Monitorage hémodynamique pédiatrique

Les pièges à éviter !

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JARCA 2015

Pas de conflits d’intérêt
Pas de contrat avec l’industrie

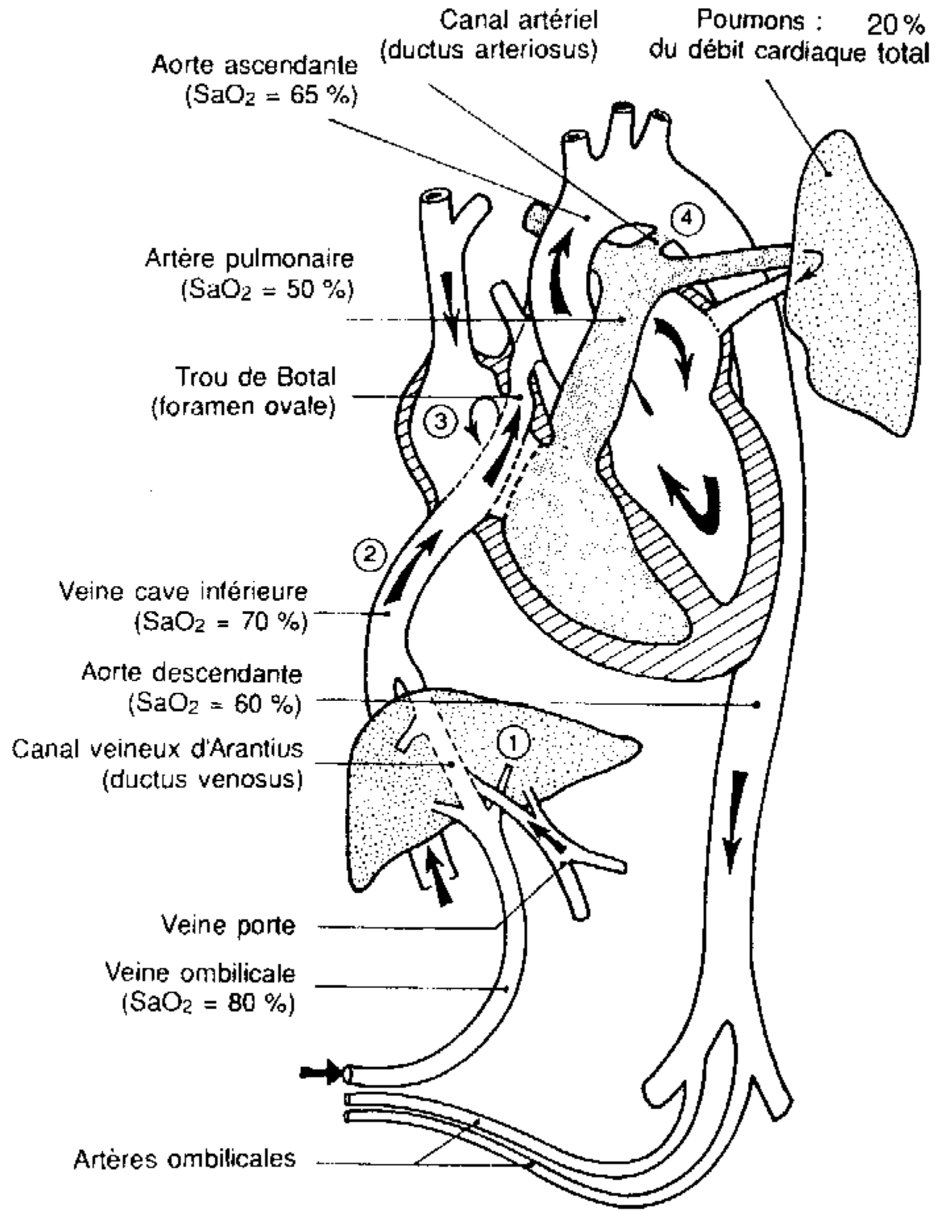
Pas de compte en Suisse ;-)

I PHYSIOLOGIE

Transition

Transition

- Aération pulmonaire
  - ➚ PaO2
  - ➘ RAP
- Clampage du cordon
  - ➚ RAS
- Fermeture shunts
- « Resetting »
- Instabilité
  - ➚ catécholamines

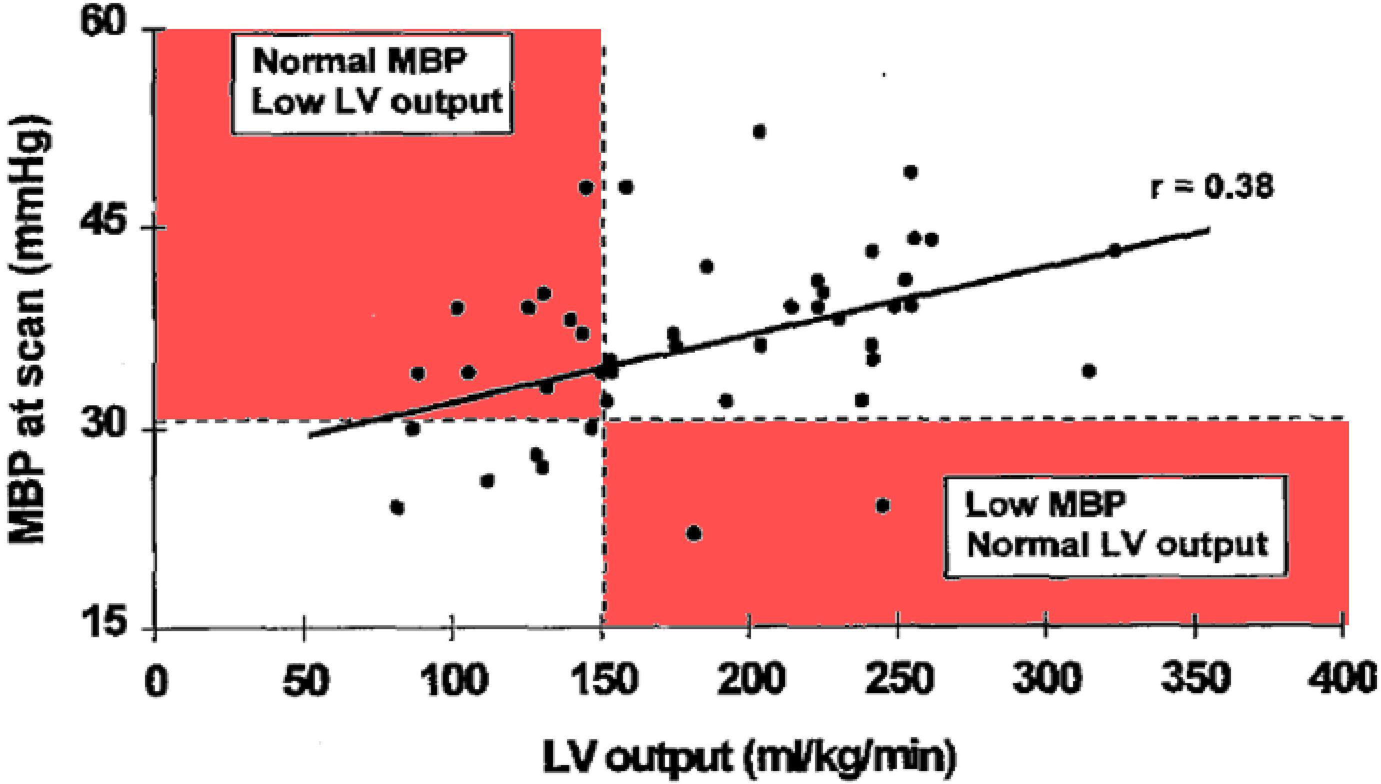


Mécanismes d'hypoTA *NN* <24h, 27-32SA

- Bas débit (n = 4) 24%
  - Dysfonction myocardique (<1/2 des cas)
  - RAP élevée (précharge VG basse+ dysfct septale)
  - Hypovolémie (test d'expansion volémique) ➔ **RARE**

- Débit non bas (n=13) 76%
  - CA significatif associé dans >3/4 des cas (11/13)
  - cinétique ventriculaire toujours normale
  - Diminution isolée des RAS (1/17)

