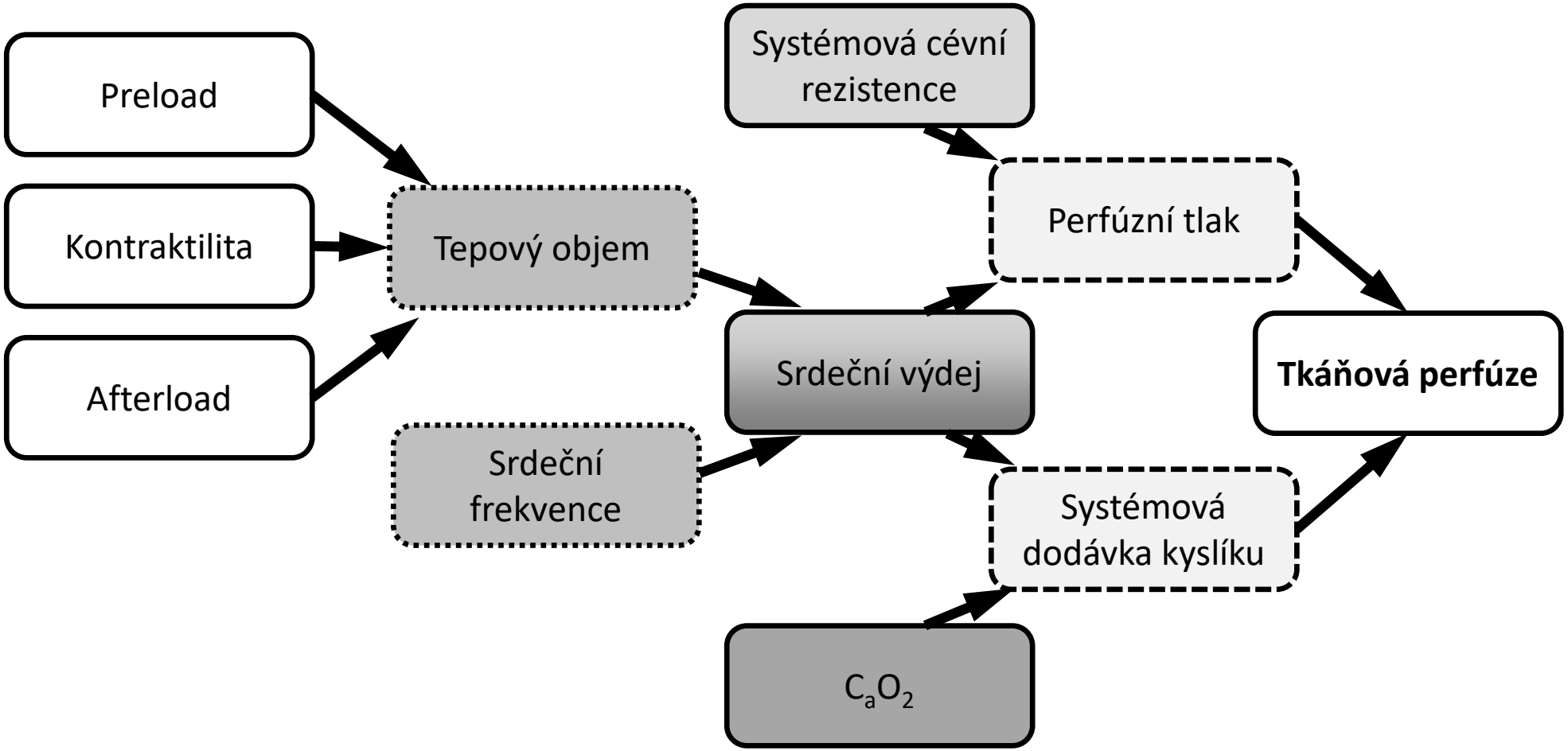
Open Access

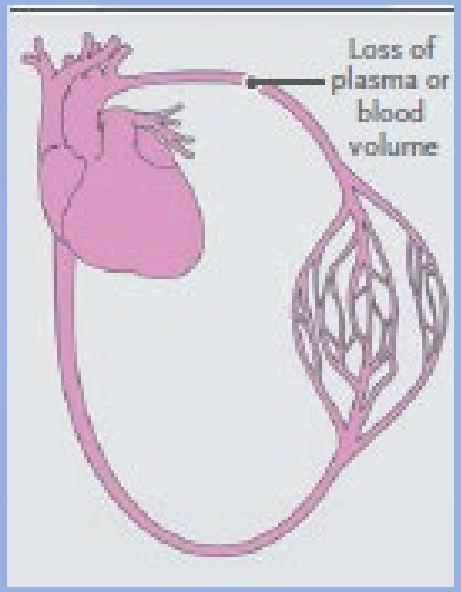
Recommendations for hemodynamic monitoring for critically ill children—expert consensus statement issued by the cardiovascular dynamics section of the European Society of Paediatric and Neonatal Intensive Care (ESPNIC)

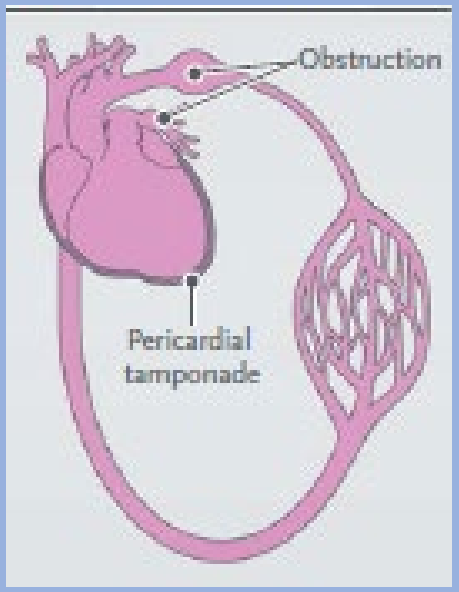
Yogen Singh[1*], Javier Urbano Villaescusa[2], Eduardo M. da Cruz[3], Shane M. Tibby[4], Gabriella Bottari[5], Rohit Saxena[6], Marga Guillén[7], Jesus Lopez Herce[2], Matteo Di Nardo[5], Corrado Cecchetti[5], Joe Brierley[6], Willem de Boode[8] and Joris Lemson[9]

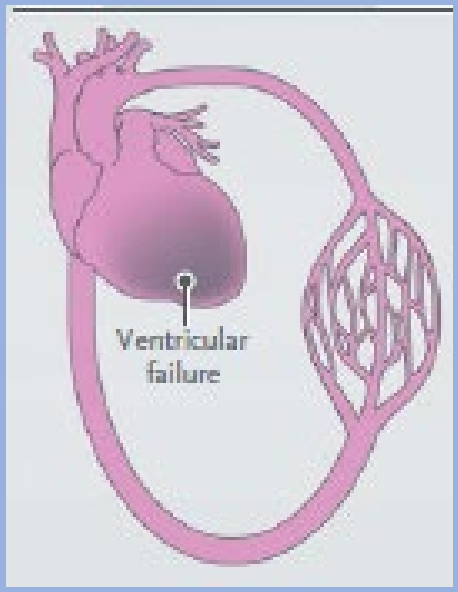
Determinanty orgánové perfúze

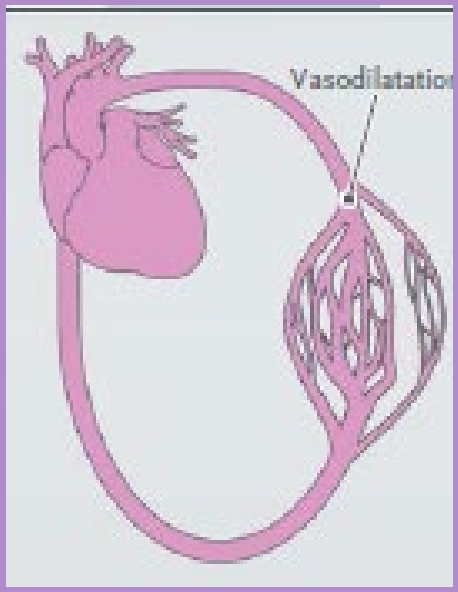
1. Systémová dodávka kyslíku
2. Perfúzní tlak


Preload
Kontraktilita
Afterload
Tepový objem
Srdeční frekvence
Systémová cévní rezistence
Srdeční výdej
Perfúzní tlak
Systémová dodávka kyslíku
C_aO_2
Tkáňová perfúze









Hypovolemický

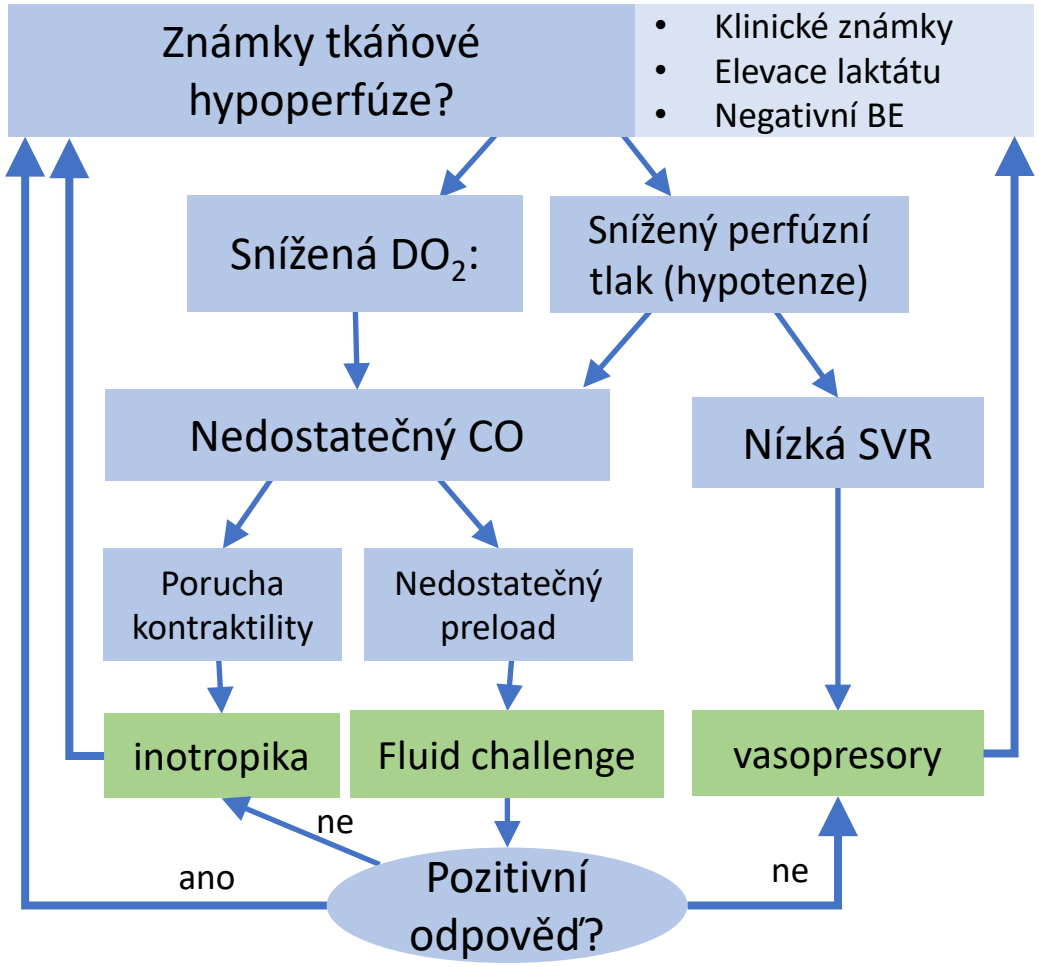
Obstrukční

Kardiogenní

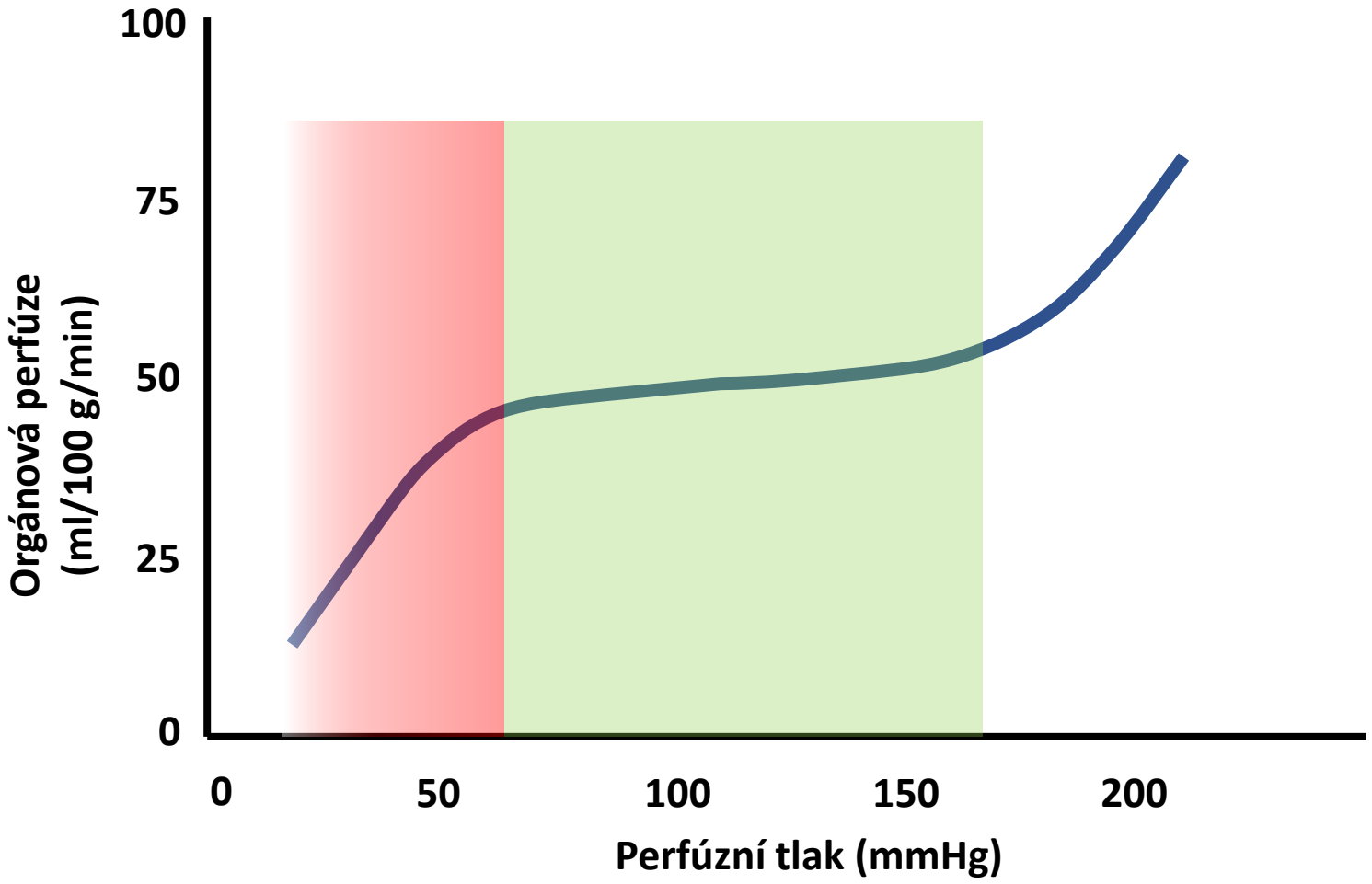
Distributivní

↓ CO

↑ CO?

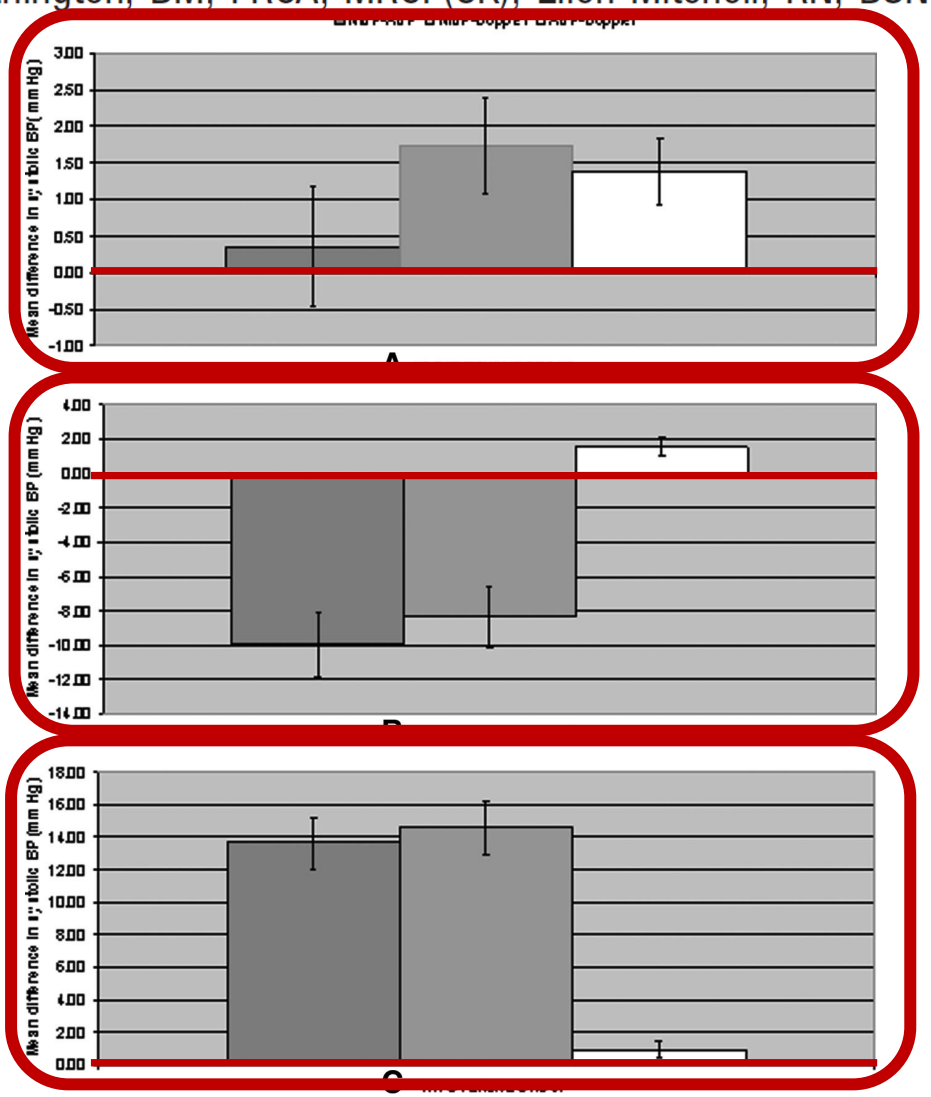

Známky tkáňové hypoperfúze?
Klinické známky
Elevace laktátu
Negativní BE
Snížená DO_2:
Snížený perfúzní tlak (hypotenze)
Nedostatečný CO
Nízká SVR
Porucha kontraktility
Nedostatečný preload
inotropika
Fluid challenge
vasopresory
ne
ano
Pozitivní odpověď?
ne

Perfúzní tlak


100
75
50
25
0
Orgánová perfúze
(ml/100 g/min)
0
50
100
150
200
Perfúzní tlak (mmHg)

Which pressure to believe? A comparison of direct arterial with indirect blood pressure measurement techniques in the pediatric intensive care unit

Tanya R. Holt, MD, FRCPC; Davinia E. Withington, BM, FRCA, MRCP(UK); Ellen Mitchell, RN, BSN

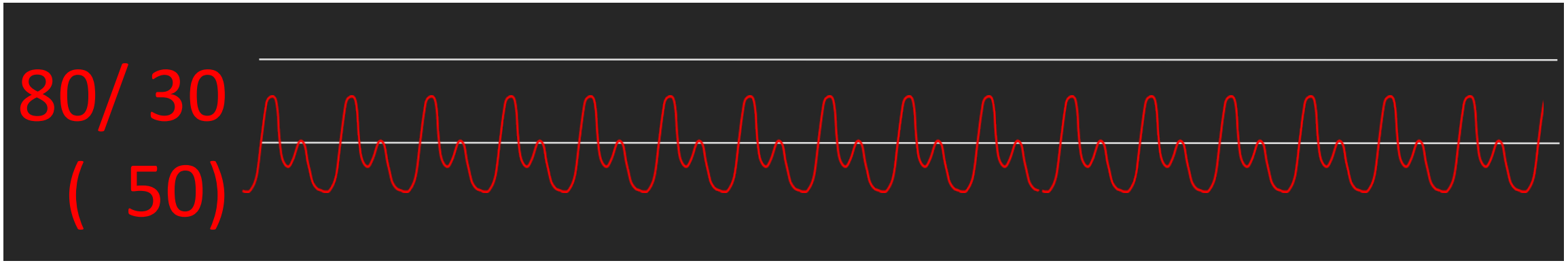


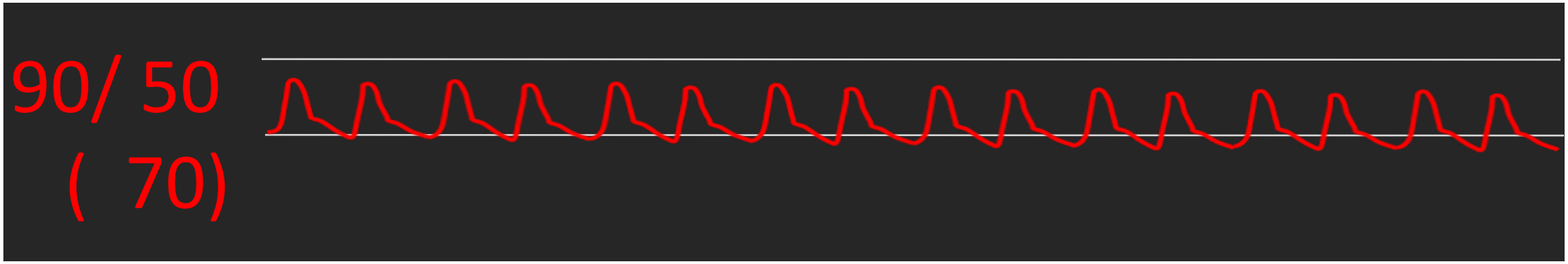
Pediatr Crit Care Med 2011 Vol. 12, No. 6

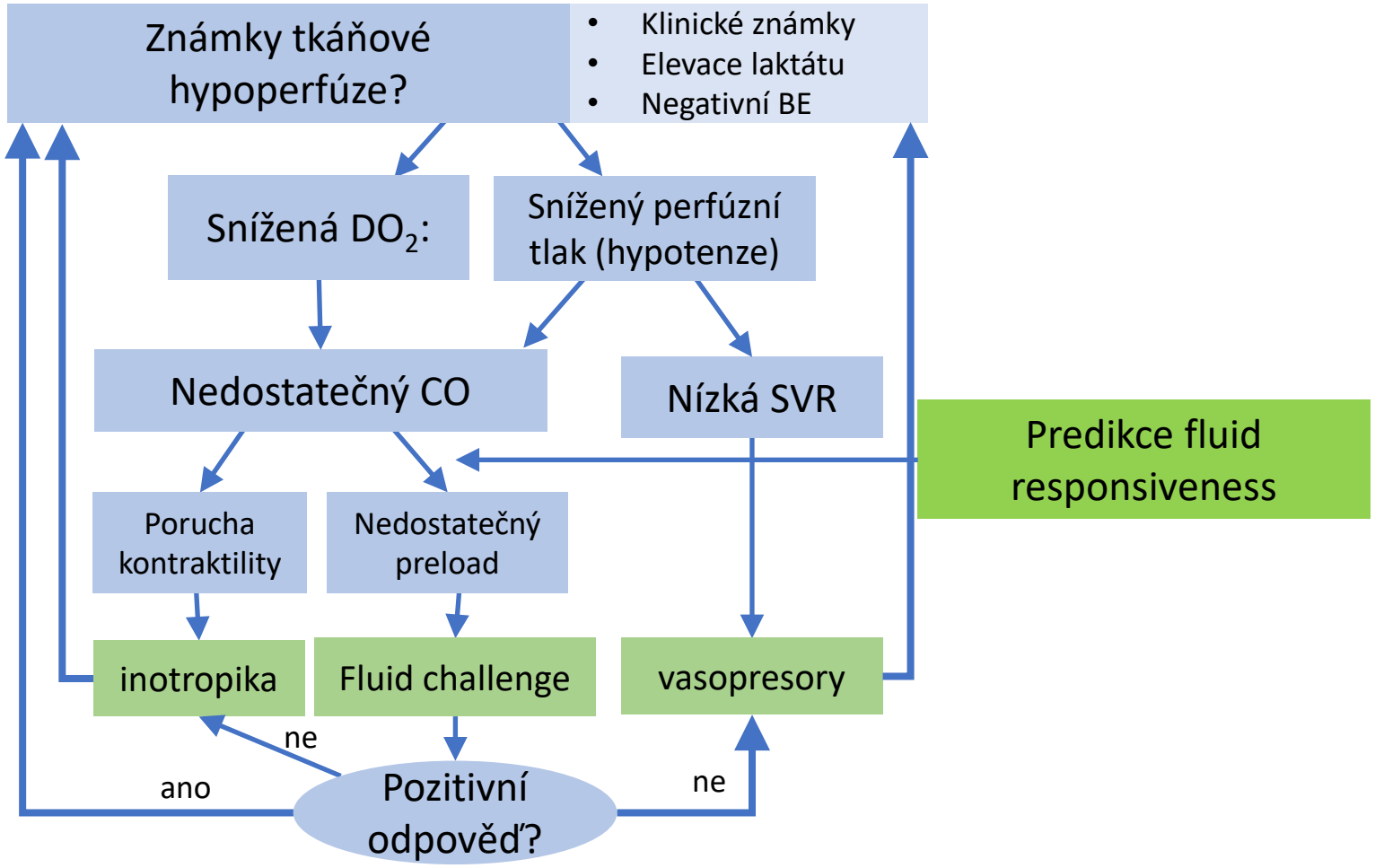
Indikace invazivního měření TK u dětí

- Šok s nedostatečnou odpovědí na iniciální tekutinovou terapii
- Nutnost podávání vazopresorů a/nebo inotropik
- Nitrolební hypertenze, měření CPP
- Rizikový chirurgický výkon
- Hypertenzní emergence
- Sledování efektu inotropik a vazopresorů

Singh et al. Critical Care (2020) 24:620


80/ 30
(50)


90/ 50
(70)


Známky tkáňové hypoperfúze?
Klinické známky
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Snížená DO_2:
Snížený perfúzní tlak (hypotenze)
Nedostatečný CO
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Predikce fluid responsiveness
Porucha kontraktility
Nedostatečný preload
inotropika
Fluid challenge
vasopresory
ne
ano
ne
Pozitivní odpověď?

Pozitivní tekutinová bilance

	OR (95% CI)	p Value
SAPS II score[a] (per point increase)	1.0 (1.0–1.1)	<.001
Cumulative fluid balance[b] (per liter increase)	1.1 (1.0–1.1)	.001
Age (per year increase)	1.0 (1.0–1.0)	.001
Initial SOFA score (per point increase)	1.1 (1.0–1.1)	.002
Blood stream infection	1.7 (1.2–2.4)	.004
Cirrhosis	2.4 (1.3–4.5)	.008
Pseudomonas infection	1.6 (1.1–2.4)	.017
Medical admission	1.4 (1.0–1.8)	.049
Female gender	1.4 (1.0–1.8)	.044

Crit Care Med 2006 Vol. 34, No. 2

Table 3. Main Outcome Variables.*

Outcome	Conservative Strategy	Liberal Strategy	P Value
Death at 60 days (%)	25.5	28.4	0.30
Ventilator-free days from day 1 to day 28†	14.6±0.5	12.1±0.5	<0.001
ICU-free days†			
Days 1 to 7	0.9±0.1	0.6±0.1	<0.001
Days 1 to 28	13.4±0.4	11.2±0.4	<0.001
Organ-failure–free days†‡			
Days 1 to 7			
Cardiovascular failure	3.9±0.1	4.2±0.1	0.04
CNS failure	3.4±0.2	2.9±0.2	0.02
Renal failure	5.5±0.1	5.6±0.1	0.45
Hepatic failure	5.7±0.1	5.5±0.1	0.12
Coagulation abnormalities	5.6±0.1	5.4±0.1	0.23
Days 1 to 28			
Cardiovascular failure	19.0±0.5	19.1±0.4	0.85
CNS failure	18.8±0.5	17.2±0.5	0.03
Renal failure	21.5±0.5	21.2±0.5	0.59
Hepatic failure	22.0±0.4	21.2±0.5	0.18
Coagulation abnormalities	22.0±0.4	21.5±0.4	0.37
Dialysis to day 60			
Patients (%)	10	14	0.06
Days	11.0±1.7	10.9±1.4	0.96

N ENGL J MED 354;24

TABLE 2 | Fluid overload during admission and oxygenation index.