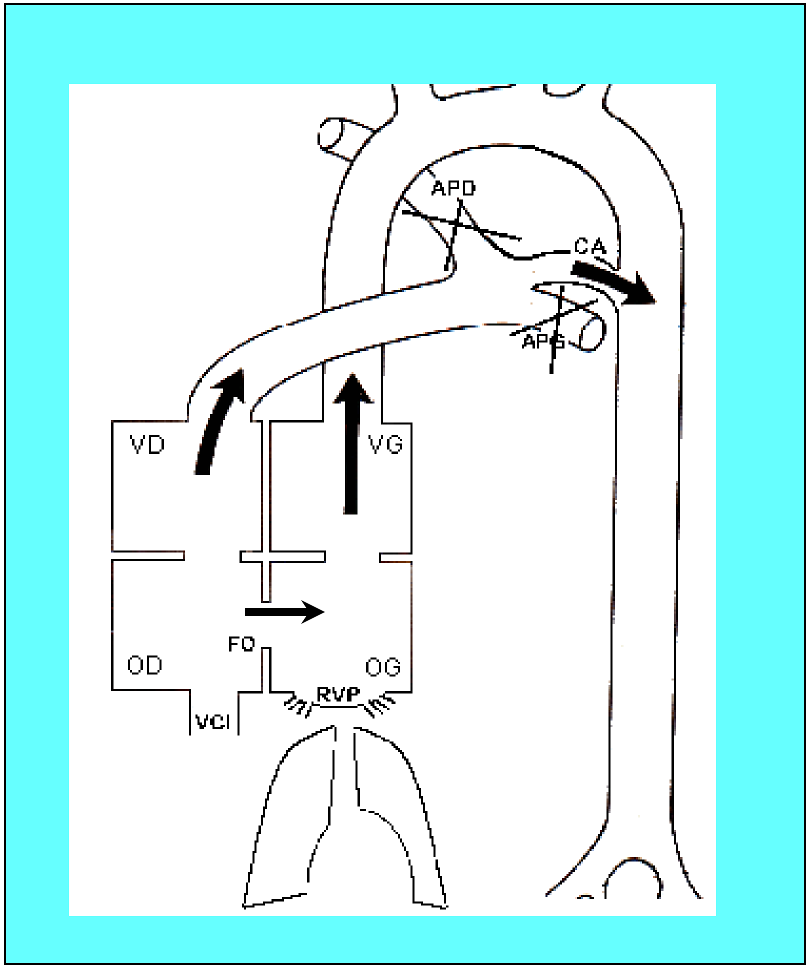
La PA n’est pas la perfusion

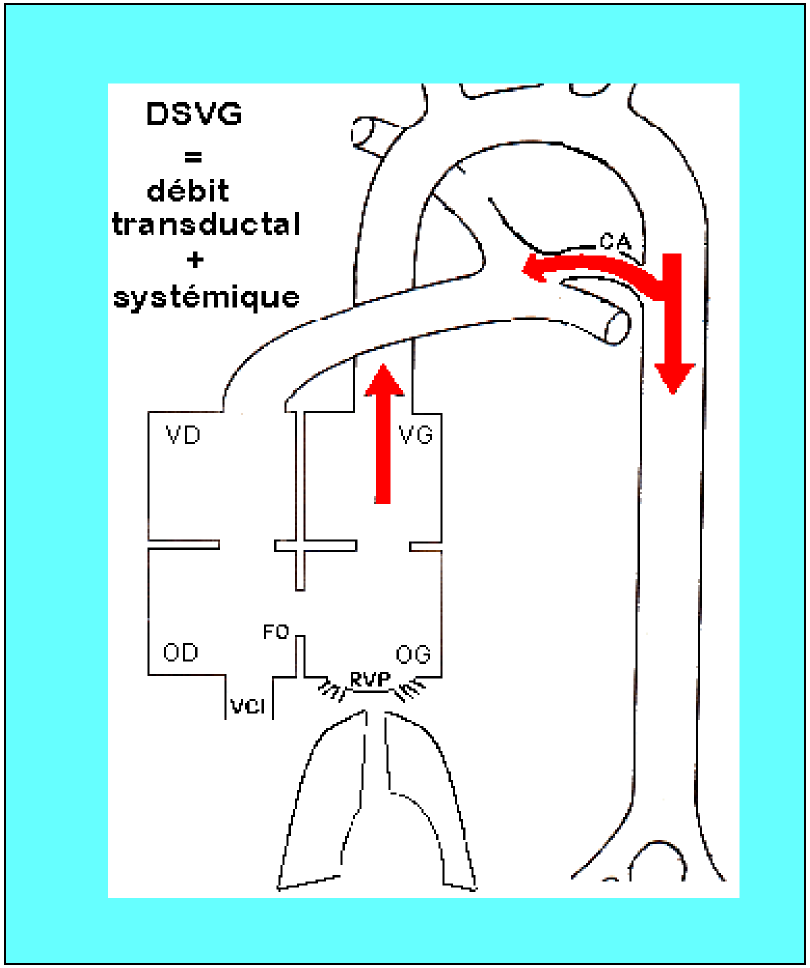


45 prématurés <1500g
APN<36h
Intubés ventilés
CA fermé ou <1.5mm

Kucklow M, J Pediatr. 1996

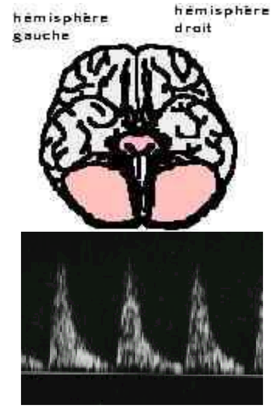
Canal artériel
Évolution hémodynamique

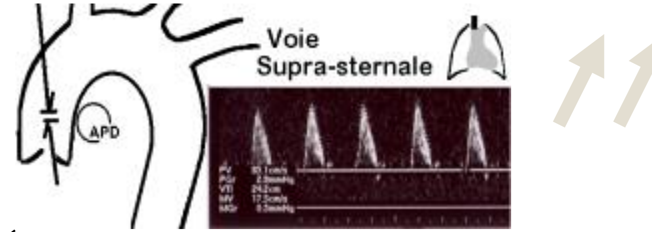




Canal artériel tubulaire

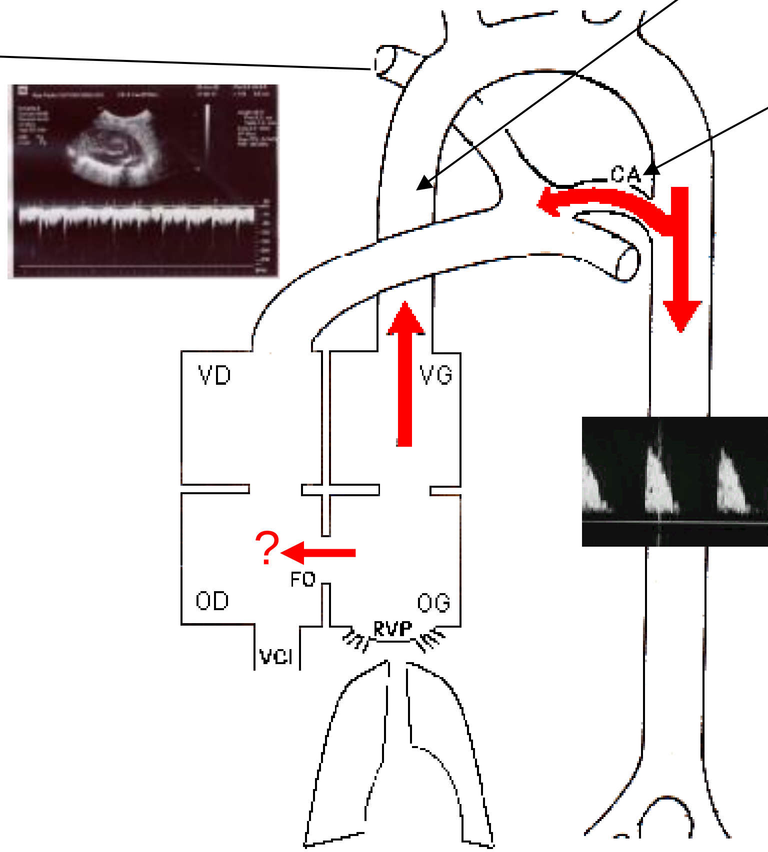
DSVG = D Syst + transductal

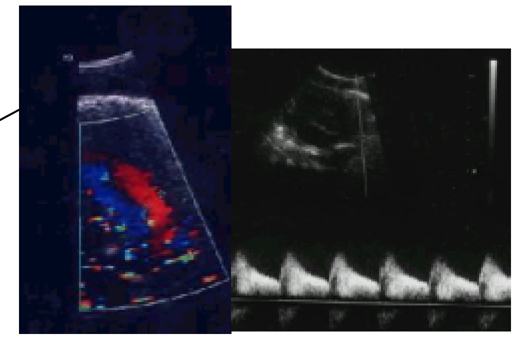




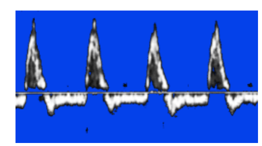
HTAP de débit

Séquestration volémique





ou



↗ pulsatilité

vol systémique

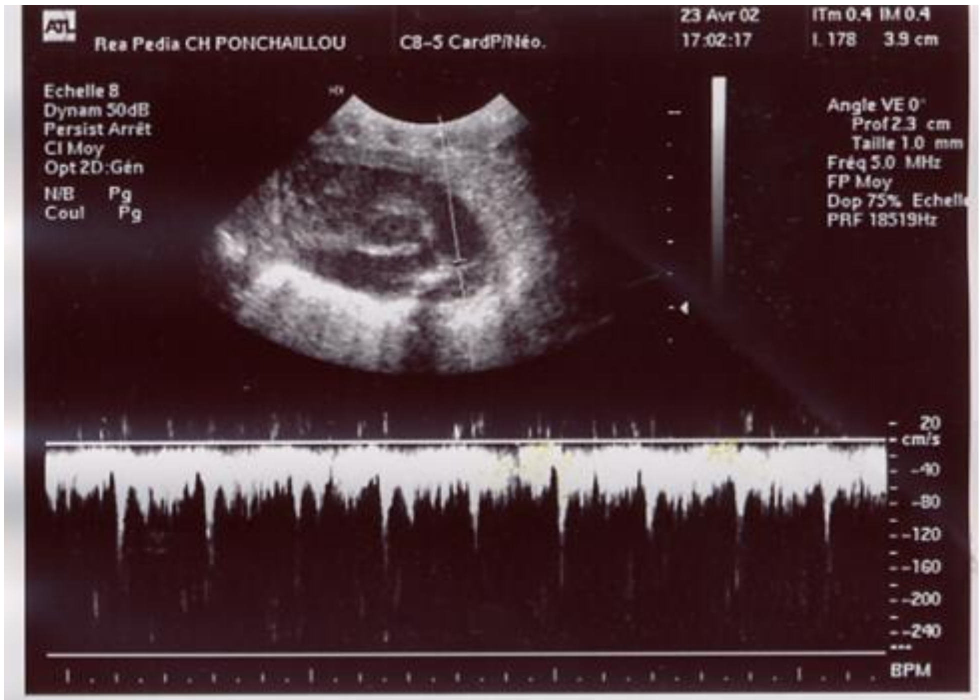
↘PA,

↘ perfusion d'organes

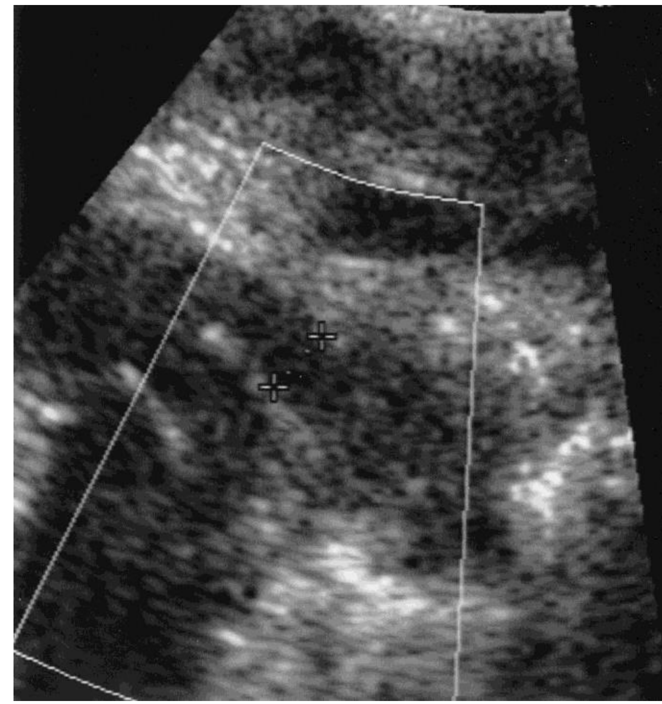
↗ RAS

↗ instabilité hémodyn.

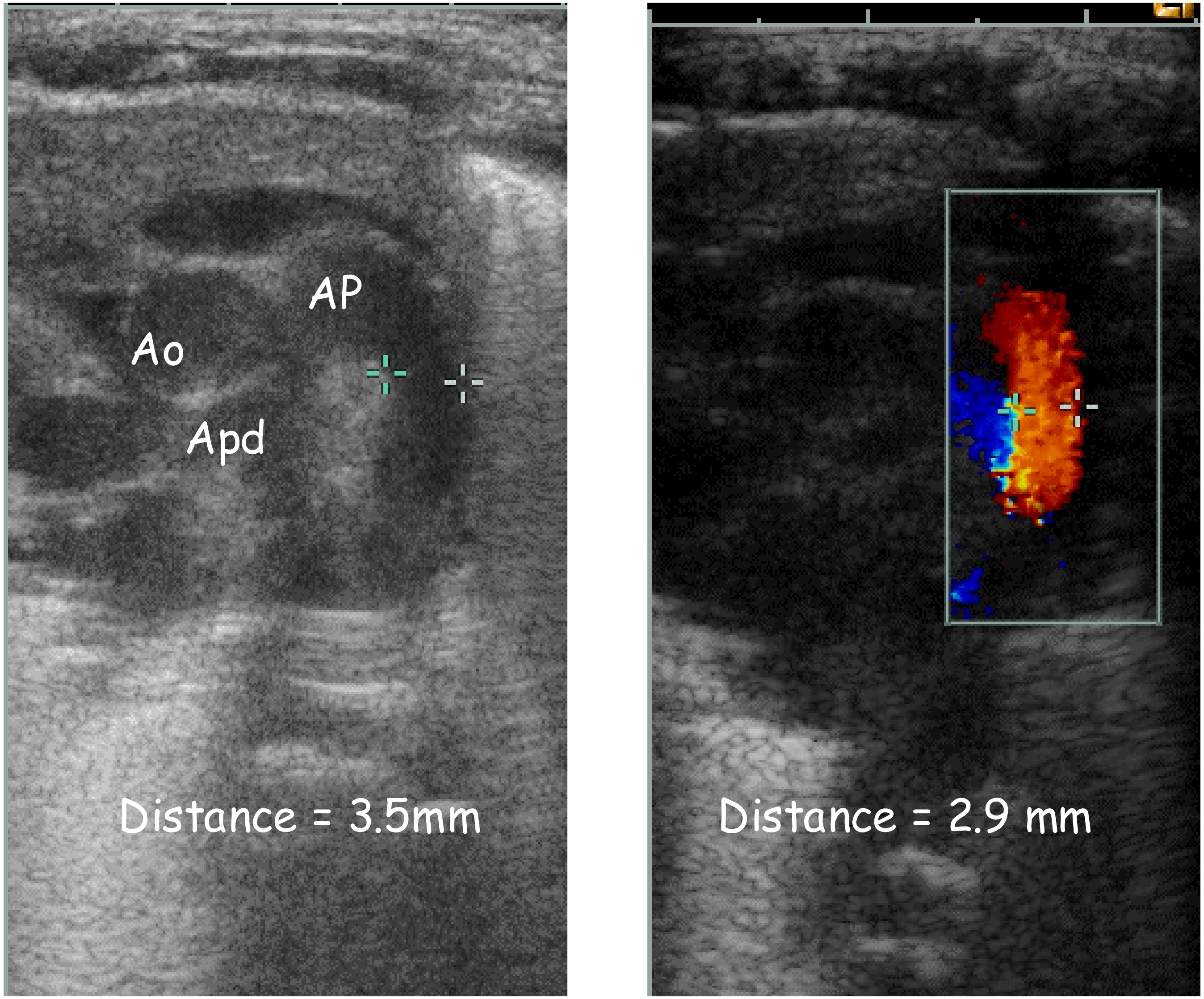
Le CA est il ouvert?



Hyperdébit pulmonaire



« Patte de canard »



Voie: parasternale haute, diamètre interne

Hémodynamiquement significatif ?

- Diamètre
  - >1.4 mm/kg
  - Evans 1995: >2 mm, risque évolutif entre 1.5 et 2 mm
- OG/Ao
  - > 1.4
- VmoyAPG
  - >0.5 m/sec (ou Vdiast APG >0.2m/sec)
- PAM
  - <10ème percentile

El Hajjar M..L Storme, Arch Dis Child 2005

- Flux diastolique absent ou rétrograde dans l'Aorte descendante (sous ductale)
  - Qp/Qs = 1.3 ± 0.11 si abs.
  - Qp/Qs = 1.6 ± 0.18 si rétr.

Evans J Pediatr 19994

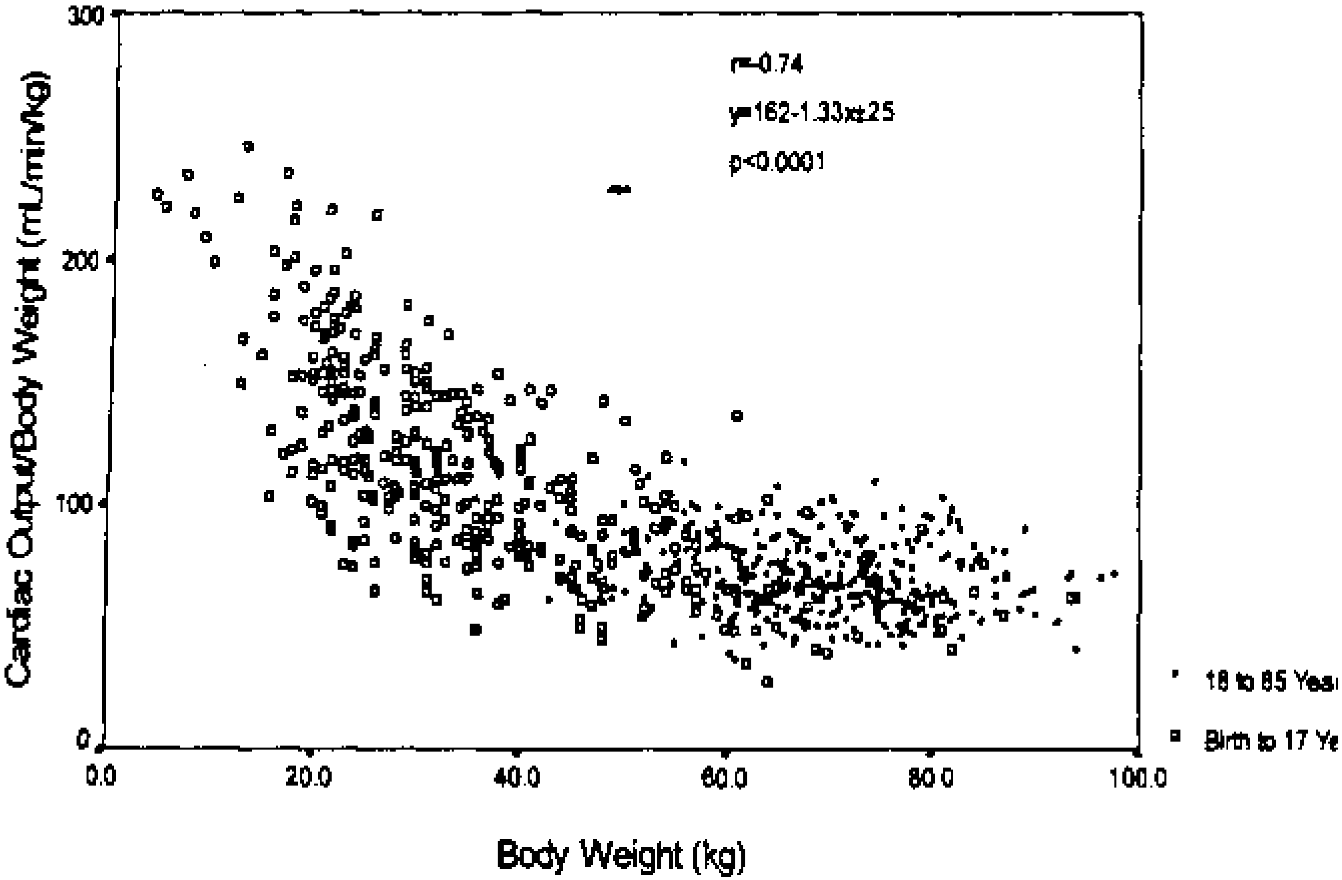
- Classification de SU
  - Aspect croissant ou pulsatile
- ➘ flux de VCS (<40 ml/kg/mn)

Rôle du FO si > 3 mm

Au delà d’un mois….

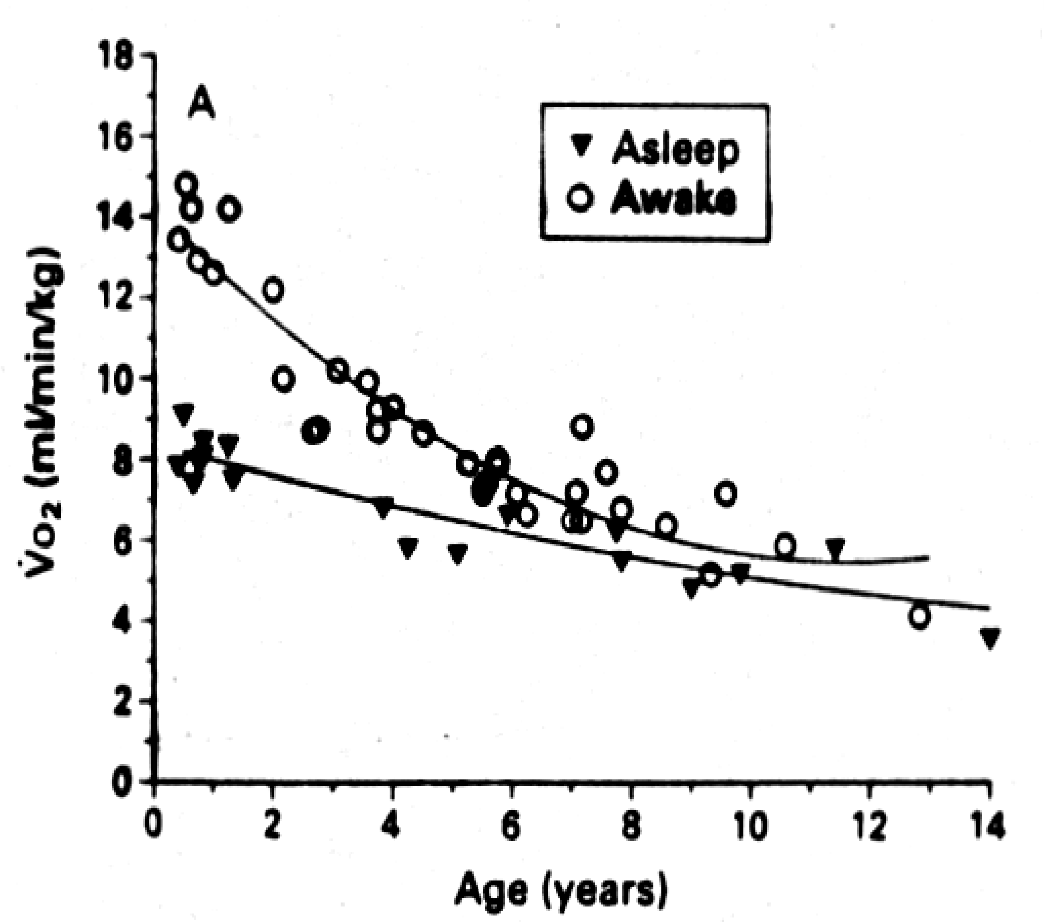
… encore quelques évolutions.

Index cardiaque / poids



de Simone et al. Circulation 1997

VO_2 Enfant



Childs C. Arch Dis CHild 1993

Attention: Effet « croissance »

Toutes les variables physiologiques ne sont pas liées « linéairement » à l'âge ou au poids!

« Volumes » Respiratoires

Paramètres	**1 semaine**	**1 an**	**3 ans**	**5 ans**	**8 ans**	**12 ans**	
Taille (cm)	48		75	96	109	130	150
Poids (kg)	3,3		10	15	18	26	39
CRF (ml)	75		263	532	660	1174	1855
CRF (ml.kg-1)	25		26	37	36	46	48
Capacité Vitale (ml)	100		475	910	1100	1855	2830
VE (ml.min-1)	550		1775	2460	2600	3240	4150
VT (ml)	17		78	112	130	180	260
VT (ml.kg-1)	*6*		*7,5*	*7,5*	*7,5*	*7*	*6,5*
Fréquence	30		24	22	20	18	16

Morbidité per Op / âge (n = 29220)

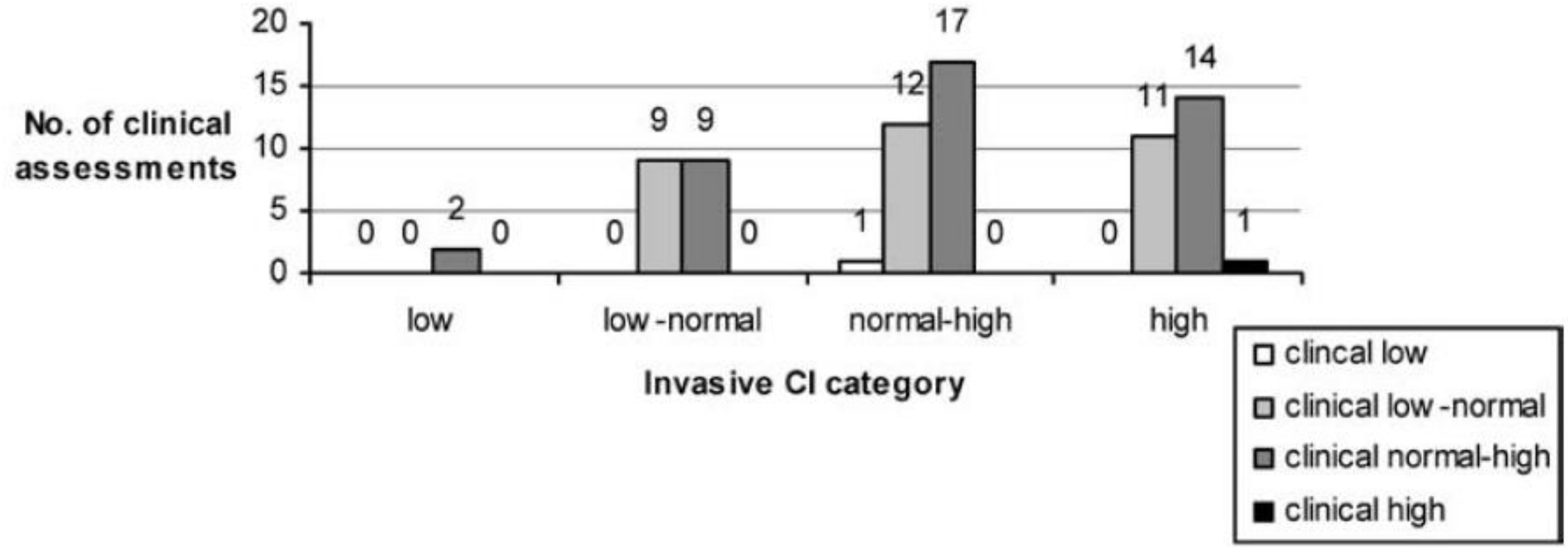
	Age									
	<1 mo (n = 361)		1–12 mo (n = 2,544)		1–5 yr (n = 13,484)		6–10 yr (n = 7,184)		11+ yr (n = 5,647)	
	n	Rate	n	Rate	n	Rate	n	Rate	n	Rate
None	308	8,532	2,368	9,308	12,585	9,333	6,381	8,882	5,126	9,077
Vomiting	1	28	12	47	76	56[a]	71	99	77	136[a]
Arrhythmia	6	166	22	86	527	391	670	933	317	561
Blood pressure	14	388[a]	14	55	30	22[a]	14	19	26	46
Temperature	3	83	6	24	18	13	6	8	9	16
Cardiac arrest	1	28	3	12	4	3	3	4	3	5
Airway obstruction	8	222	51	200[a]	133	99	62	86	51	90
Other respiratory	26	720[a]	81	318[a]	159	118	59	82[a]	56	99
Drug incident	0		5	20	27	20	20	28	20	35
Surgical	1	28	8	31	53	39	31	43	22	39
Death	3	83[a]	2	8	4	3	1	1	1	2

Cohen MM et al, Anesth Analg 1990

Les pièges du MONITORING

Jonathan R. Egan
Marino Festa
Andrew D. Cole
Graham R. Nunn
Jonathan Gillis
David S. Winlaw

Clinical assessment of cardiac performance in infants and children following cardiac surgery

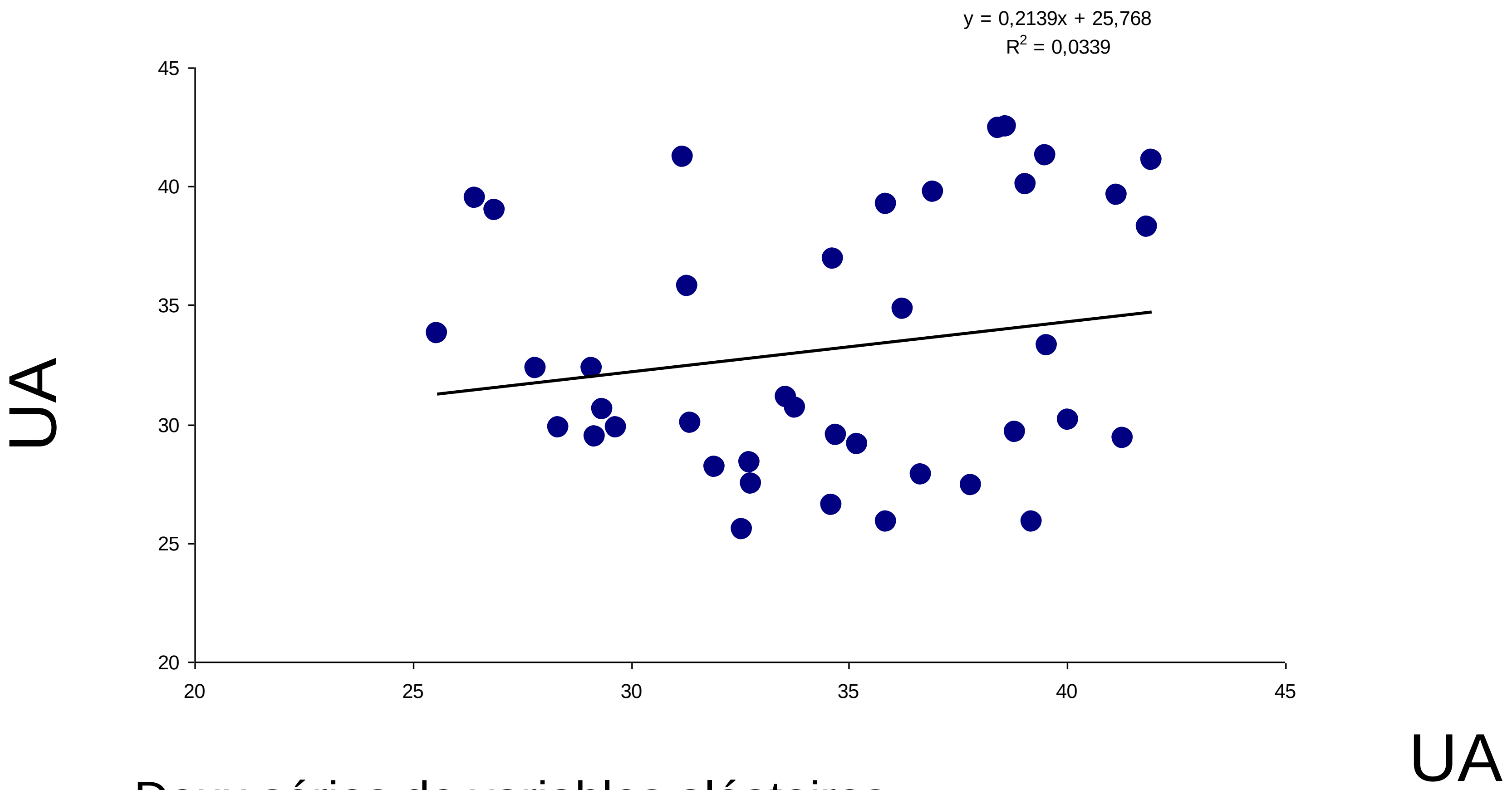


Monitoring : Pourquoi ?