FO Day 1	Oxygenation index
<5%	4.77 (3.93–5.60)
5–9.99%	11.47 (4.22–18.72)
10–14.99%	19.50 (1.6–28.4)

p = 0.002.

TABLE 7 | Association of peak fluid overload and clinical parameters.

Parameter	Regression coefficient (95% CI)	*p*-value
Age (years)	−0.234 (0.049 to 0.031)	0.082
Sex	−0.732 (−4.00 to 2.54)	0.658
PELOD Score at admission	0.219 (0.075 to 0.36)	0.003
Ventilation (days)	0.342 (0.17 to 0.85)	0.0388
ICU (days)	−0.029 (−0.46 to 0.40)	0.896
Hospital stay (days)	0.148 (−0.088 to 0.38)	0.215

TABLE 6 | Independent association of peak FO with mortality.

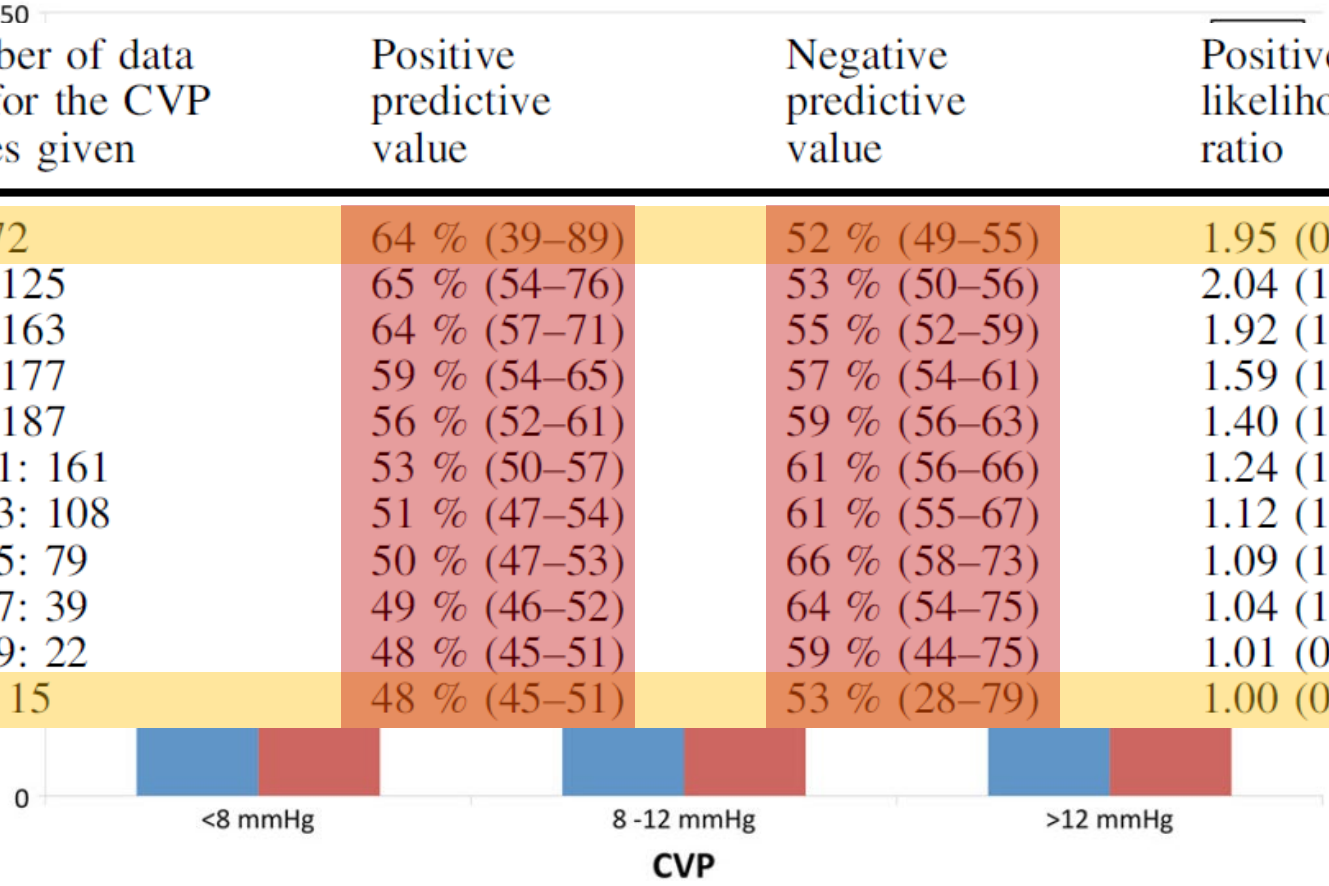
	Parameter	Adjusted OR for mortality (95% CI)	*p*-value
Peak FO%	<5% (Baseline/Constant)		
	5–9.99%	2.520 (1.80–7.92)	0.011
	10–14.99%	2.751 (1.32–15.66)	0.041
	>15%	3.675 (1.28–23.18)	0.039
Age groups	<1 year (Baseline/Constant)		
	1–3 years	0.173 (0.02–1.19)	0.075
	3–12 years	0.301 (0.06–1.50)	0.144
	12–18 years	1.471 (0.41–5.22)	0.551

Sethi 18 Front. Pediatr. 6:118

Predikce fluid-responsiveness

Statické prediktory

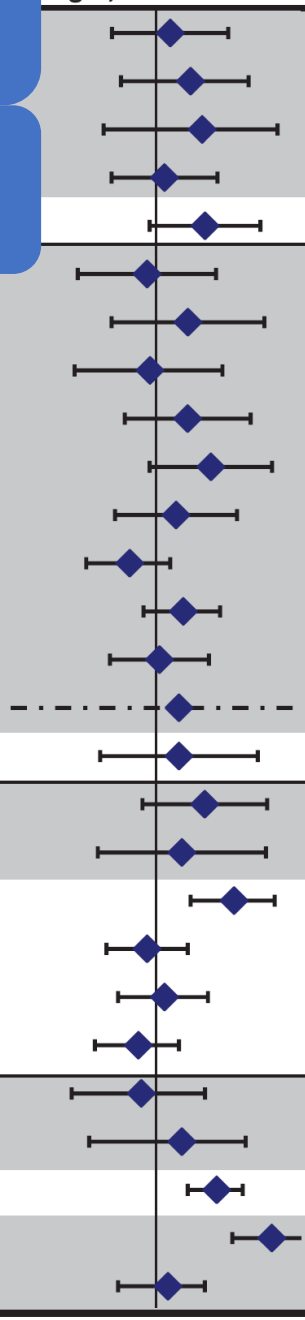
CVP cut-off point (mmHg)	Number of data sets for the CVP ranges given	Positive predictive value	Negative predictive value	Positive likelihood ratio	Negative likelihood ratio
0	<2: 72	64 % (39–89)	52 % (49–55)	1.95 (0.66–5.78)	0.99 (0.98–1.00)
2	2–3: 125	65 % (54–76)	53 % (50–56)	2.04 (1.27–3.26)	0.95 (0.93–0.98)
4	4–5: 163	64 % (57–71)	55 % (52–59)	1.92 (1.47–2.51)	0.88 (0.83–0.92)
6	6–7: 177	59 % (54–65)	57 % (54–61)	1.59 (1.33–1.89)	0.81 (0.75–0.88)
8	8–9: 187	56 % (52–61)	59 % (56–63)	1.40 (1.24–1.59)	0.74 (0.66–0.83)
10	10–11: 161	53 % (50–57)	61 % (56–66)	1.24 (1.13–1.35)	0.69 (0.59–0.81)
12	12–13: 108	51 % (47–54)	61 % (55–67)	1.12 (1.05–1.19)	0.69 (0.55–0.85)
14	14–15: 79	50 % (47–53)	66 % (58–73)	1.09 (1.04–1.14)	0.56 (0.41–0.77)
16	16–17: 39	49 % (46–52)	64 % (54–75)	1.04 (1.00–1.07)	0.60 (0.38–0.94)
18	18–19: 22	48 % (45–51)	59 % (44–75)	1.01 (0.99–1.03)	0.74 (0.39–1.41)
20	>19: 15	48 % (45–51)	53 % (28–79)	1.00 (0.99–1.01)	0.95 (0.35–2.60)



Intensive Care Med (2016) 42:324–332

Predikce fluid-responsiveness

Statické prediktory



		Area under ROC with 95% CI (numerical value on right, vertical line is 0.5)	Fluid bolus, *n*	Setting	Study
		0.55	33	Neuro OR	Byon[24]
		0.62	19	Neuro OR, 0-6 yrs	Pereira de Souza Neto[6]
		0.66	11	Neuro OR, 6-14 yrs	Pereira de Souza Neto[6]
		0.53	27	Cardiac OR	Renner 2011[8]
		0.67	33	Neuro OR	Byon[24]
Preload pressure	CVP	0.47	33	Neuro OR	Byon[24]
		0.61	19	Cardiac cath	Chandler[5]
		0.48	21	Cardiac PICU	Choi[2]
		0.61	26	Cardiac OR, ASD/VSD	Renner 2012[7]
		0.69	26	Cardiac OR, closed ASD/VSD	Renner 2012[7]
		0.57	27	Cardiac OR	Renner 2011[8]
		0.41	65	Mixed PICU	Saxena[9]
		0.60	58	Cardiac PICU	Tibby[25]
		0.51	36	General PICU	Tibby[25]
		0.58	44	Cardiac OR	Tran[26]
	PAOP	0.67	19	Cardiac cath	Chandler[5]
Thermodilution & US dilution	GEDVI	0.59	26	Cardiac OR, ASD/VSD	Renner 2012[7]
		0.77	26	Cardiac OR, closed ASD/VSD	Renner 2012[7]
	ACV	0.47	65	Mixed PICU	Saxena[9]
	CBV	0.53	65		
	TEDV	0.44	65		
	TEF	0.45	65		
Echocardiography & Doppler	LVEDA	0.59	19	Neuro OR, 0-6 yrs, TTE	Pereira de Souza Neto[6]
		0.71	11	Neuro OR, 6-14 yrs, TTE	Pereira de Souza Neto[6]
	SVI	0.90	50	General OR, TED	Raux[3]
	FTc	0.54	58	Cardiac PICU, TED	Tibby[25]
		0.76	36	General PICU, TED	Tibby[25]

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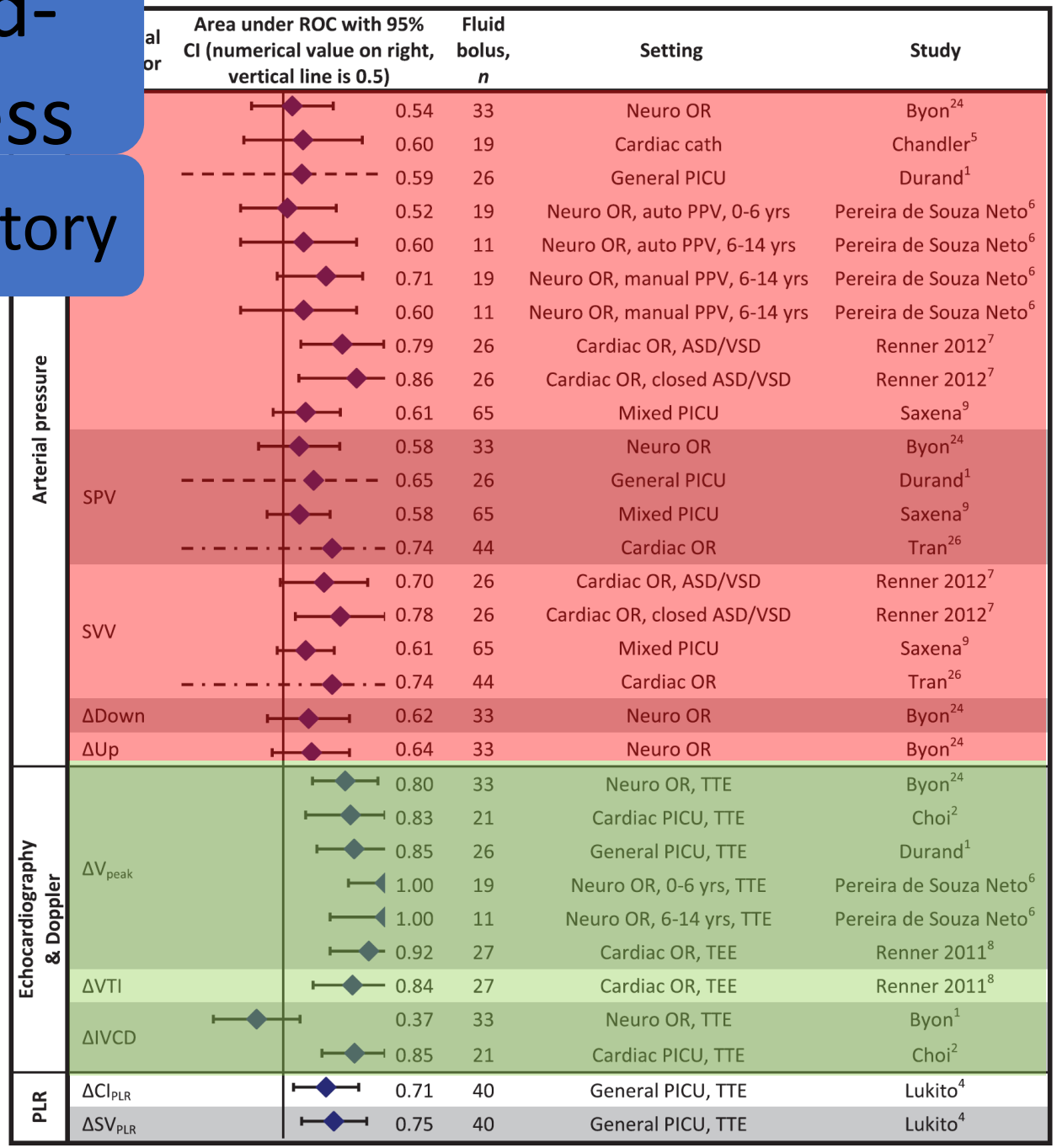
Predikce fluid-responsiveness