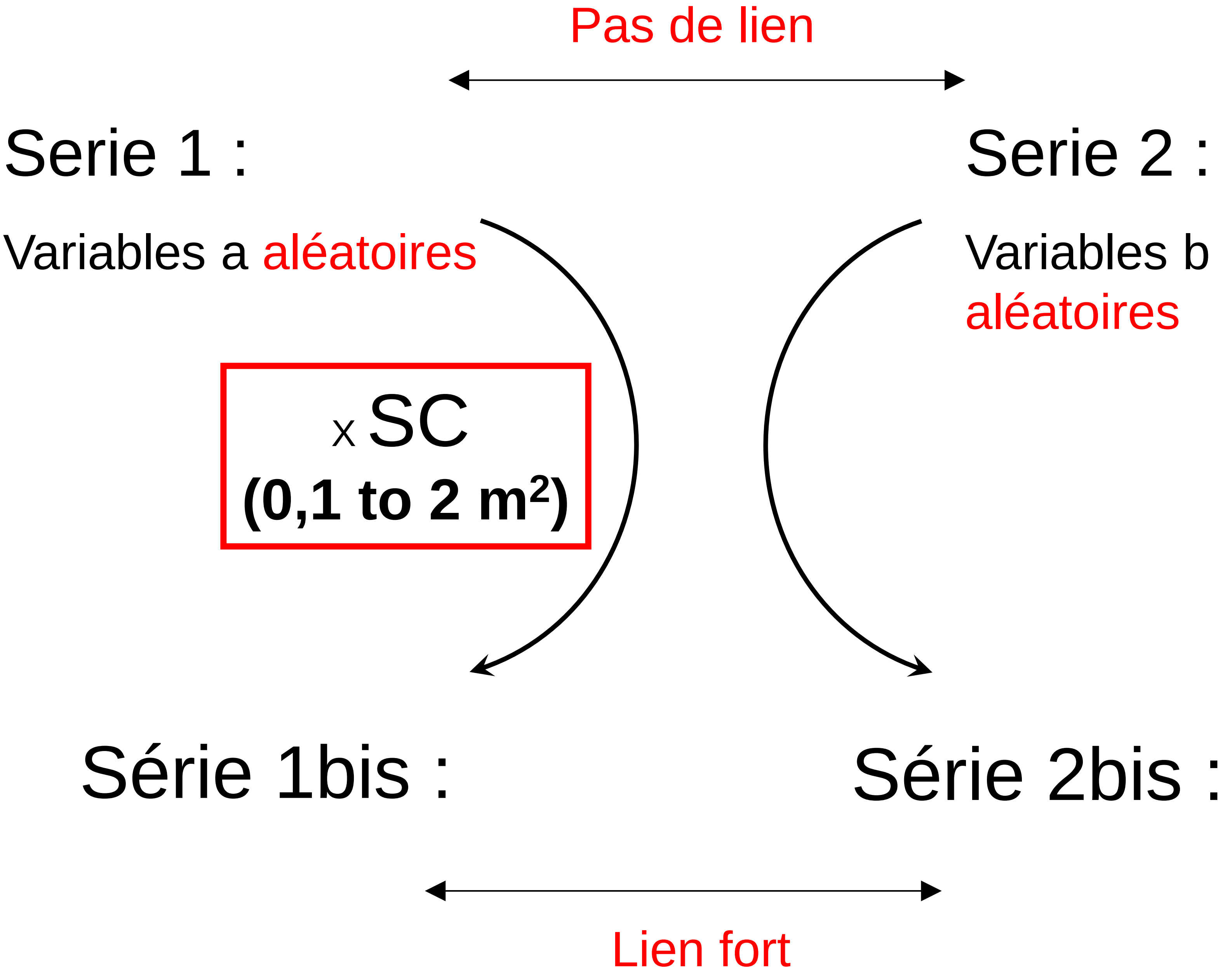
Intensive Care Med (2005) 31:568–573

Monitoring: les pièges de bases

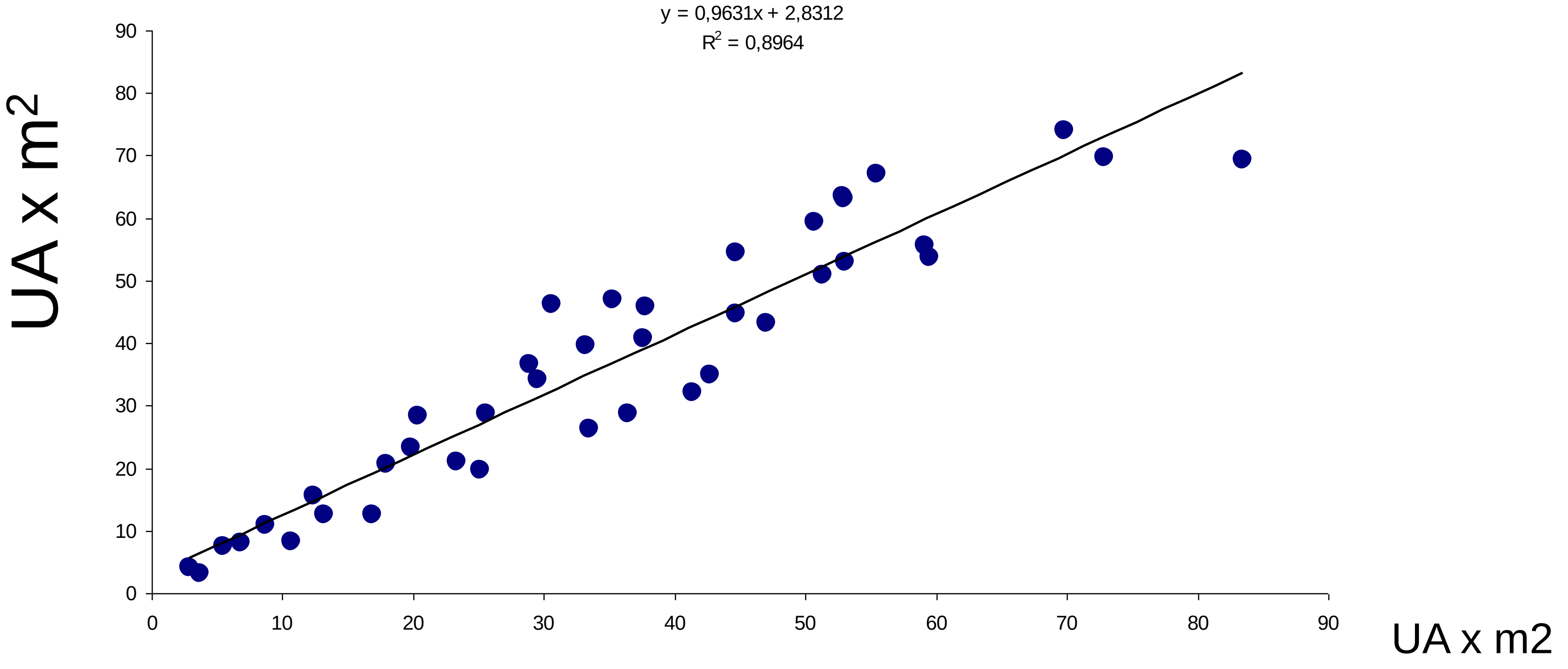
Un peu de mathematique…



- Deux séries de variables aléatoires
- de 25 to 42
- <u>Pas de lien entre les variables</u>

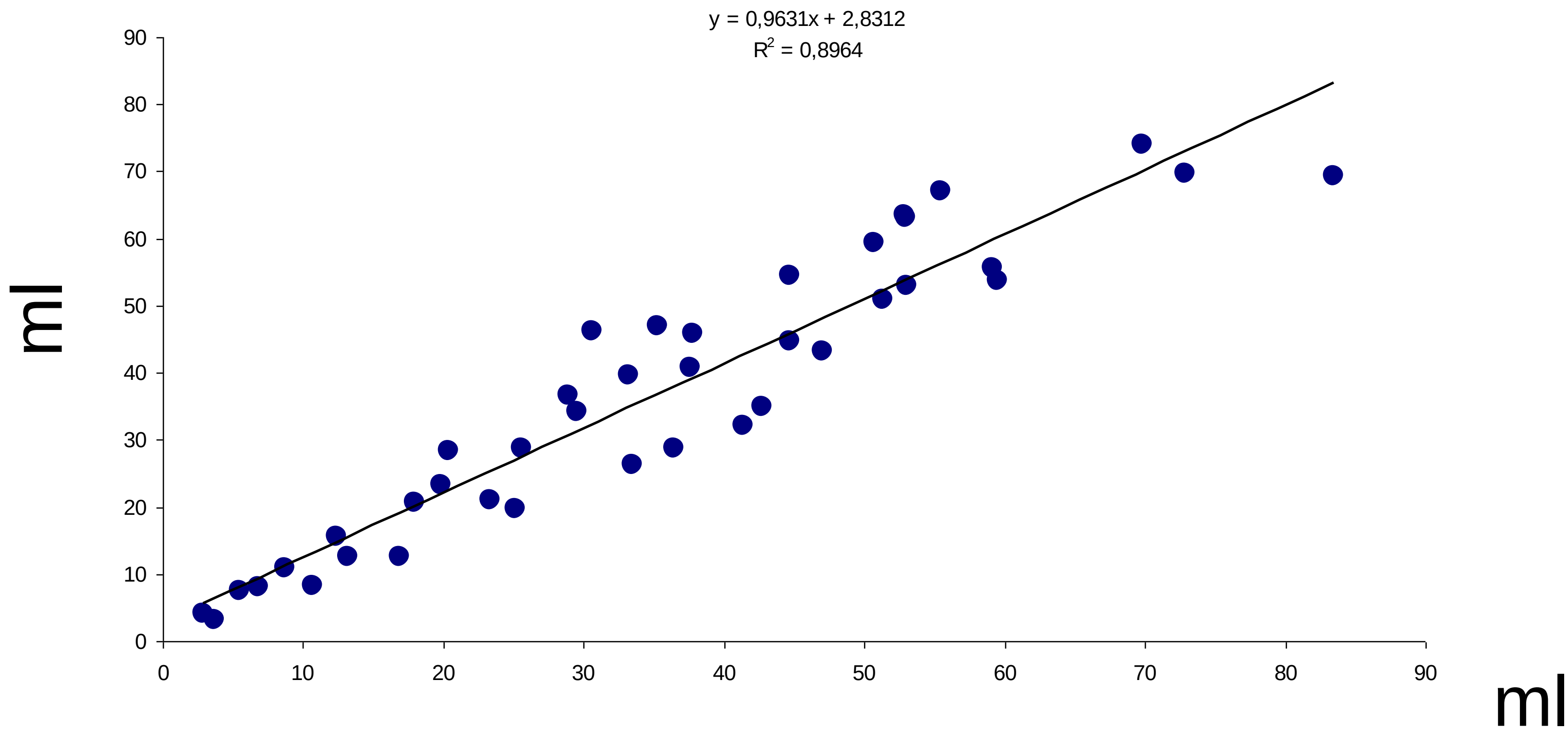

Pas de lien
Serie 1 :
Serie 2 :
Variables a aléatoires
Variables b aléatoires
x SC
(0,1 to 2 m²)
Série 1bis :
Série 2bis :
Lien fort