Dynamické prediktory



		Area under ROC with 95% CI (numerical value on right, vertical line is 0.5)	Fluid bolus, *n*	Setting	Study
Arterial pressure		0.54	33	Neuro OR	Byon[24]
		0.60	19	Cardiac cath	Chandler[5]
		0.59	26	General PICU	Durand[1]
		0.52	19	Neuro OR, auto PPV, 0-6 yrs	Pereira de Souza Neto[6]
		0.60	11	Neuro OR, auto PPV, 6-14 yrs	Pereira de Souza Neto[6]
		0.71	19	Neuro OR, manual PPV, 6-14 yrs	Pereira de Souza Neto[6]
		0.60	11	Neuro OR, manual PPV, 6-14 yrs	Pereira de Souza Neto[6]
		0.79	26	Cardiac OR, ASD/VSD	Renner 2012[7]
		0.86	26	Cardiac OR, closed ASD/VSD	Renner 2012[7]
		0.61	65	Mixed PICU	Saxena[9]
	SPV	0.58	33	Neuro OR	Byon[24]
		0.65	26	General PICU	Durand[1]
		0.58	65	Mixed PICU	Saxena[9]
		0.74	44	Cardiac OR	Tran[26]
	SVV	0.70	26	Cardiac OR, ASD/VSD	Renner 2012[7]
		0.78	26	Cardiac OR, closed ASD/VSD	Renner 2012[7]
		0.61	65	Mixed PICU	Saxena[9]
		0.74	44	Cardiac OR	Tran[26]
	ΔDown	0.62	33	Neuro OR	Byon[24]
	ΔUp	0.64	33	Neuro OR	Byon[24]
Echocardiography & Doppler	ΔV_{peak}	0.80	33	Neuro OR, TTE	Byon[24]
		0.83	21	Cardiac PICU, TTE	Choi[2]
		0.85	26	General PICU, TTE	Durand[1]
		1.00	19	Neuro OR, 0-6 yrs, TTE	Pereira de Souza Neto[6]
		1.00	11	Neuro OR, 6-14 yrs, TTE	Pereira de Souza Neto[6]
		0.92	27	Cardiac OR, TEE	Renner 2011[8]
	ΔVTI	0.84	27	Cardiac OR, TEE	Renner 2011[8]
	ΔIVCD	0.37	33	Neuro OR, TTE	Byon[1]
		0.85	21	Cardiac PICU, TTE	Choi[2]
PLR	ΔCI_{PLR}	0.71	40	General PICU, TTE	Lukito[4]
	ΔSV_{PLR}	0.75	40	General PICU, TTE	Lukito[4]

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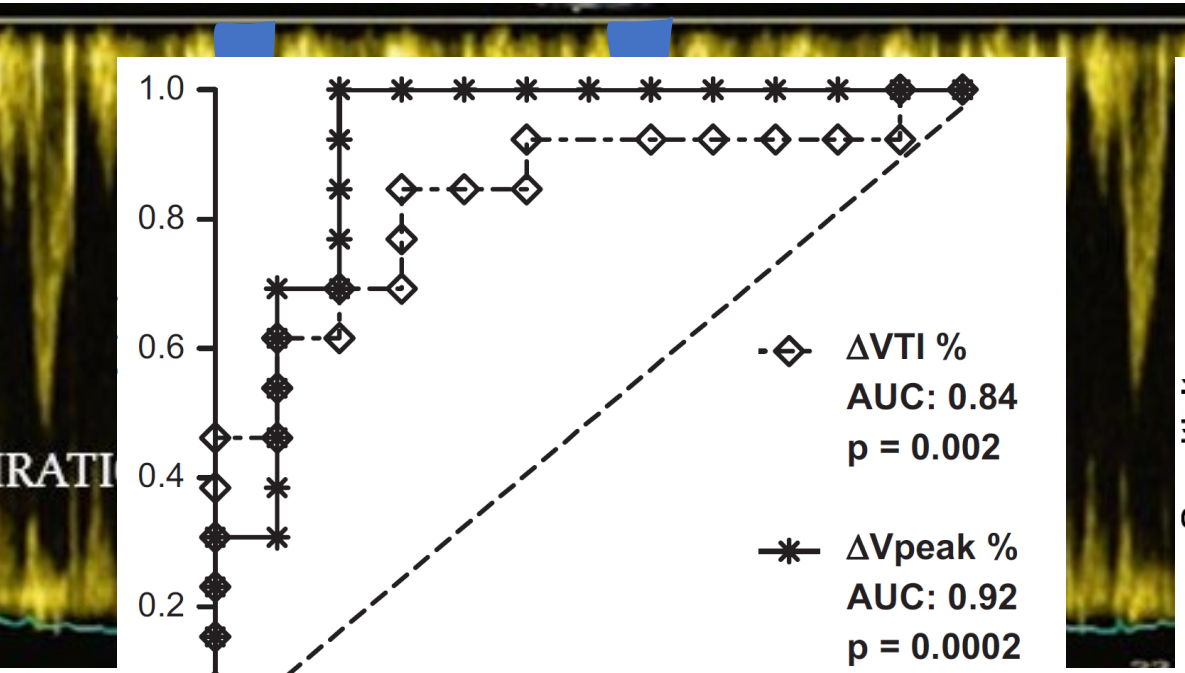
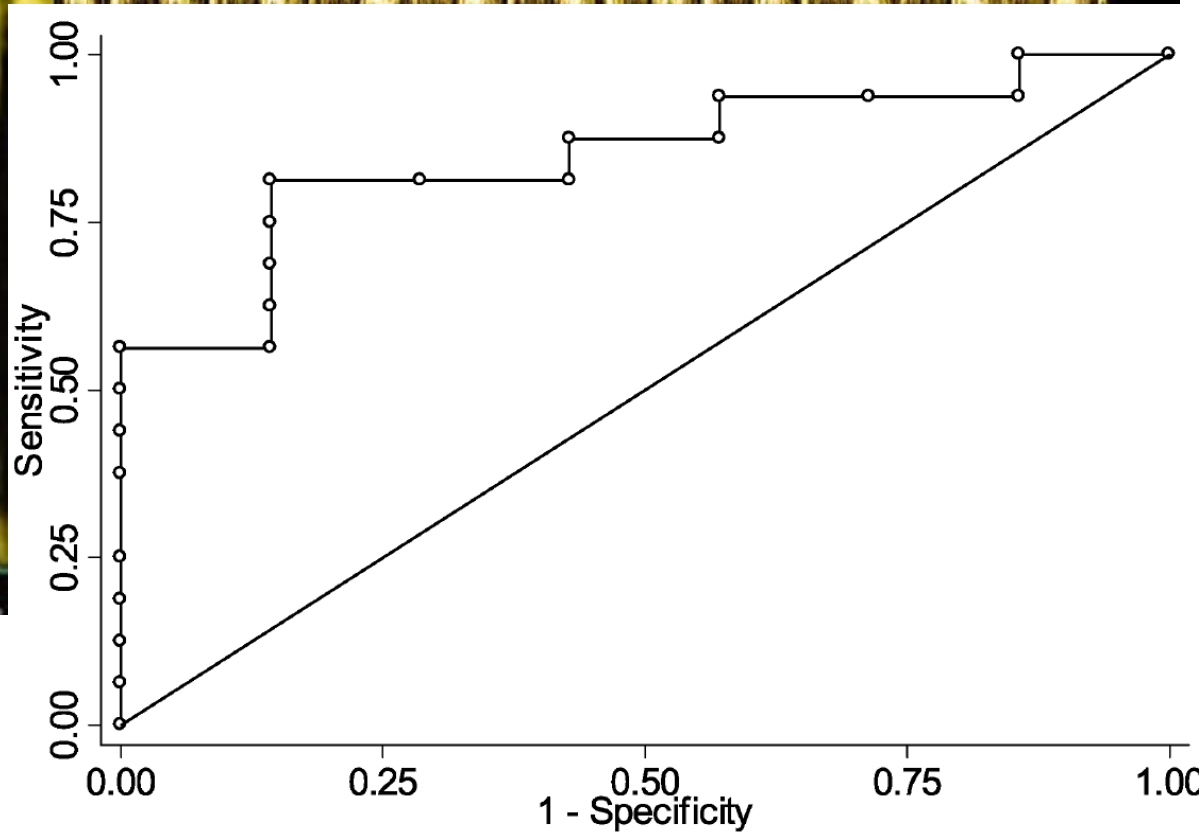
Variabilita aortálního průtoku



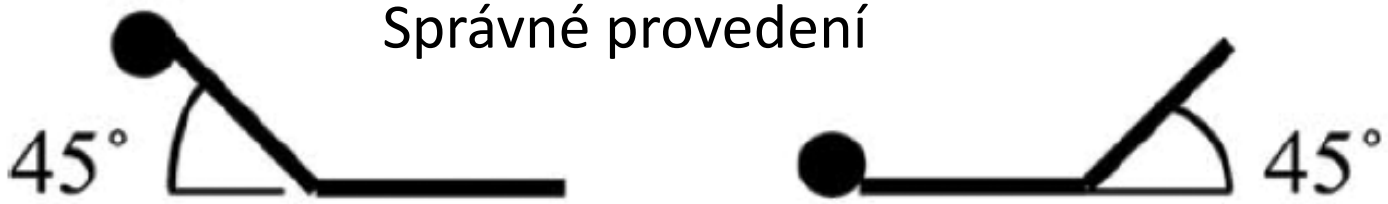


Anaesthesia, 2011, **66**, pages 582–589

Intensive Care Med (2008) 34:888–894

Passive leg raising

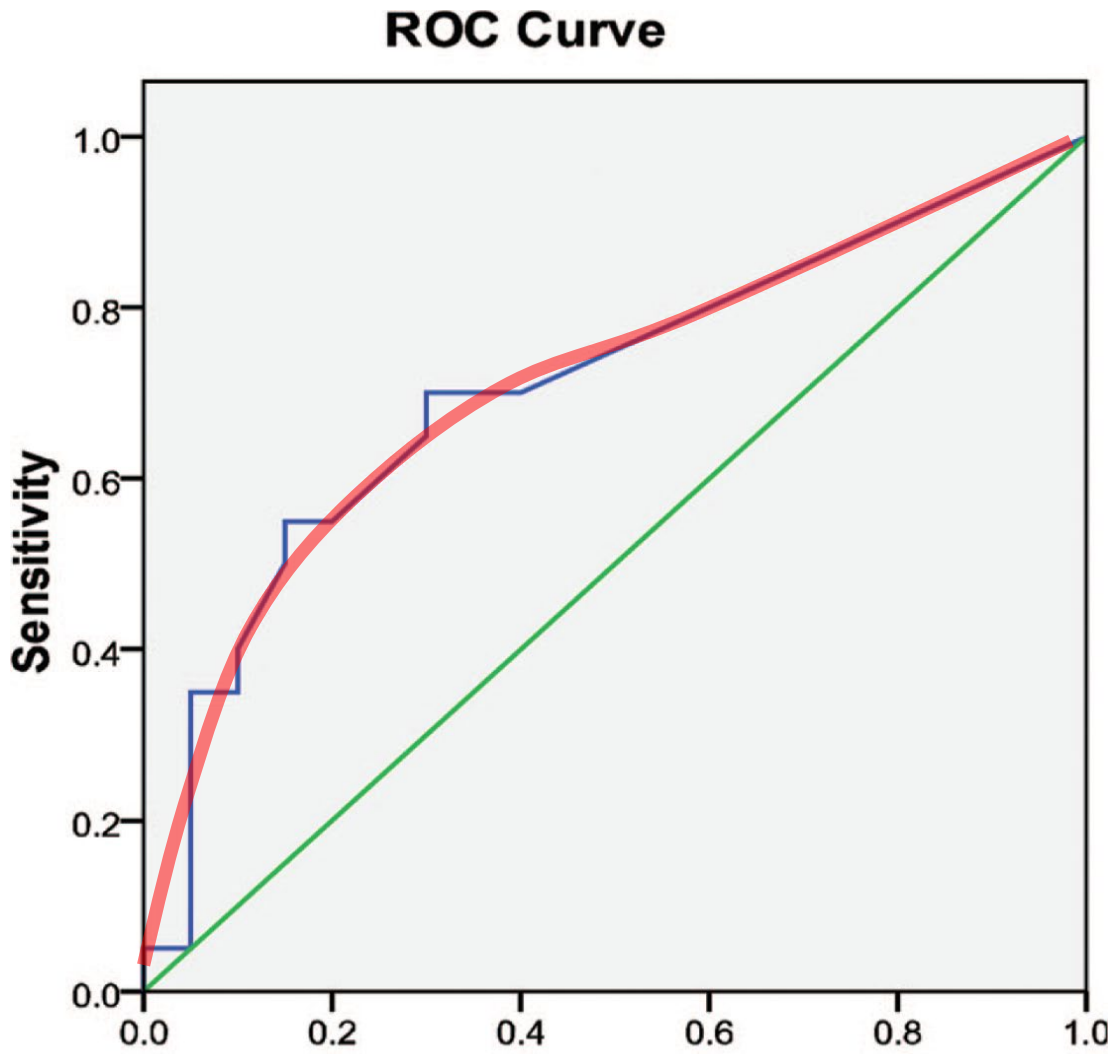
Správné provedení



Odpověď - měření SV

The role of passive leg raising to predict fluid responsiveness in pediatric intensive care unit patients*