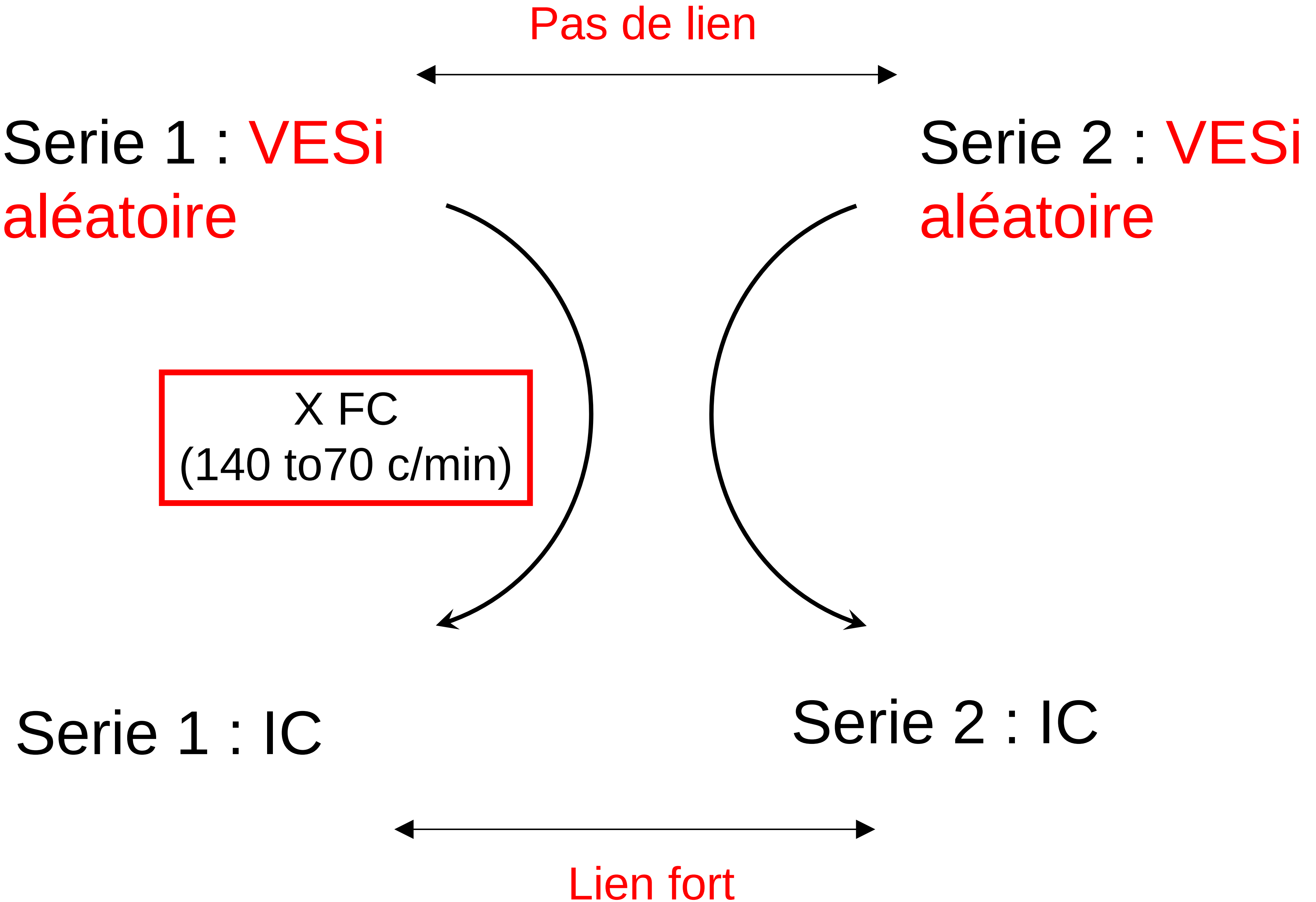
Lien séries 1 bis et 2 bis



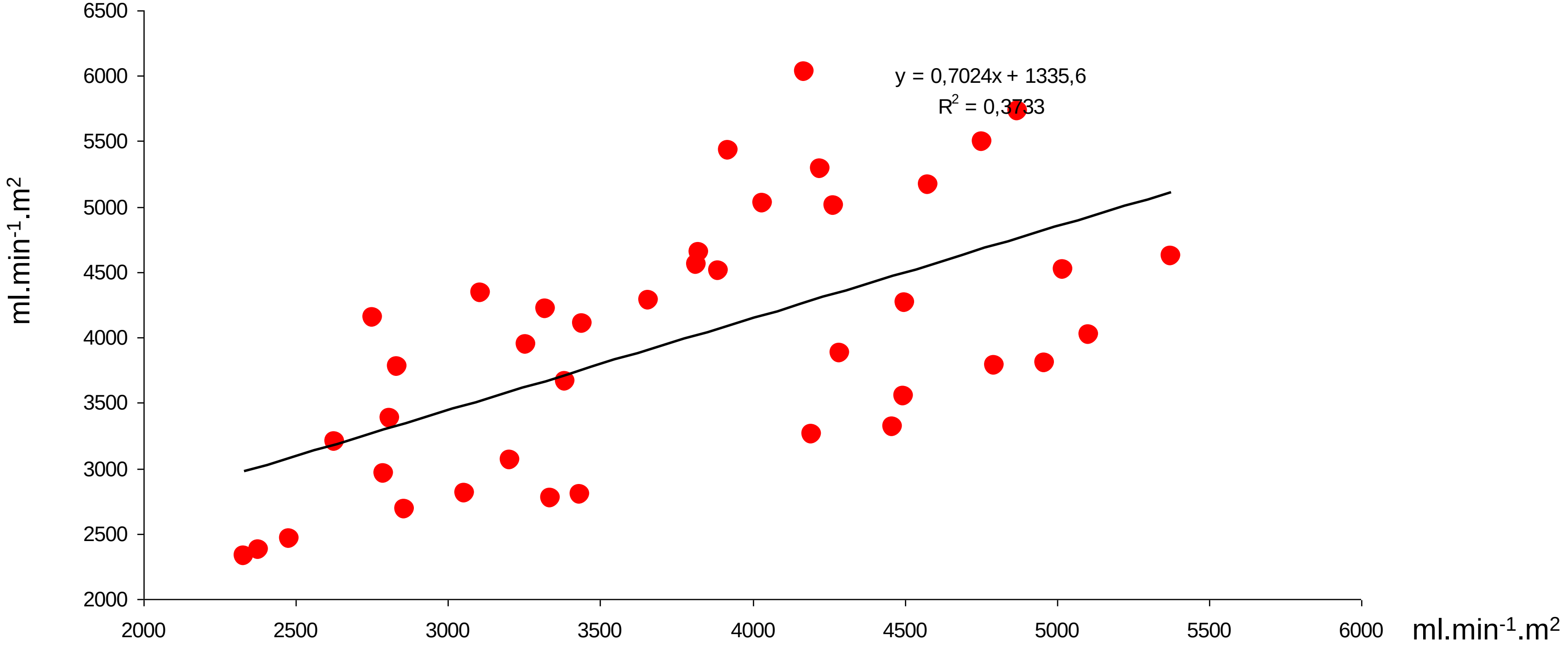
$$\boxed{ml/m^2} \times m^2 = ml$$

Lien entre deux variables ….à l'origine aléatoires

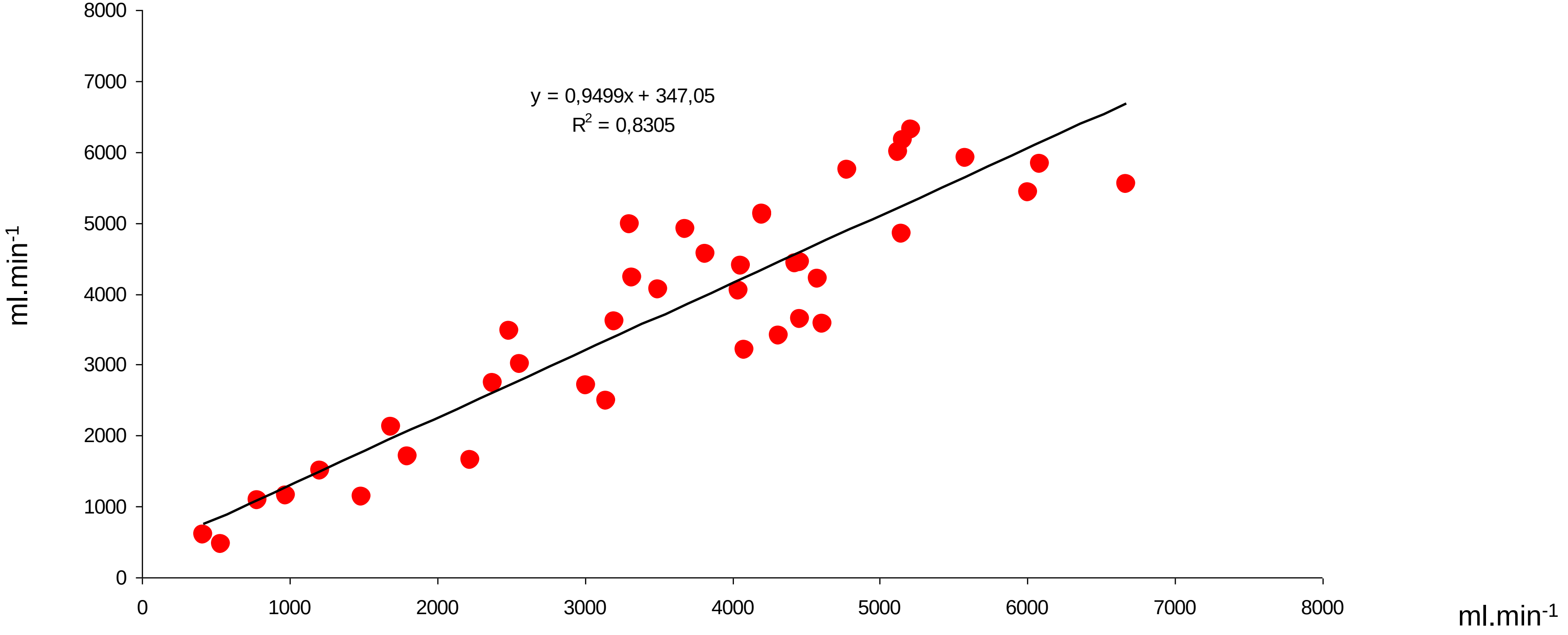


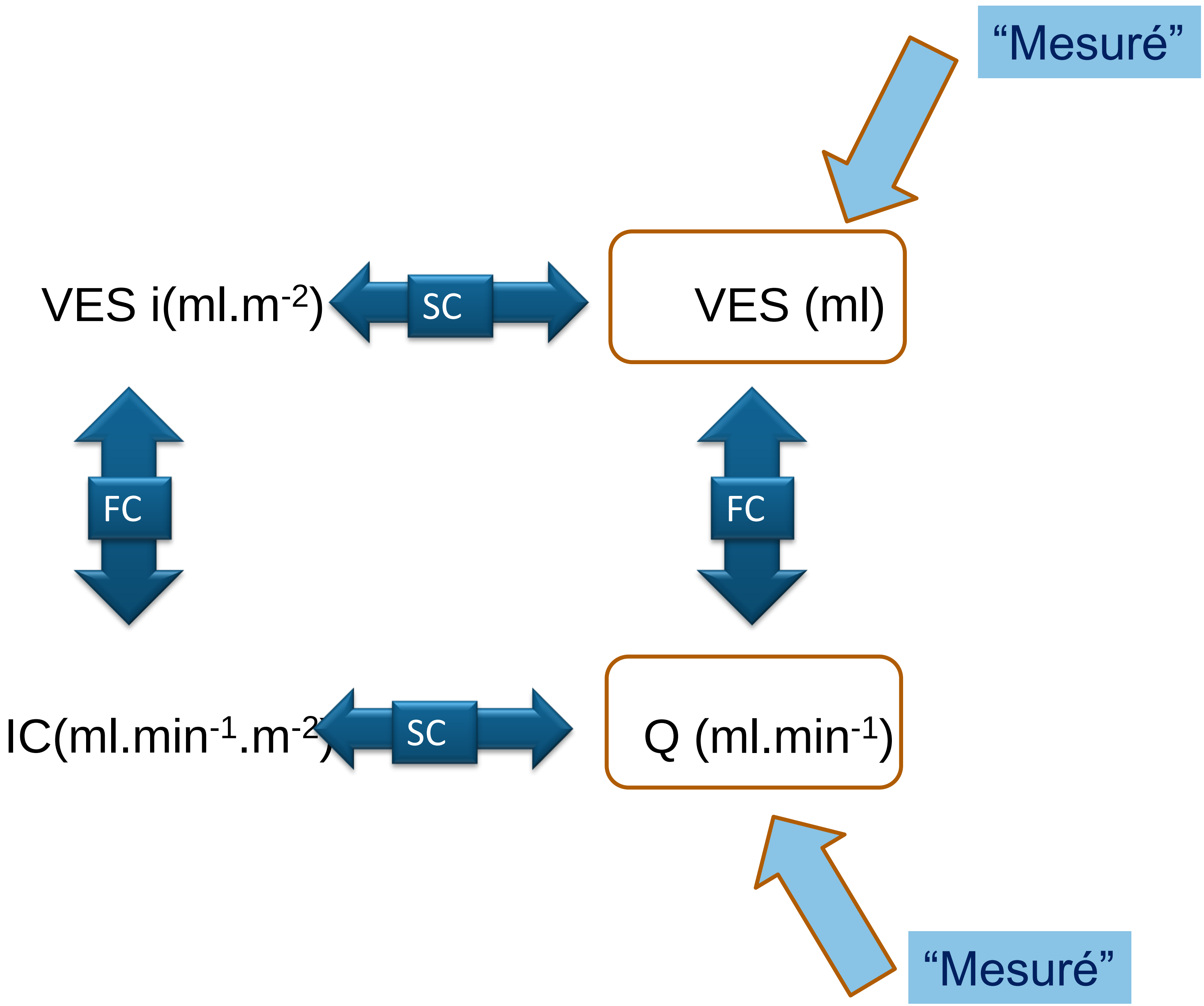

Pas de lien
Serie 1 : VESi aléatoire
Serie 2 : VESi aléatoire
X FC
(140 to70 c/min)
Serie 1 : IC
Serie 2 : IC
Lien fort

Index cardiaque



Débit cardiaque





"Mesuré"
VES i(ml.m-2)
SC
VES (ml)
FC
FC
IC(ml.min-1.m-2)
SC
Q (ml.min-1)
"Mesuré"

D’un point de vue scientifique, pour un calcul juste, il est important de faire attention aux unités !

Hauteur: m
Surface: m^2
Volume: m^3
Débit: cm^3/min(Volume/Temps)
Vitesse : m/sec (Distance/temps)

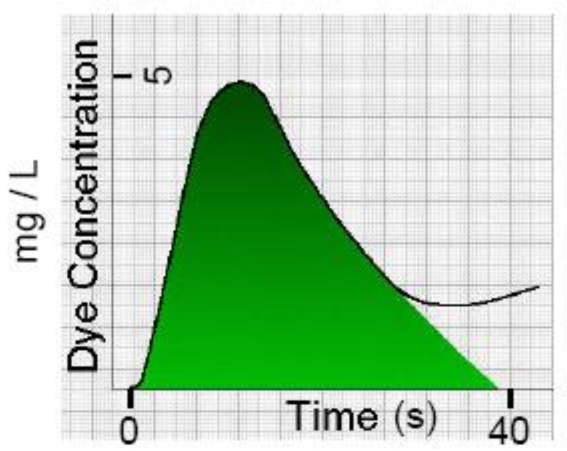
Le résultat d’un calcul de vitesse ne peux pas s’affranchir des unités (Kg ?)

Sinon, c’est une approximation…

From Damien Garcia / Montreal

Calcul:

Dye dilution

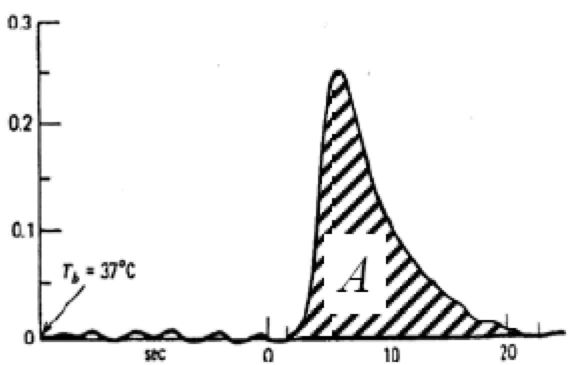


Q = (masse / aire de dilution)x60

m = 5 mg
A = 61 $(mg.L^{-1})$xsec

Q= ((mg/$(mg.L^{-1})$)x sec)x60
⇒ Q = 4.9 L/min

Thermodilution



$Q = V (T_b-T_i)$ x(0,891) / area of T°

T_{bang}= 37° $T_{injection}$=5°
$V_{olume\ injection}$ = 5 ml
Aire (A) = 1.7 °C.sec

Q= (ml x (ΔC°))/ C°.sec x60
⇒ Q = 4900 mL/min
= 4.9L/min

Respect des unités et mesures directes

Variable

“Estimée….”