Vimaladewi Lukito, MD; Mulyadi M. Djer, PhD; Antonius H. Pudjiadi, MD; Zakiudin Munasir, MD

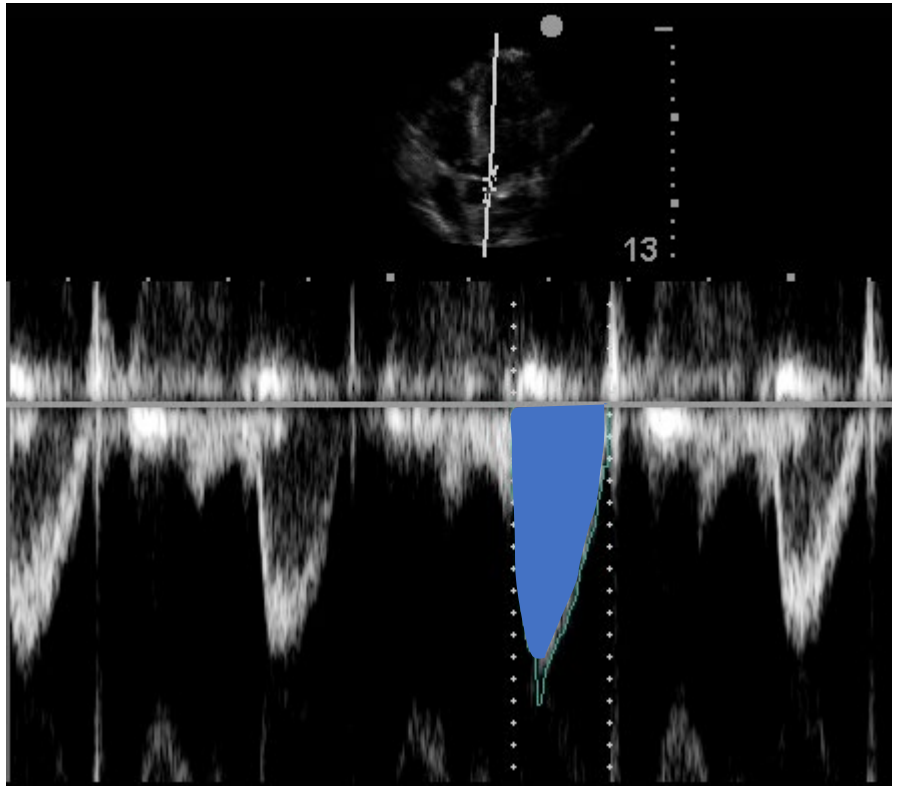


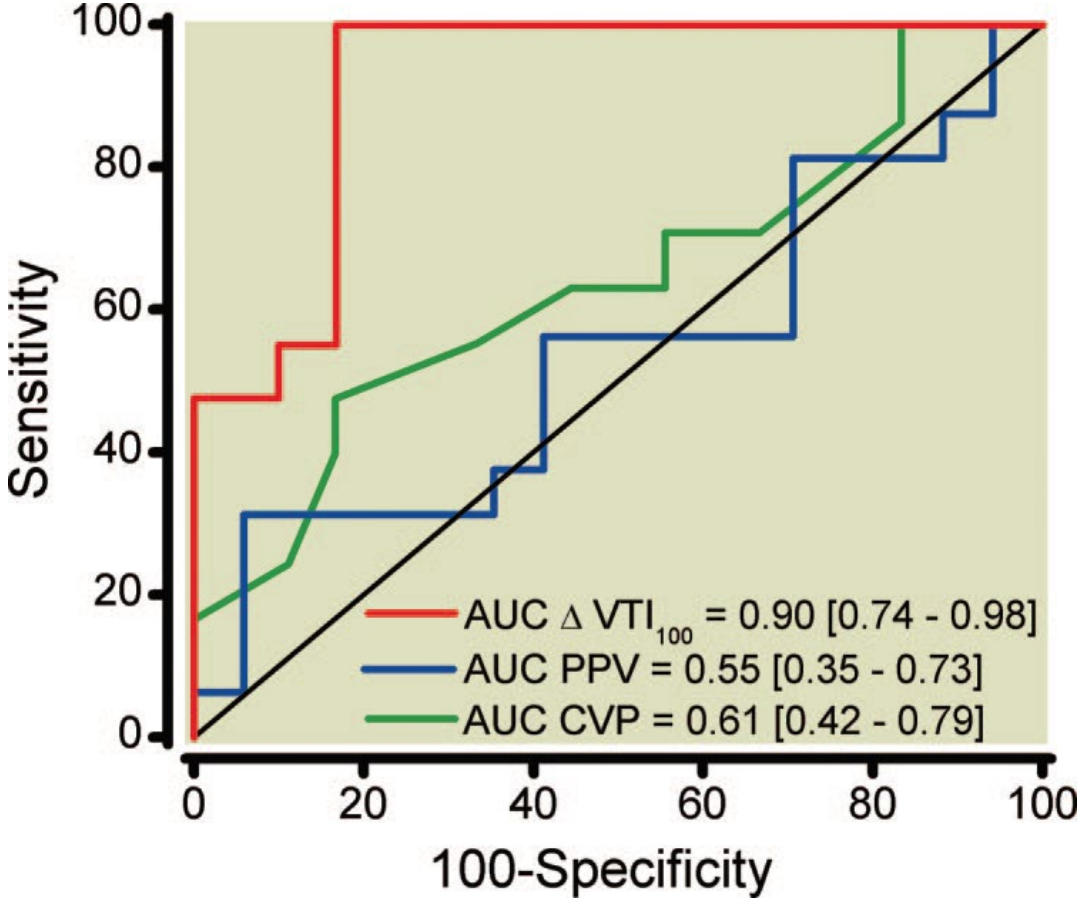
Pediatr Crit Care Med 2012 Vol. 13, No. 3

An Increase in Aortic Blood Flow after an Infusion of 100 ml Colloid over 1 Minute Can Predict Fluid Responsiveness

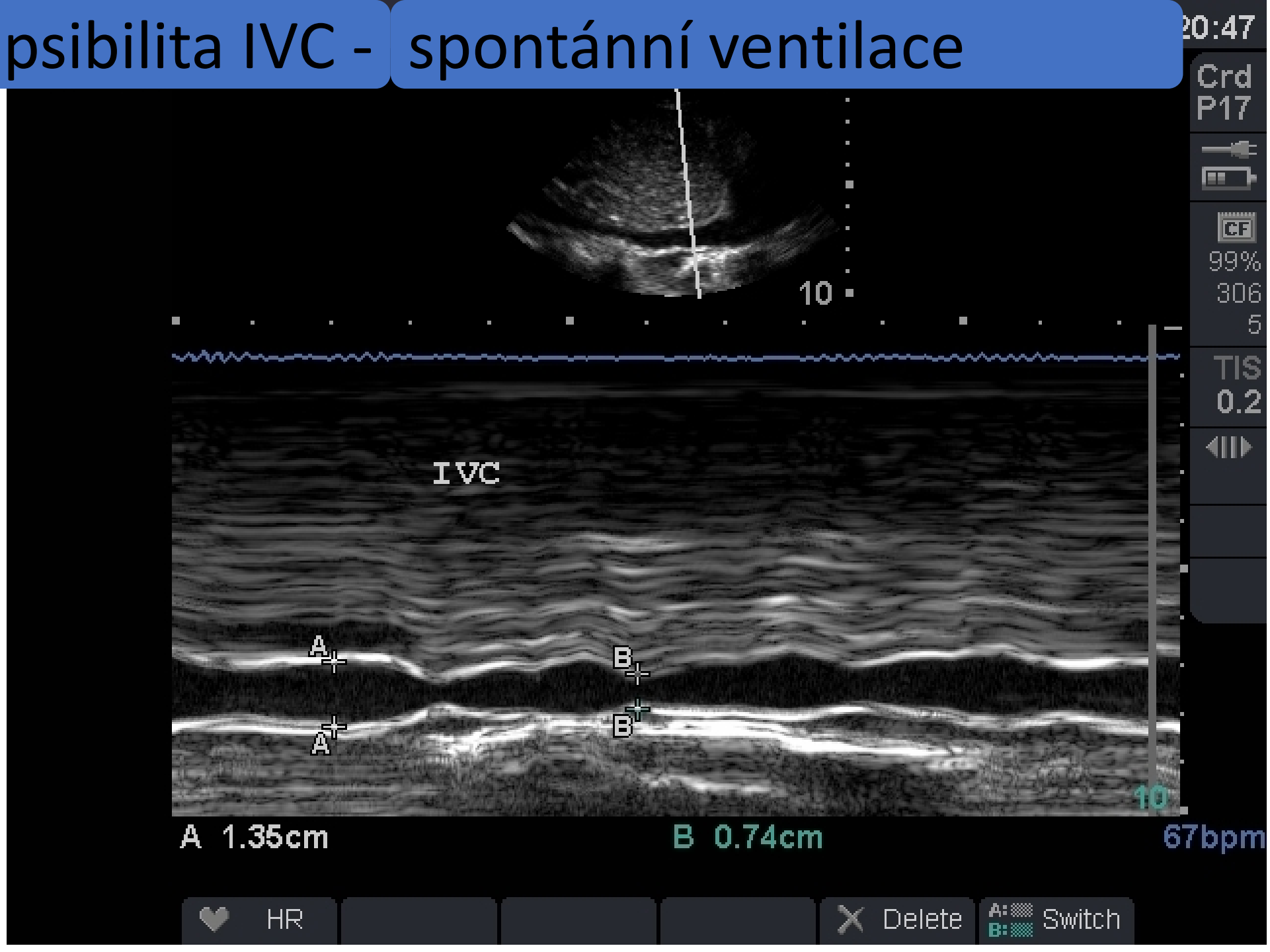
The Mini-fluid Challenge Study

Laurent Muller, M.D., M.Sc.,* Medhi Toumi, M.D.,* Philippe-Jean Bousquet, M.D.,†
Béatrice Riu-Poulenc, M.D.,‡ Guillaume Louart, M.D.,* Damien Candela, M.D.,* Lana Zoric, M.D.,*
Carey Suehs, Ph.D.,† Jean-Emmanuel de La Coussaye, M.D., Ph.D.,§ Nicolas Molinari, Ph.D.,†
Jean-Yves Lefrant, M.D., Ph.D.,§ in the AzuRéa Group

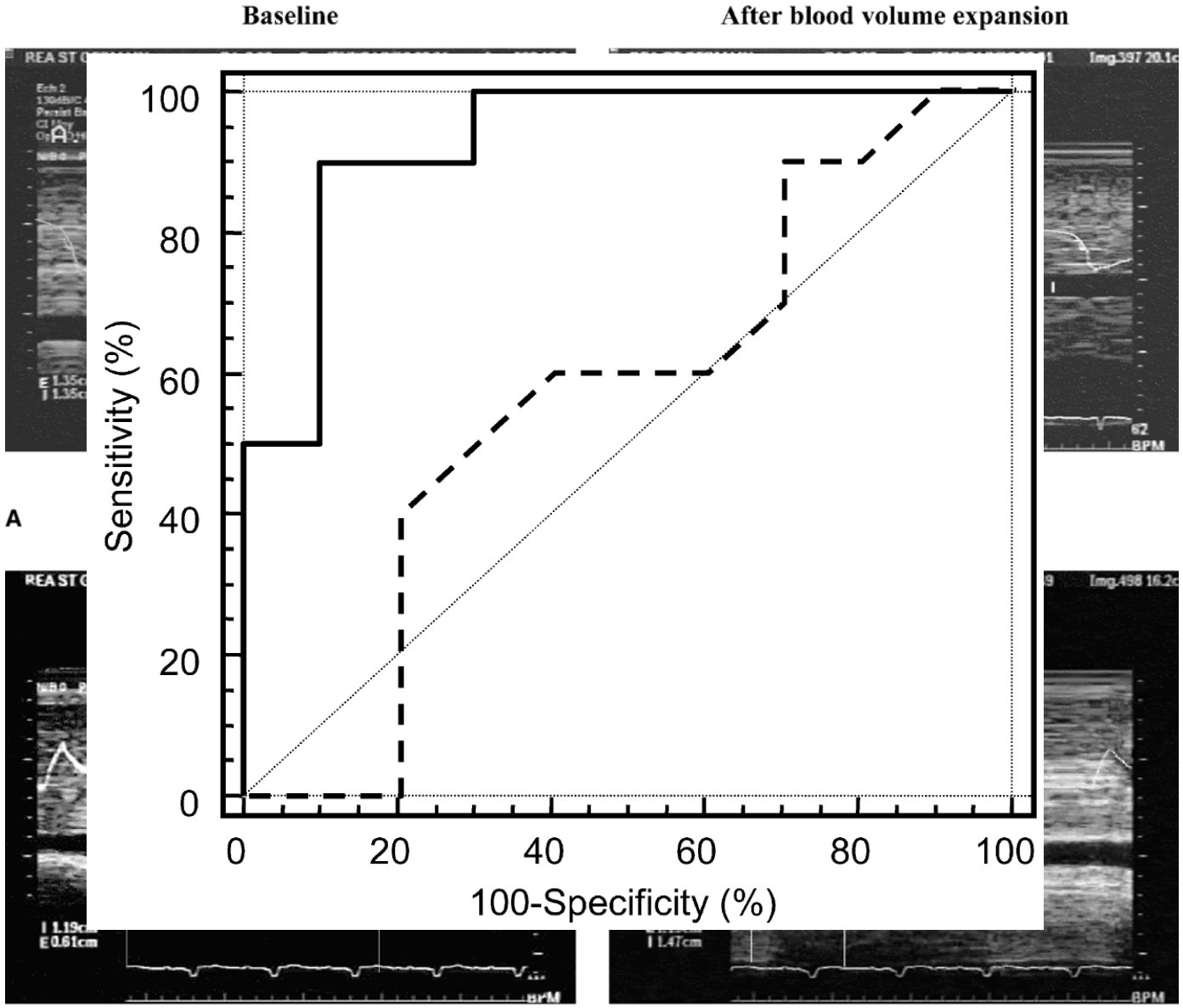




Kolapsibilita IVC - spontánní ventilace



Distendibilita IVC - řízená ventilace



Intensive Care Med (2004) 30:1740–1746

Low Predictability of Three Different Noninvasive Methods to Determine Fluid Responsiveness in Critically Ill Children

Thomas Weber, MD, DEEA[1]; Thomas Wagner, MD[2]; Konrad Neumann, PhD[3]; Engelbert Deusch, MD[4]

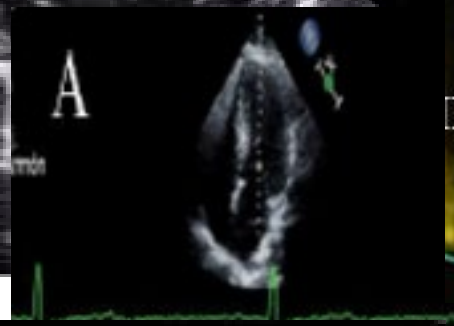
TABLE 3. Predictability of Fluid Responsiveness Defined as 10% Increase of Stroke Volume Index (mL/m² Body Surface Area) Measured by Transthoracic Echocardiography Before Fluid Loading

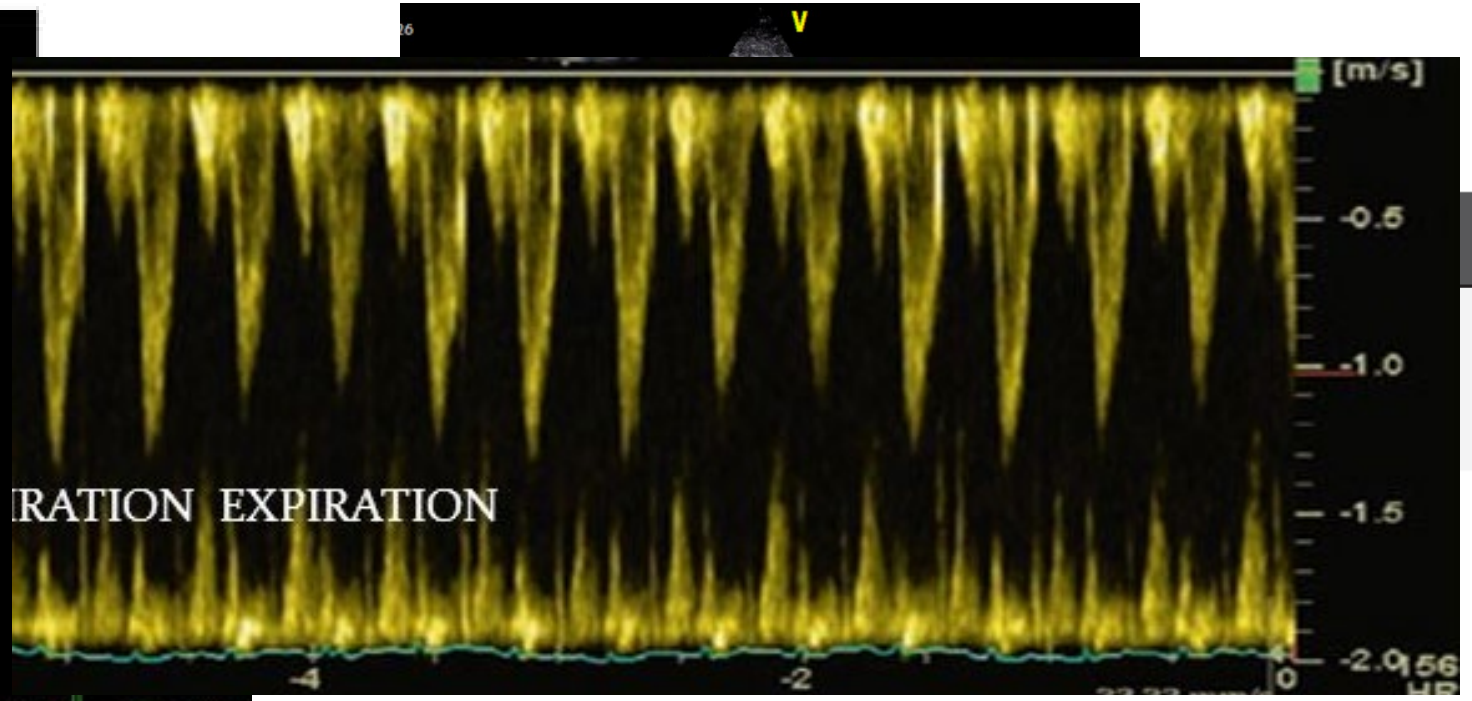
	AUC	*p*	95% CI
Heart rate	0.417	0.43	0.21–0.62
Mean arterial pressure	0.502	0.98	0.29–0.71
Central venous pressure	0.490	0.92	0.28–0.70
Central venous oxygen saturation	0.596	0.36	0.39–0.81
CardioQ stroke volume index	0.494	0.95	0.28–0.71
CardioQ cardiac index	0.396	0.32	0.19–0.60
CardioQ flow time corrected[a]	0.538	0.72	0.33–0.75
CardioQ peak velocity[b]	0.717	0.040*	0.53–0.90
LiDCOrapid stroke volume index	0.371	0.22	0.16–0.58
LiDCOrapid cardiac index	0.371	0.22	0.17–0.57
LiDCOrapid stroke volume variation	0.513	0.91	0.30–0.72
LiDCOrapid systemic vascular resistance index	0.588	0.41	0.38–0.79
Inferior vena cava pulsations (dIVC%)[c]	0.502	0.98	0.29–0.71

Pediatr Crit Care Med 2015; 16:e89–e94

TABLE 1

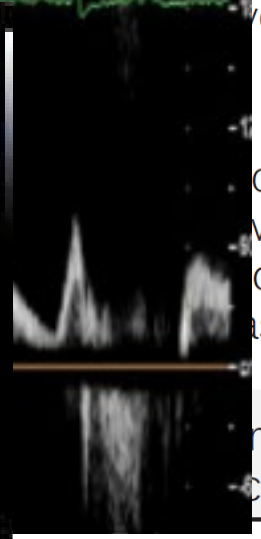
Goal	
Volume	ve to LV
Cardiac	op
LV an fun	val
	cu
LV diast funct	ast
Pericardia	me cul

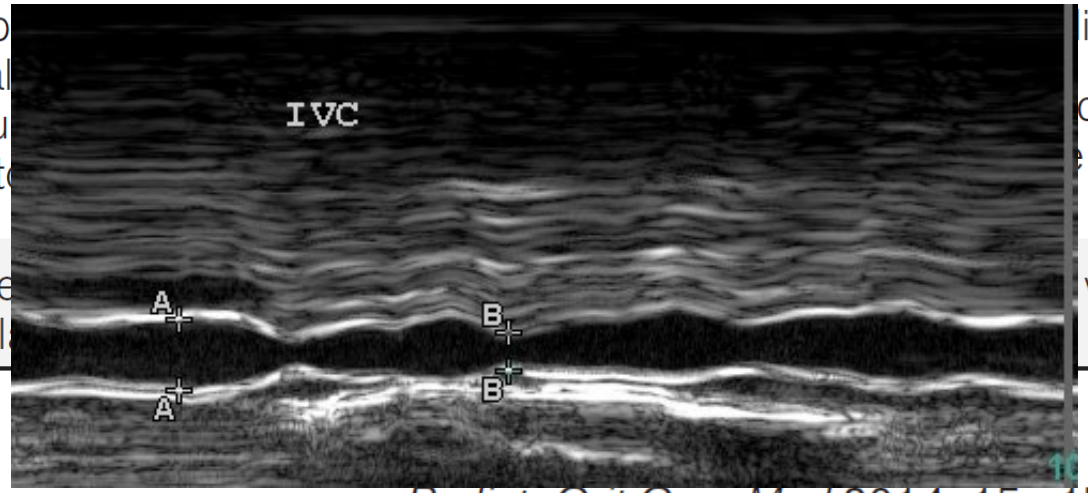




Improvement with inotropy

Fluid overload during filling





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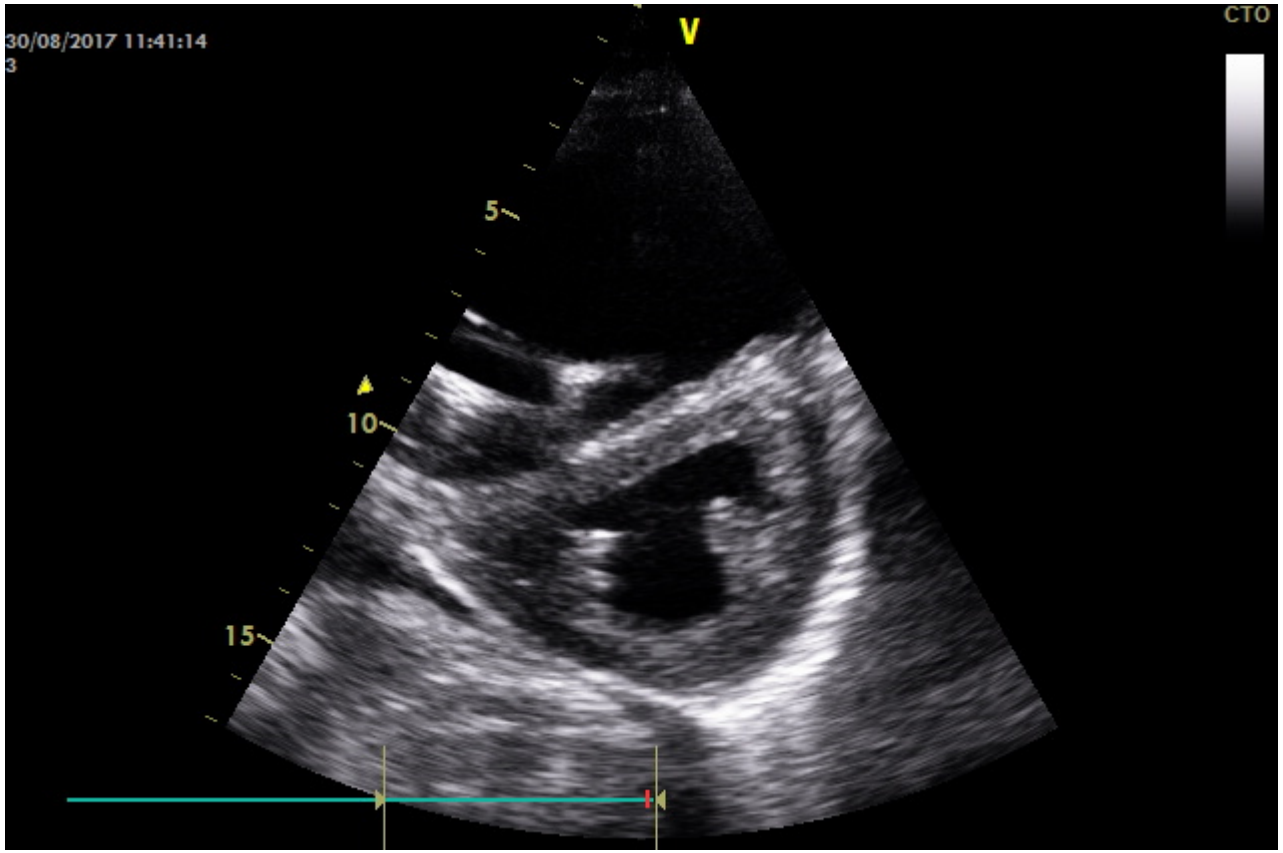
Pediatr Crit Care Med 2014; 15:e17–e26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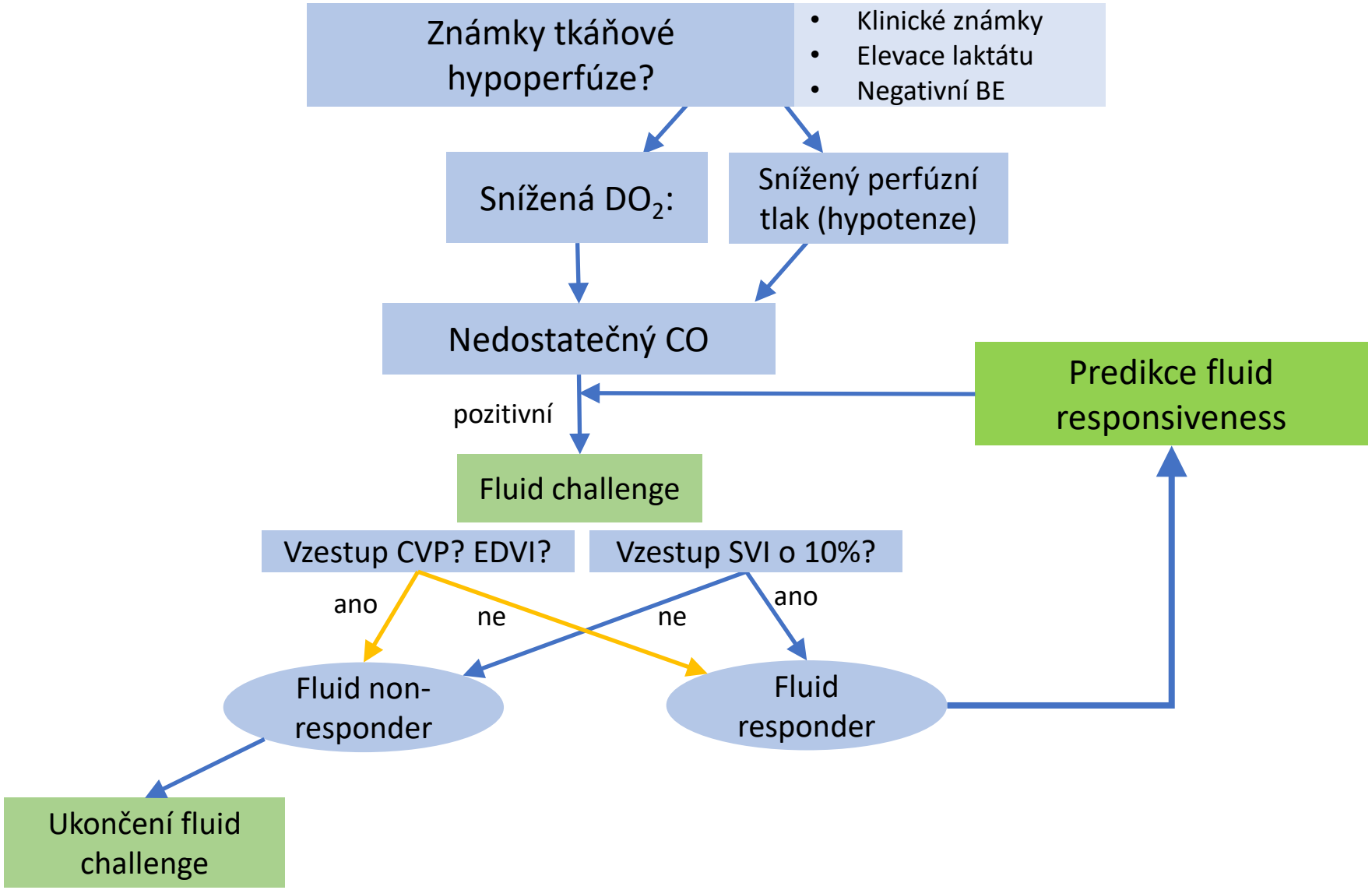