Pas de correspondance des unités

“Calculée”

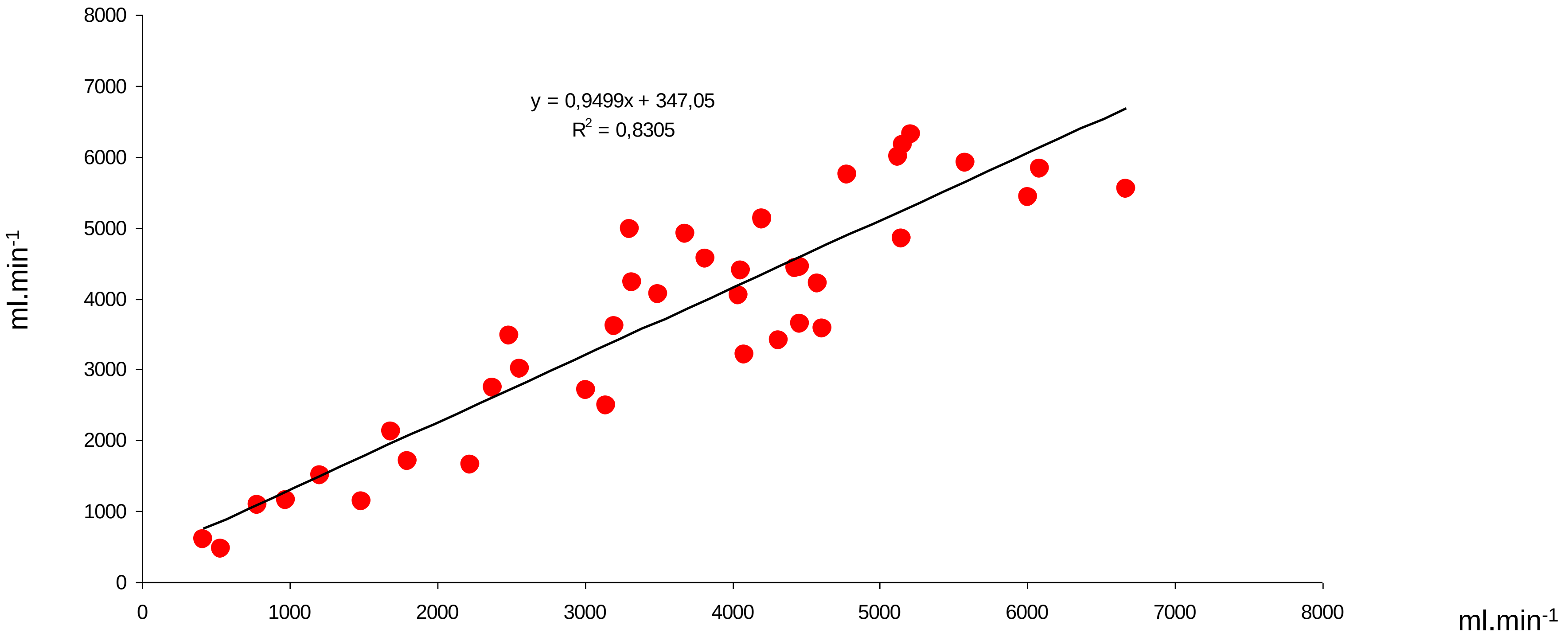
Avec correspondance des unités

?

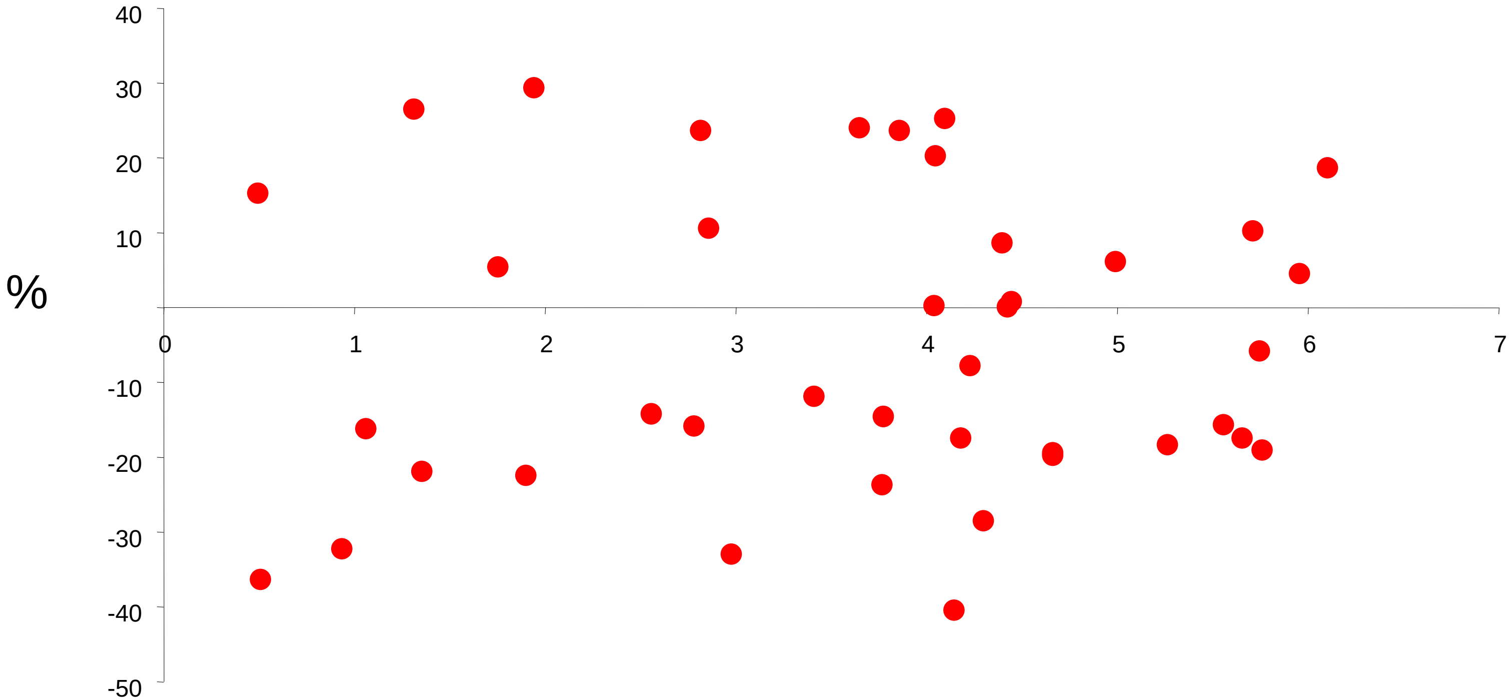
Variable

Variation

Débit cardiaque



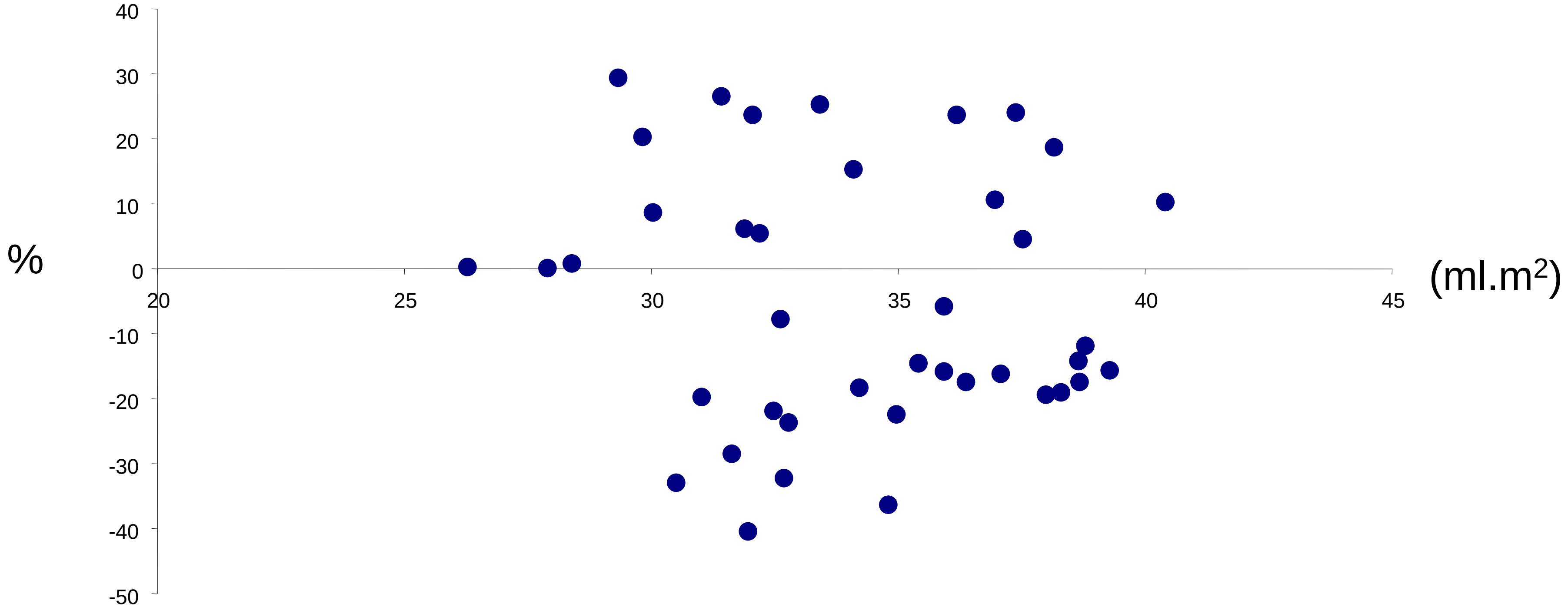
Bland & Haltman (% variation) Débit cardiaque



Biais – 0,05%
Limites d'agrément +/- 40%

Bland & Haltman (% variation)

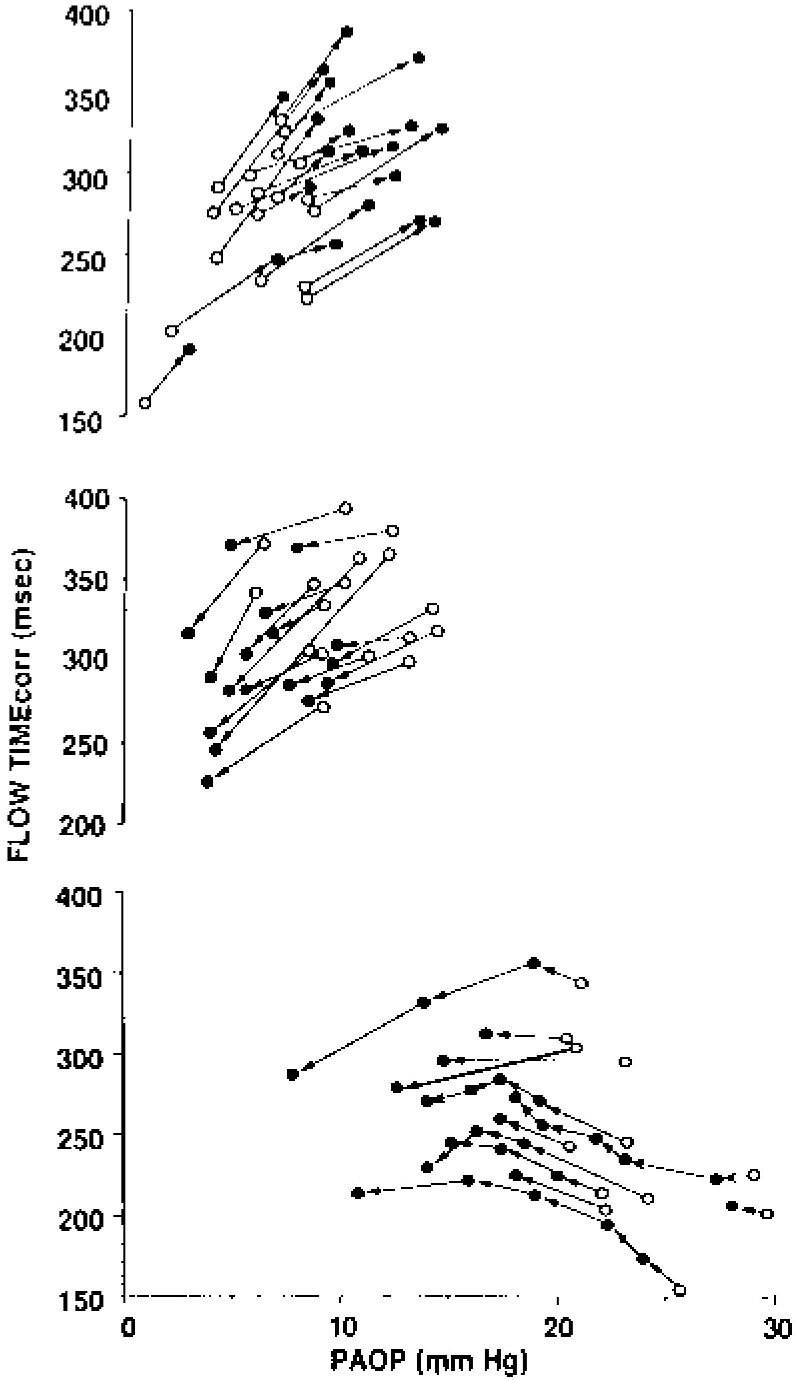
VESi

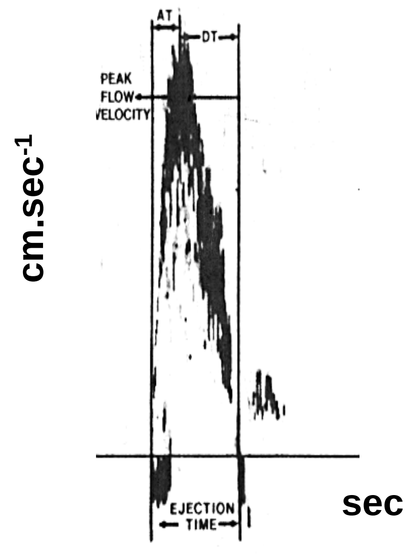


Biais – 0,05%
Limites d’agrément +/- 40%

Les « corrections »: Attention !

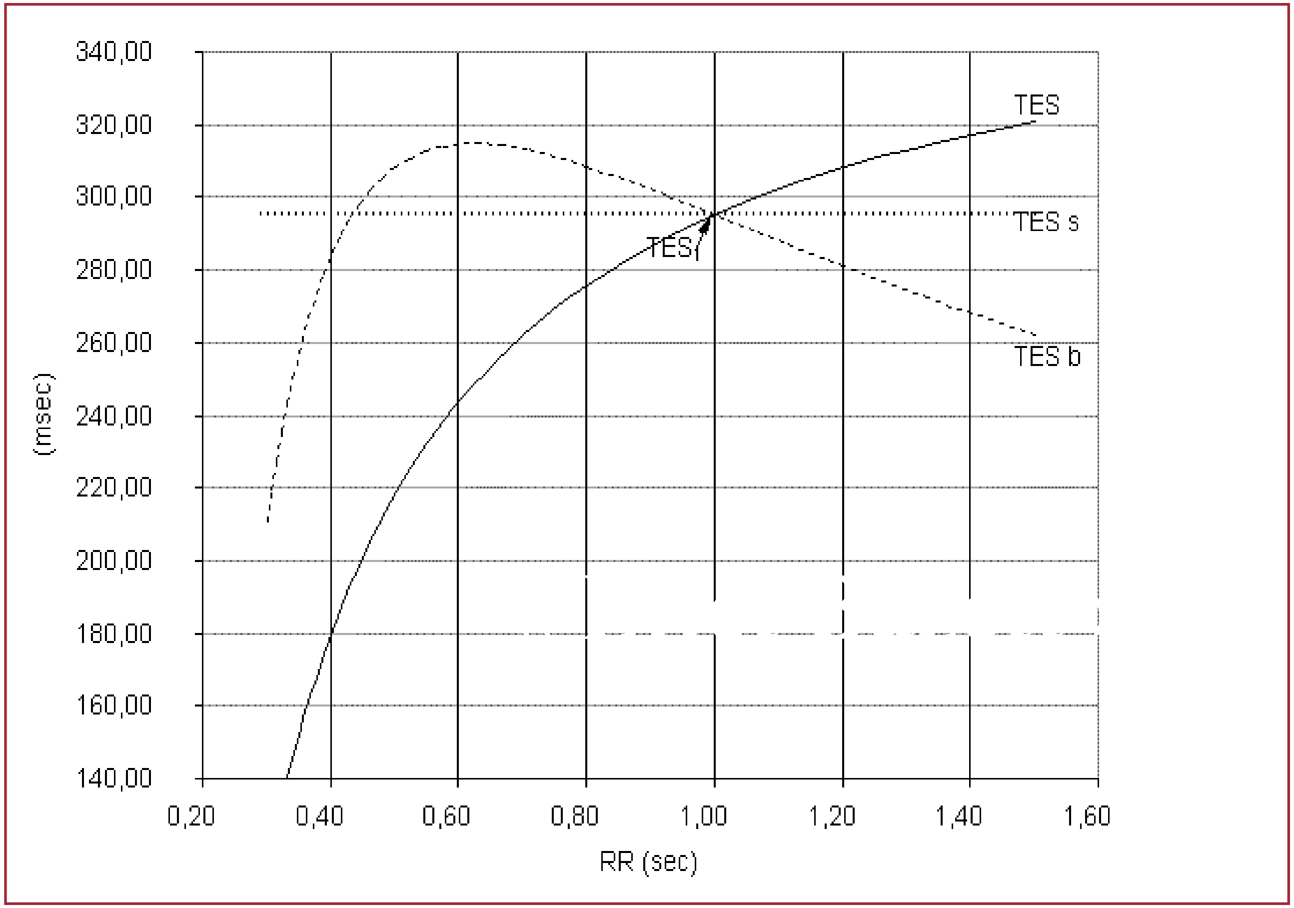
PRECHARGE



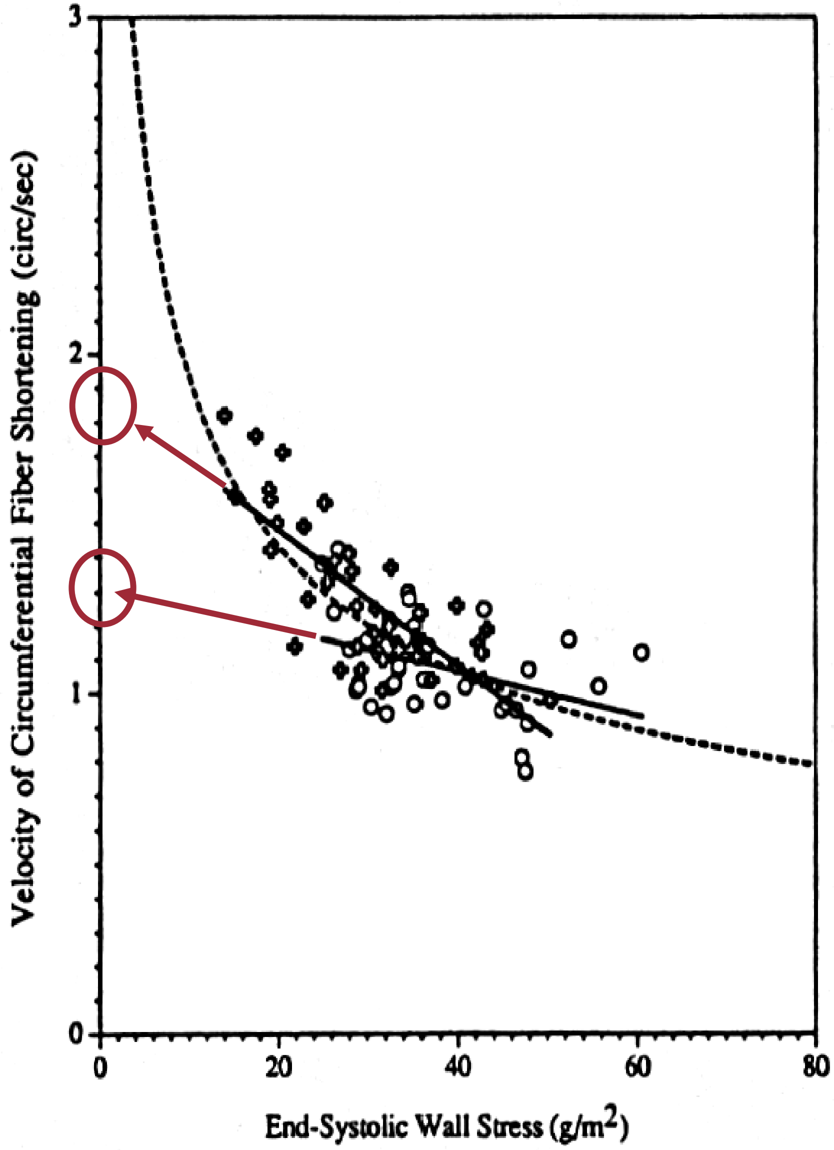


$$TEScorrigé = \frac{TES}{\sqrt{(RR)}}$$

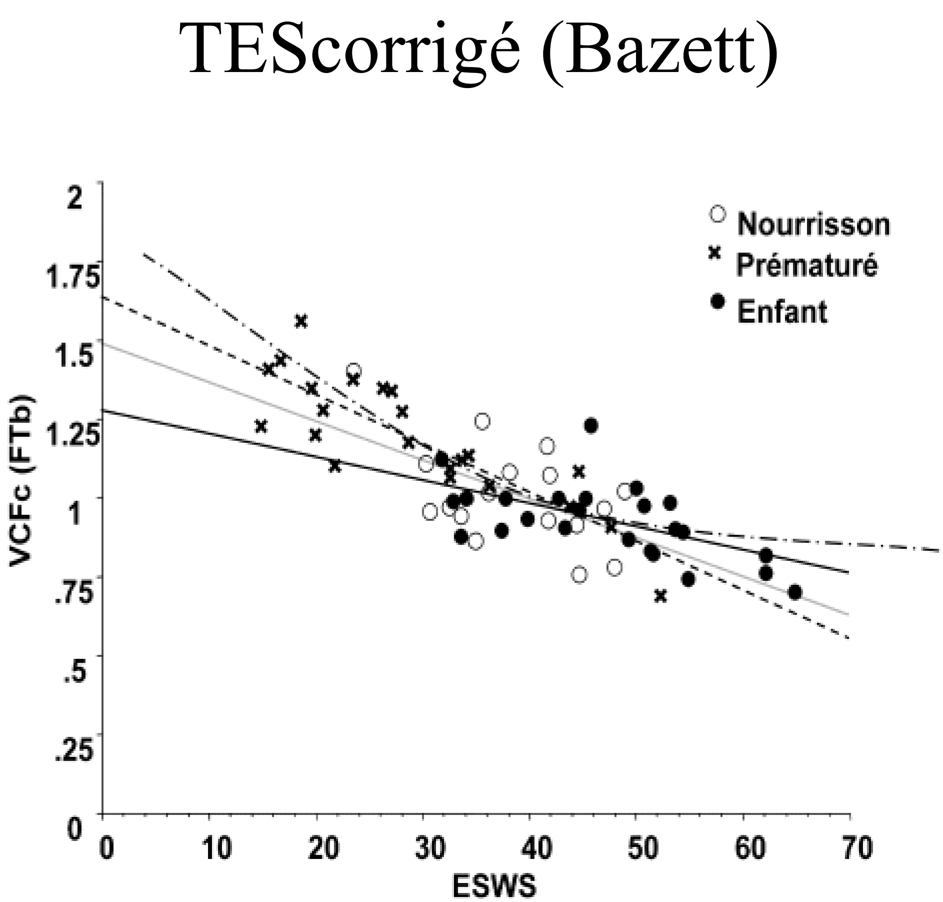
Singer et al. Crit Care Med 1991

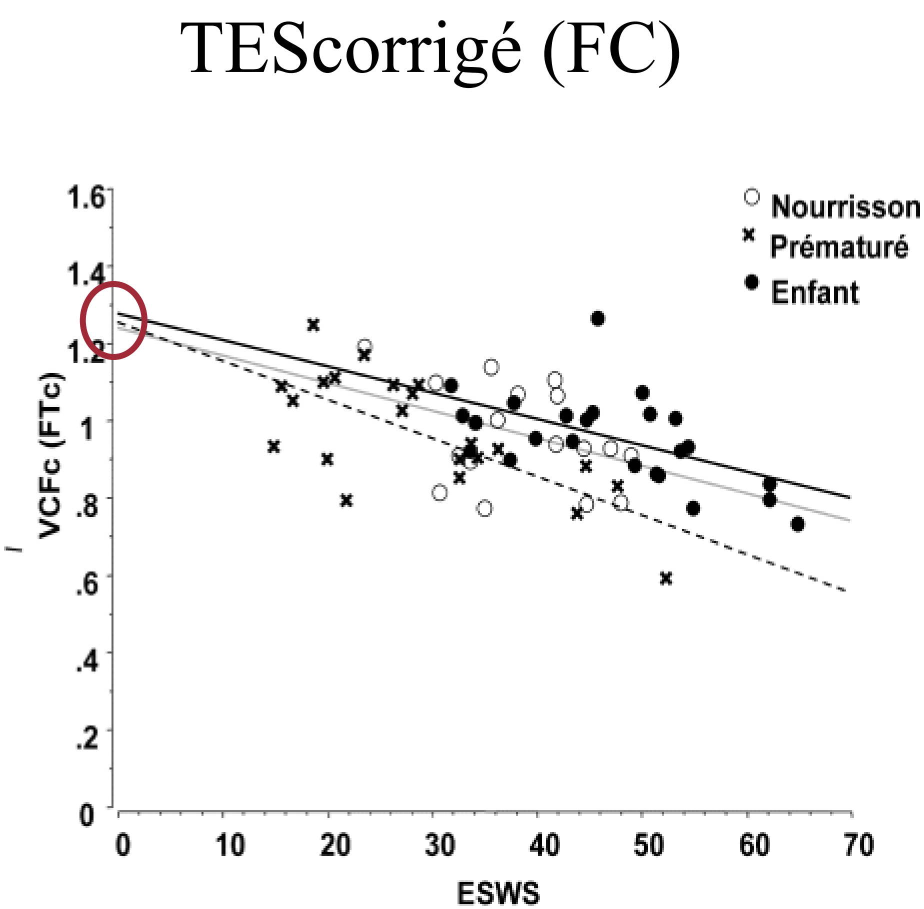


Références	Groupes	Régression
Harris et al. Am J Cardio1964	Enfants	TES =376-[Fc.(1,3)]
Spitaels et al. Circulation 1974	Enfants	TES =372.7-[Fc.(1,29)]
Golde et al. Circulation 1970	Enfants	TES = 337+[Mois.(0,35)].-[(Fc).(1,35)]
Weissler et al. Circulation 1968	Adultes	TES =413-[Fc.(1,7)]



VCFc = FR/TES corrigé





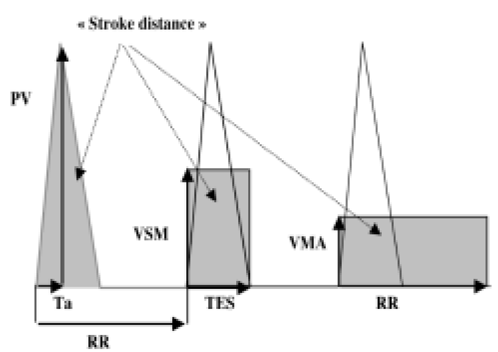
Contractilité ?