Známky tkáňové hypoperfúze?
Klinické známky
Elevace laktátu
Negativní BE
Snížená DO_2:
Snížený perfúzní tlak (hypotenze)
Nedostatečný CO
Predikce fluid responsiveness
pozitivní
Fluid challenge
Vzestup CVP? EDVI?
Vzestup SVI o 10%?
ano
ne
ne
ano
Fluid non-responder
Fluid responder
Ukončení fluid challenge

CO

PAC - PTD

Pulse contour analysis

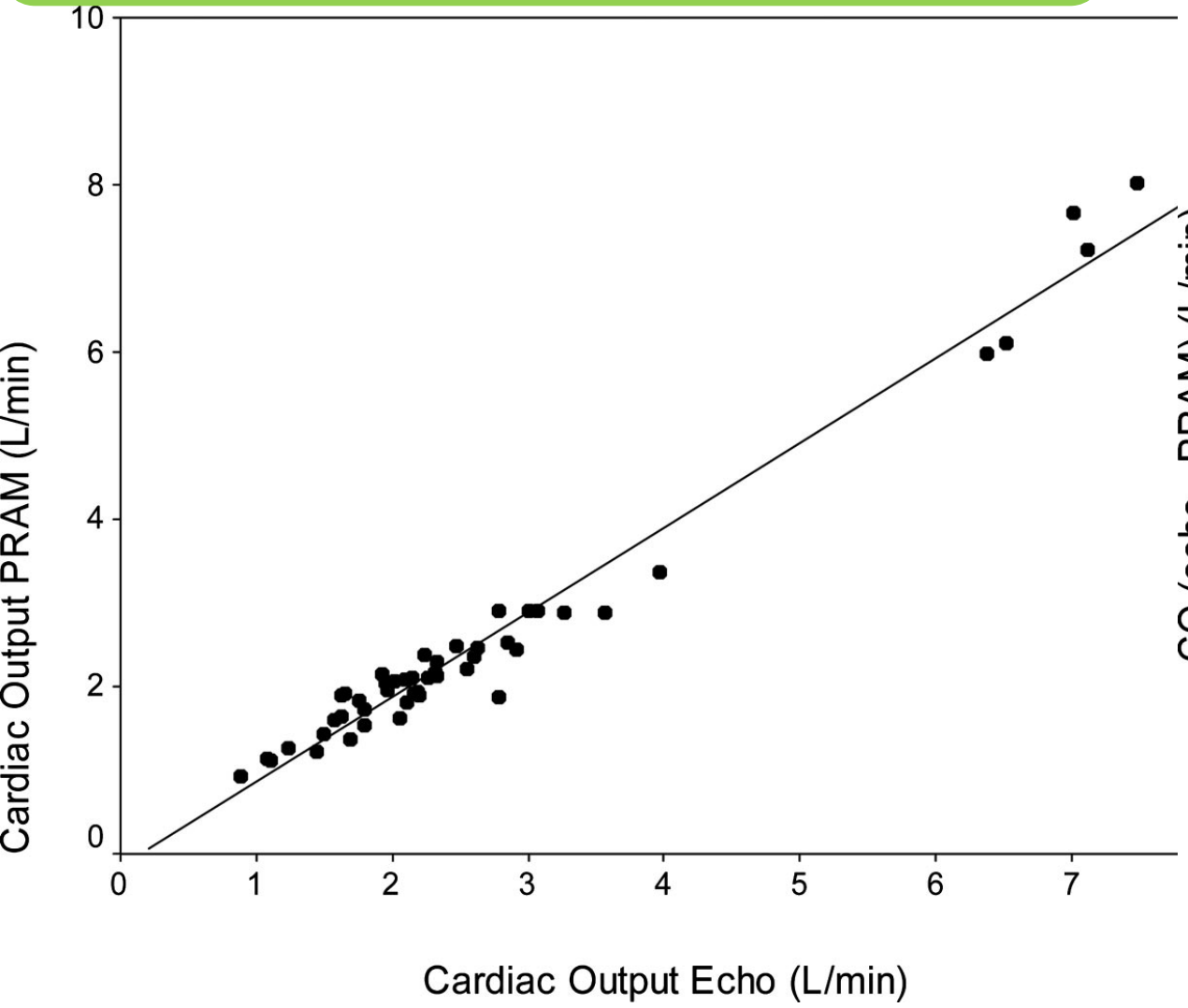
Elektrická kardiometrie

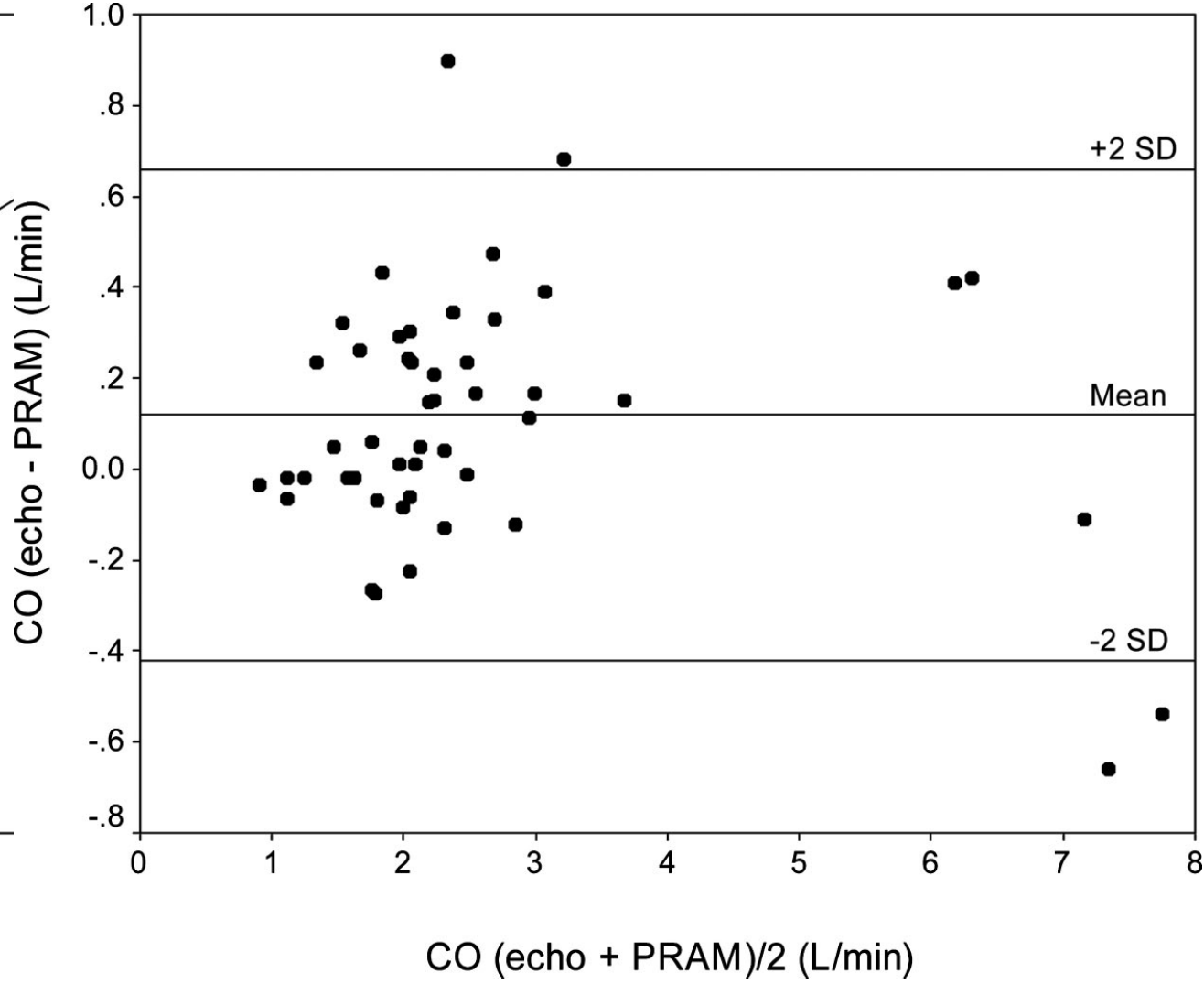
Transpulmonární diluce

USG doppler

Echokg

Pulse contour analysis

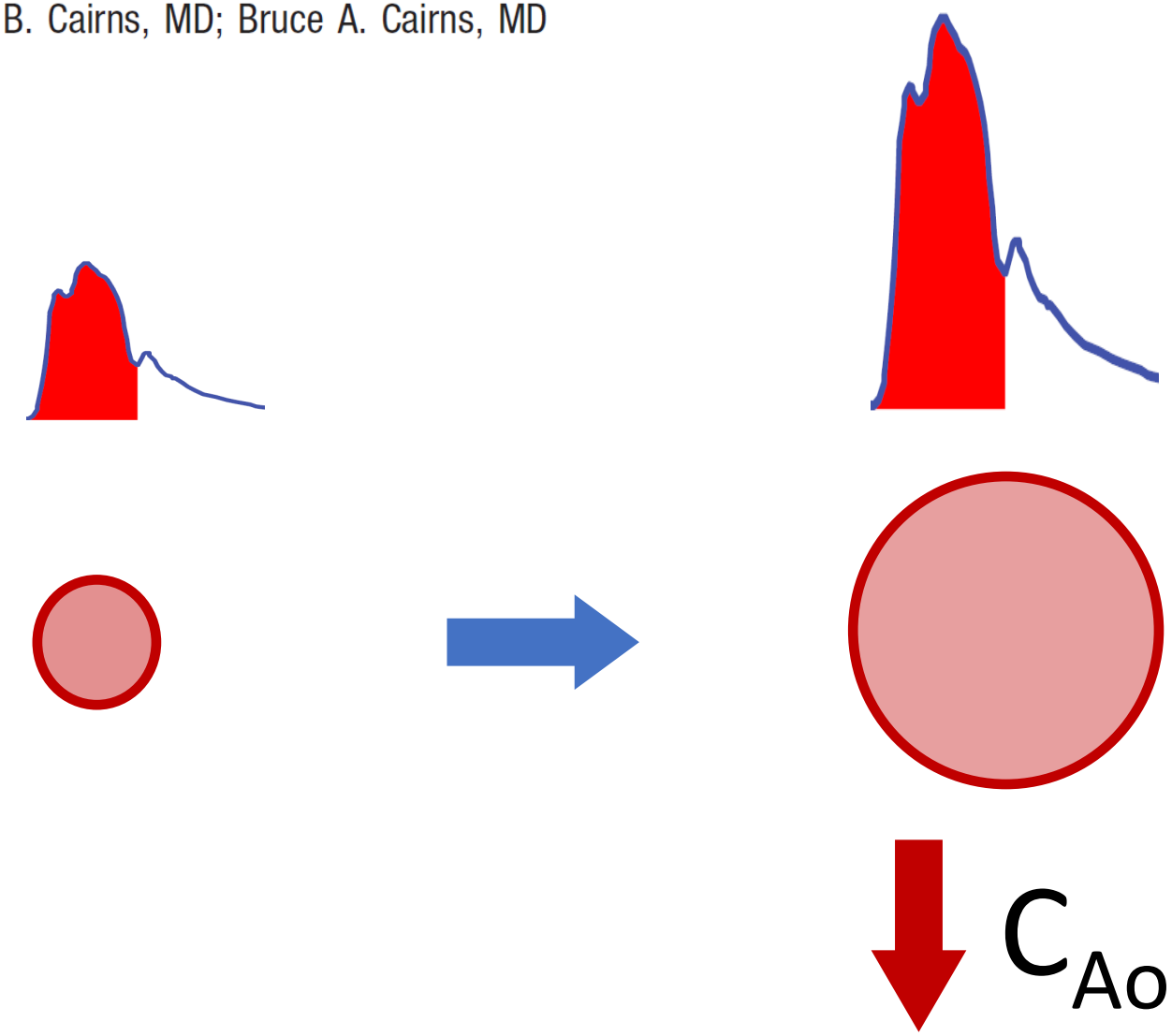




Pediatr Crit Care Med 2008 Vol. 9, No. 3

Pulse contour cardiac output analysis in a piglet model of severe hemorrhagic shock*

Mark D. Piehl, MD, MPH; James E. Manning, MD; Shane L. McCurdy, BS; Tim S. Rhue, MA; Keith C. Kocis, MD, MS, FCCM; Charles B. Cairns, MD; Bruce A. Cairns, MD



Monitoring srdečního výdeje

PAC - PTD

Pulse contour analysis

Elektrická kardiometrie

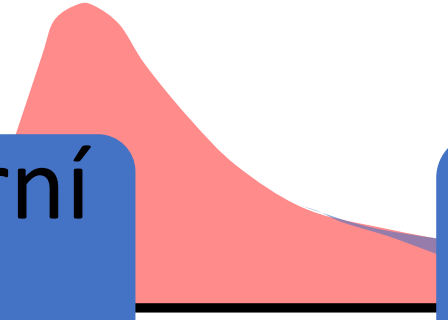
Transpulmonární diluce

USG doppler

Echokg

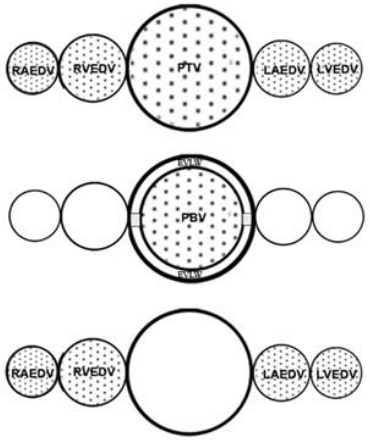
Transpulmonární diluce

injekce



Transpulmonární termodiluce

Transpulmonární Li – diluce



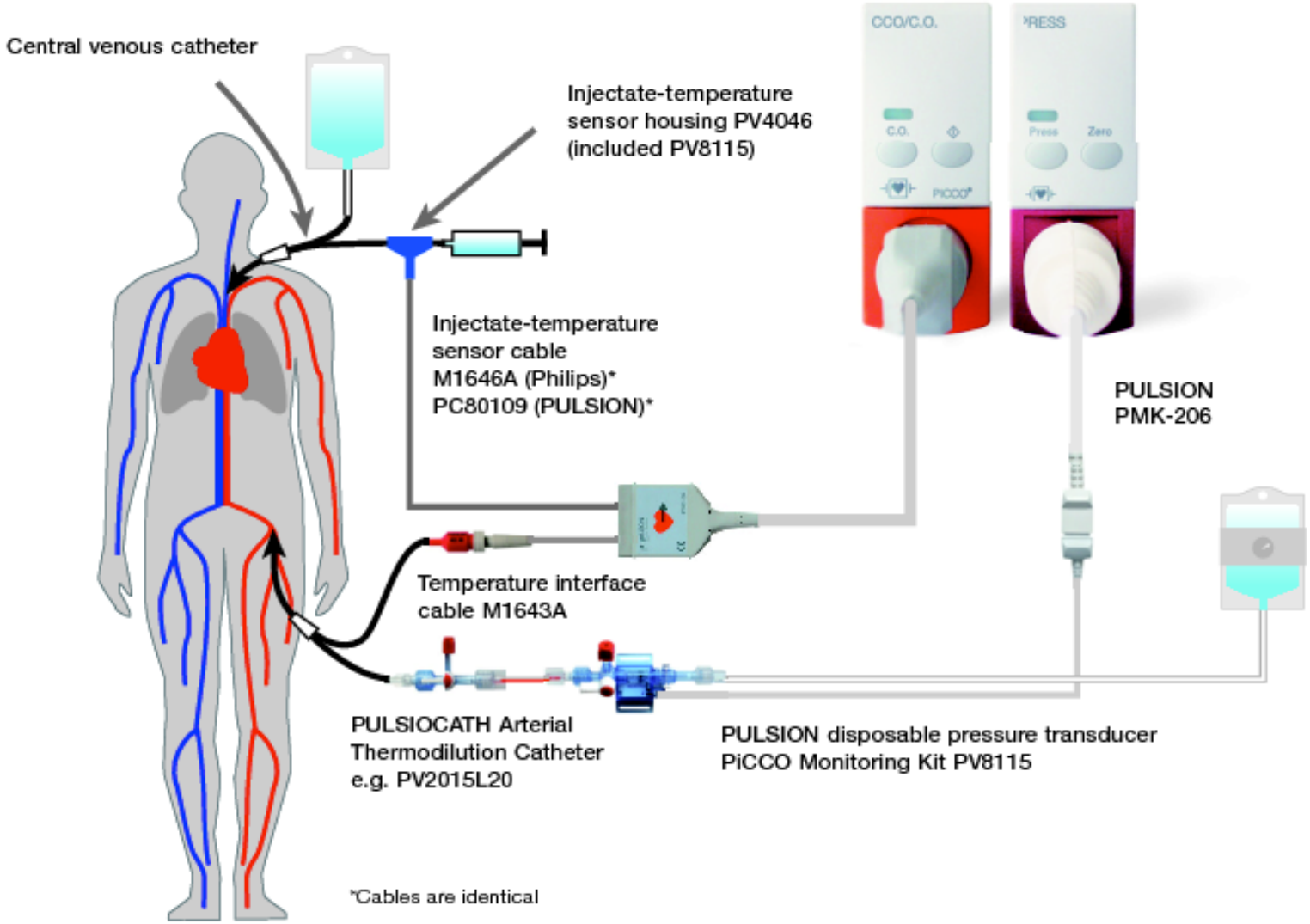
$$ITTV = MTt \times CO = GEDV + PBV + EVLW$$

$$PTV = DSt \times CO = PBV + EVLW$$

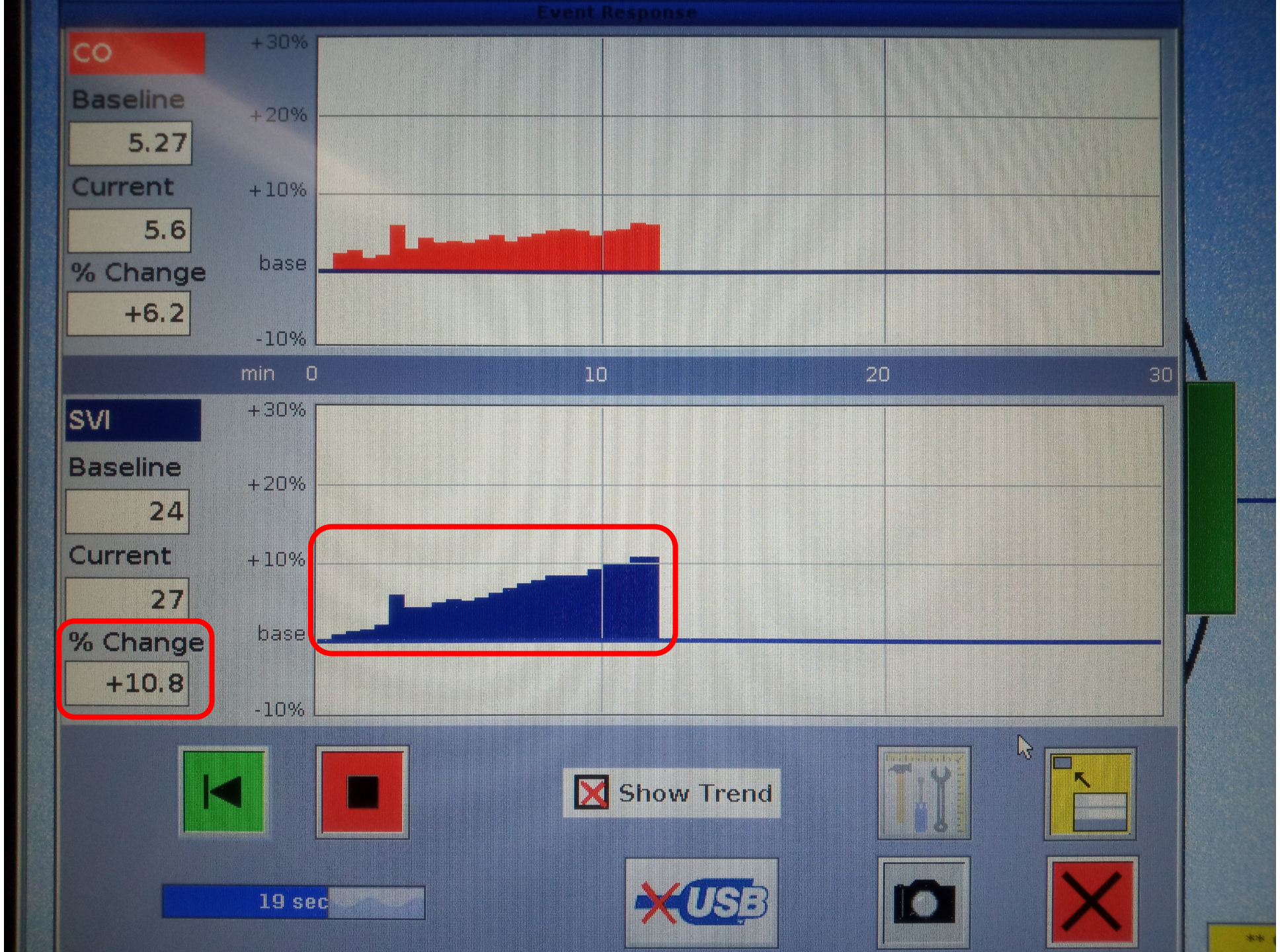
$$GEDV = ITTV - PTV$$

Transpulmonární termodiluce

- Děti>3,5 kg 3 F katétr je bezpečný
- injektát 1.5 ml + 0.15 ml/kg

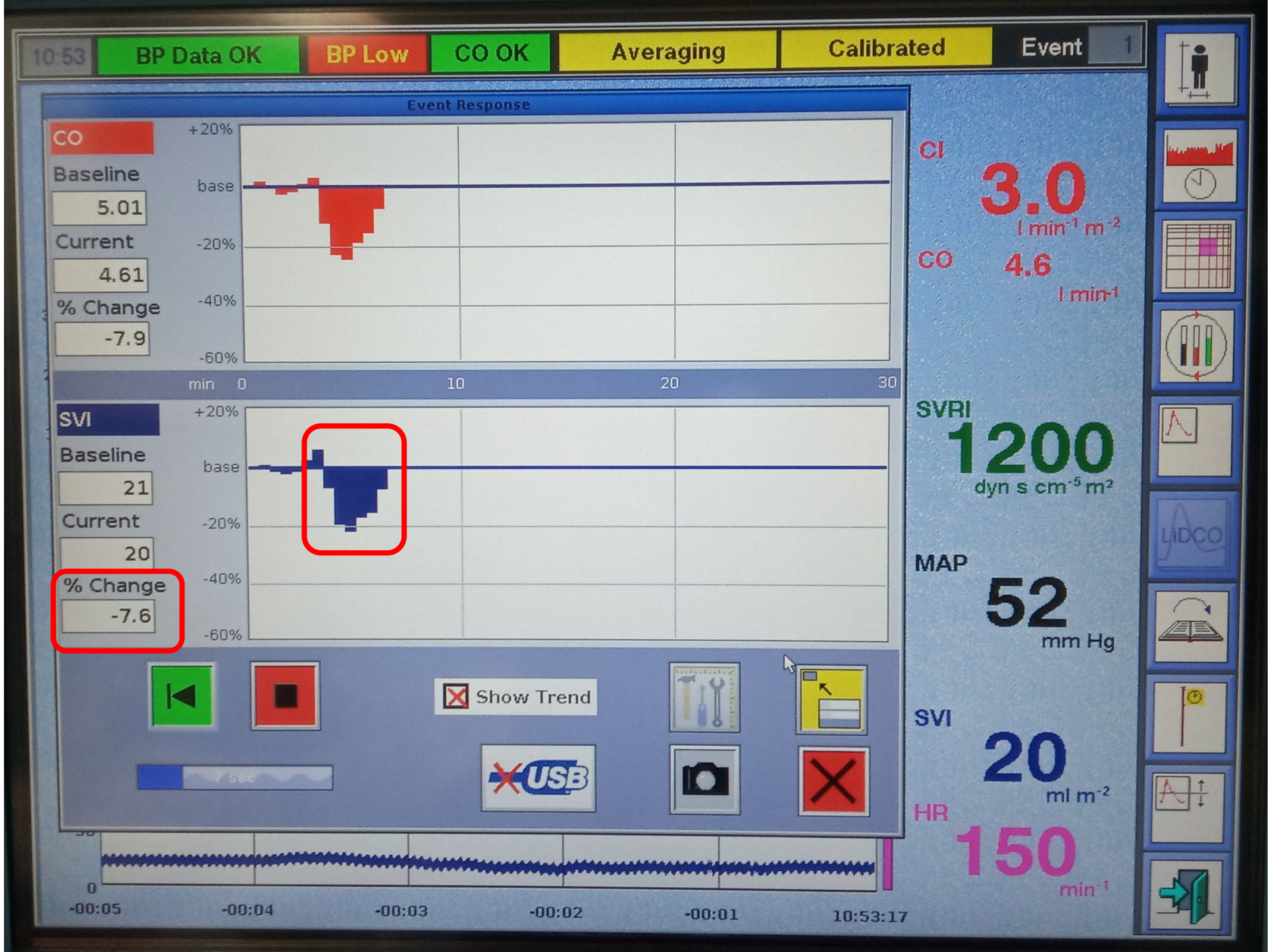


LIPOSOMA


Event Response
CO
Baseline
5.27
Current
5.6
% Change
+6.2
+30%
+20%
+10%
base
-10%
min
0
10
20
30
SVI
Baseline
24
Current
27
% Change
+10.8
+30%
+20%
+10%
base
-10%
Show Trend
19 sec
USB

Vasopresory

- Dopamin> 15 µg/kg/min
- Adrenalin > 0.3 µg/kg/min
- Noradrenalin 0,1-(0,4-0,5) µg/kg/min (až 2.5 ± 2.2 µg/kg/min)
  - Lampin et al. Acta Pædiatrica 2012 101, pp. e426–e430
- Vasopresin – rescue terapie, 0.00001 – 0.008 U/kg/min
  - Am J Respir Crit Care Med Vol 180. pp 632–639, 2009


10:53
BP Data OK
BP Low
CO OK
Averaging
Calibrated
Event
1
Event Response
CO
Baseline
5.01
Current
4.61
% Change
-7.9
+20%
base
-20%
-40%
-60%
min 0
10
20
30
SVI
Baseline
21
Current
20
% Change
-7.6
Show Trend
USB
CI
3.0
l min-1 m-2
CO
4.6
l min-1
SVRI
1200
dyn s cm-5 m2
MAP
52
mm Hg
SVI
20
ml m-2
HR
150
min-1
-00:05
-00:04
-00:03
-00:02
-00:01
10:53:17

Inotropika

- Dobutamin
  - Infants less than 12 months may be less responsive
- Adrenalin 0.05–0.3 µg/kg/min
- Dopamin 5–9 µg/kg/min
- Milrinon 0,25 – 0,75 g/kg/min, $T_{1/2}$ = 1 – 10 h
- Levosimendan no data

Děkuji za pozornost