« Retomber sur ses pieds » ?

« Dobutamine » et FTcor

	TO	T1	T2	T3	T4	Variation T4-TO
PV	119	120	140	159	184	54,6%
min distance	1364	1408	1587	1718	2032	
HR	56	58	61	62	71	
SV	24,36	24,28	26,02	27,71	28,62	17,5%
RR calculé	1,071	1,034	0,984	0,968	0,845	
FT recalculé	**368,43**	**364,14**	**334,50**	**313,69**	**279,98**	
FT cor (calculé)	**355,93**	**358,02**	**337,27**	**318,88**	**304,56**	**-14,4%**
						≠
FT Mesuré	329	329	323	313	296	
FT cor Mesuré	317	324	326	317	321	1,3%
ISVR	572	554	498	487	454	-20,6%

?

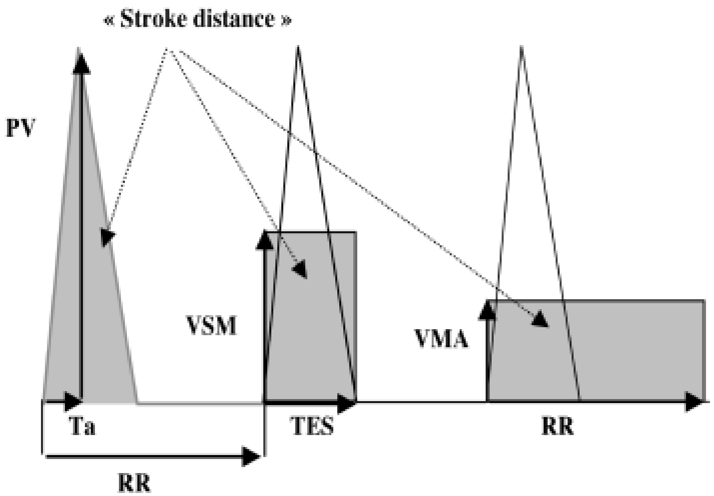


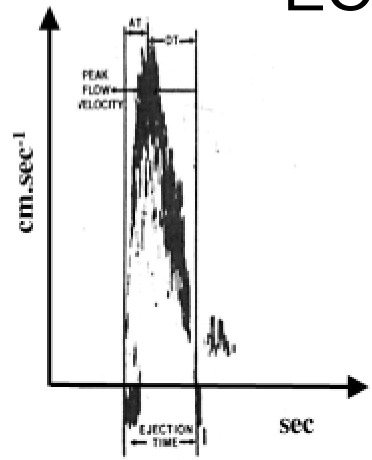
Singer et al. Crit Care Med 1991

Correspondance des unités !

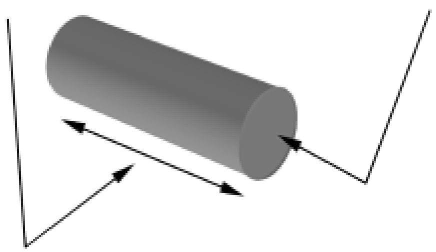
Echographie Doppler

ECHOGRAPHIE DOPPLER





SV (cm3) = « Stroke distance » (cm) x Ao Area (cm2)



Mesure réelle de SV et correspondance des unités

VES (cm^3) x FC (c/min) = Q (cm^3/min ou **ml/min)**

Mesure sur 5 cycles (variations respiratoires)

Cardiac Index Quantification by Doppler Ultrasound in Patients Without Left Ventricular Outflow Tract Abnormalities

ARTURO EVANGELISTA, MD, DAVID GARCIA-DORADO, MD, FACC,
HERMINIO GARCIA DEL CASTILLO, MD, TERESA GONZALEZ-ALUJAS, MD,
JORDI SOLER-SOLER, MD, FACC

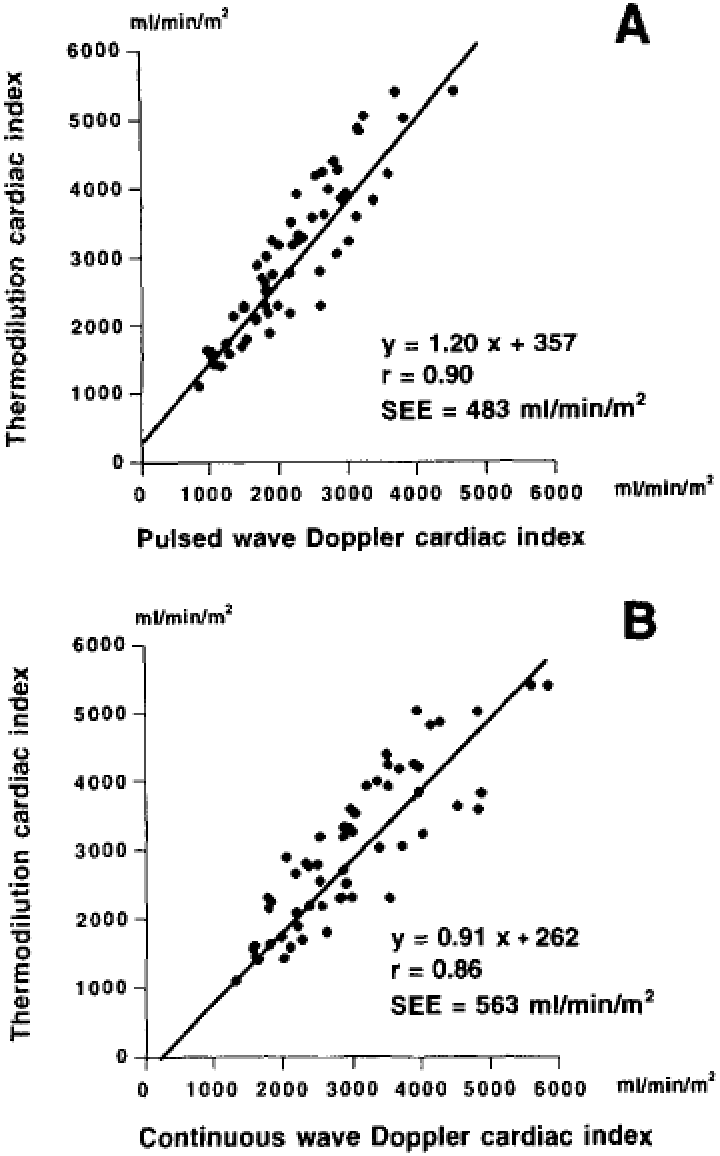
Barcelona, Spain

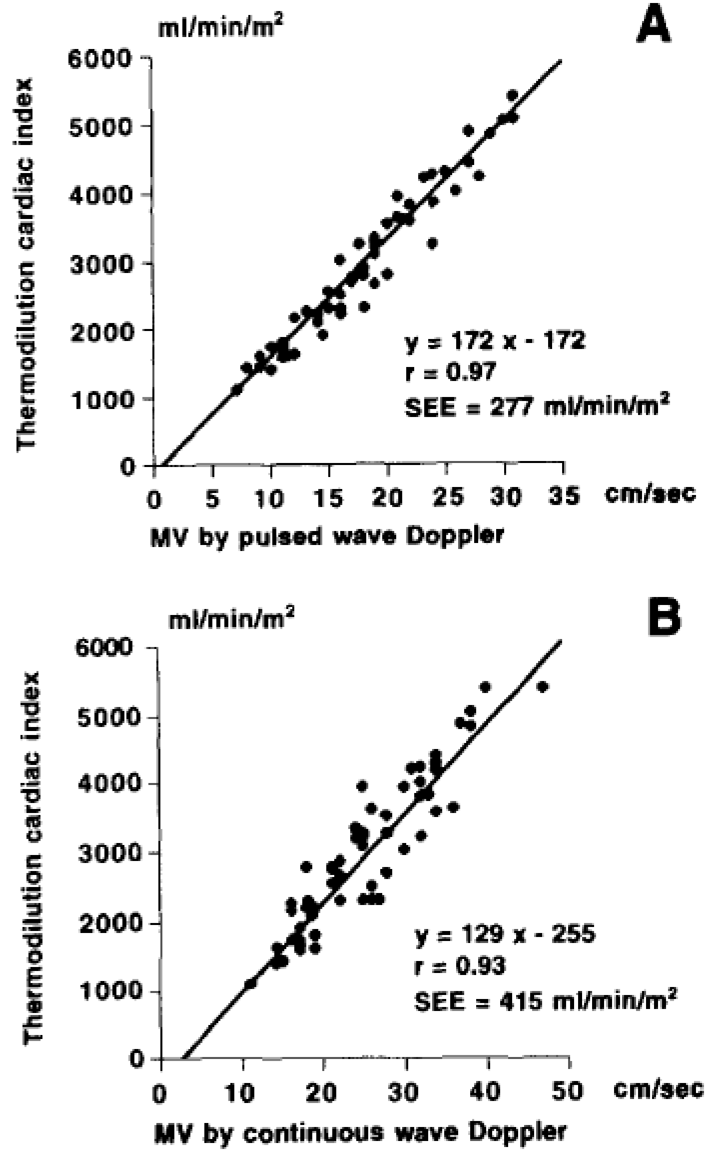
- 156 patients (84 men, 72 women; mean age 37 +/- 20 years, range 6 to 86).

- Patients in the intensive care unit who were undergoing pulmonary artery catheterization

- Absence of left ventricular outflow tract abnormalities

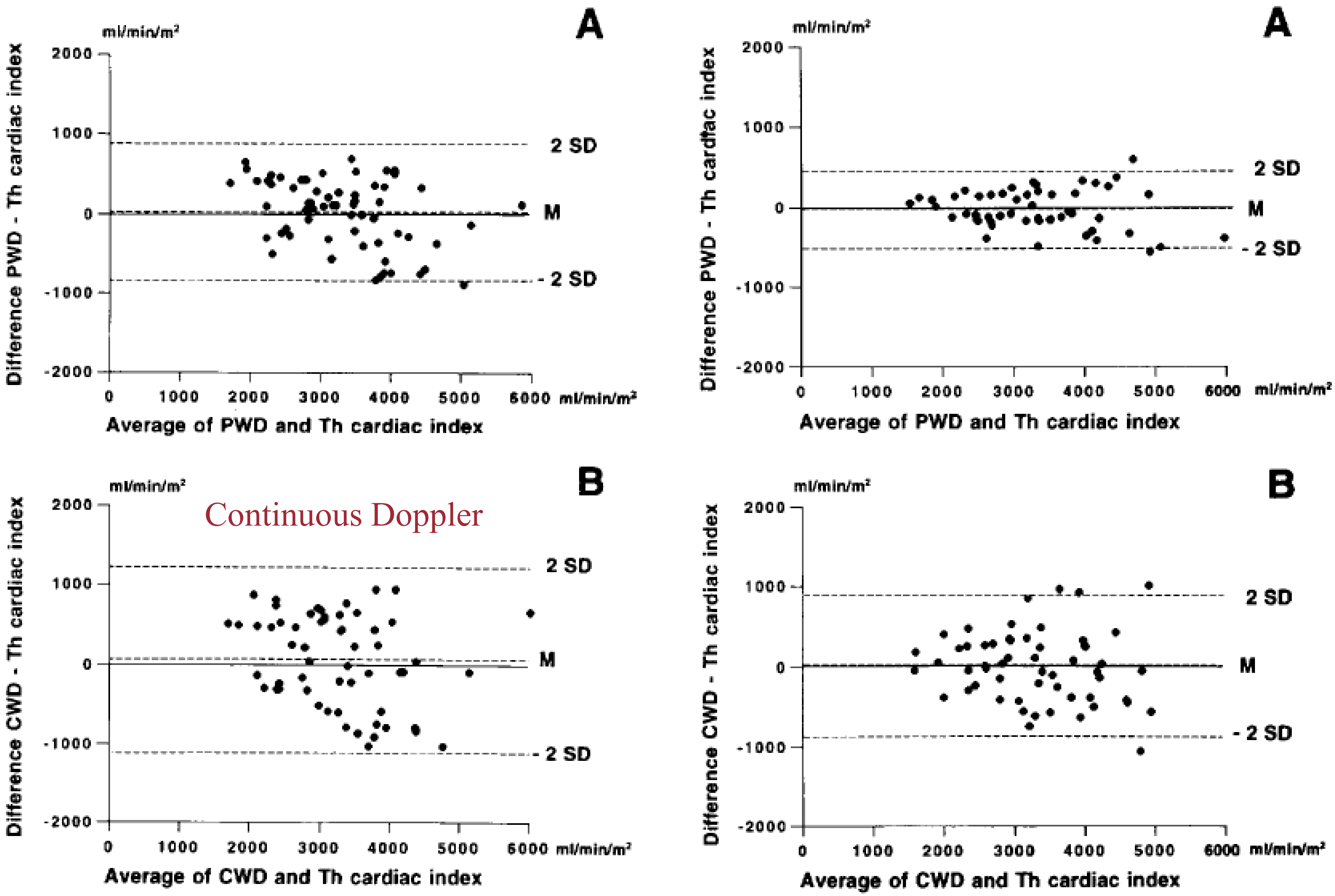
Evangelista et al. J Am Coll Cardio 1995





Evangelista et al. J Am Coll Cardio 1995

Pulsed Doppler



Evangelista et al. J Am Coll Cardio 1995

Extrapolation of cardiac index from analysis of the left ventricular outflow velocities in children: implication of the relationship between aortic size and body surface area

ERIC WODEY MD, PhD*, LOTFI SENHADJI PhD†,
FRANÇOIS CARRE MD, PhD‡ AND CLAUDE ECOFFEY MD*

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$$\text{(A) } CI(l\cdot min^{-1}\cdot m^{-2}) = 0.129 \times MAVF\ (cm\cdot s^{-1})$$

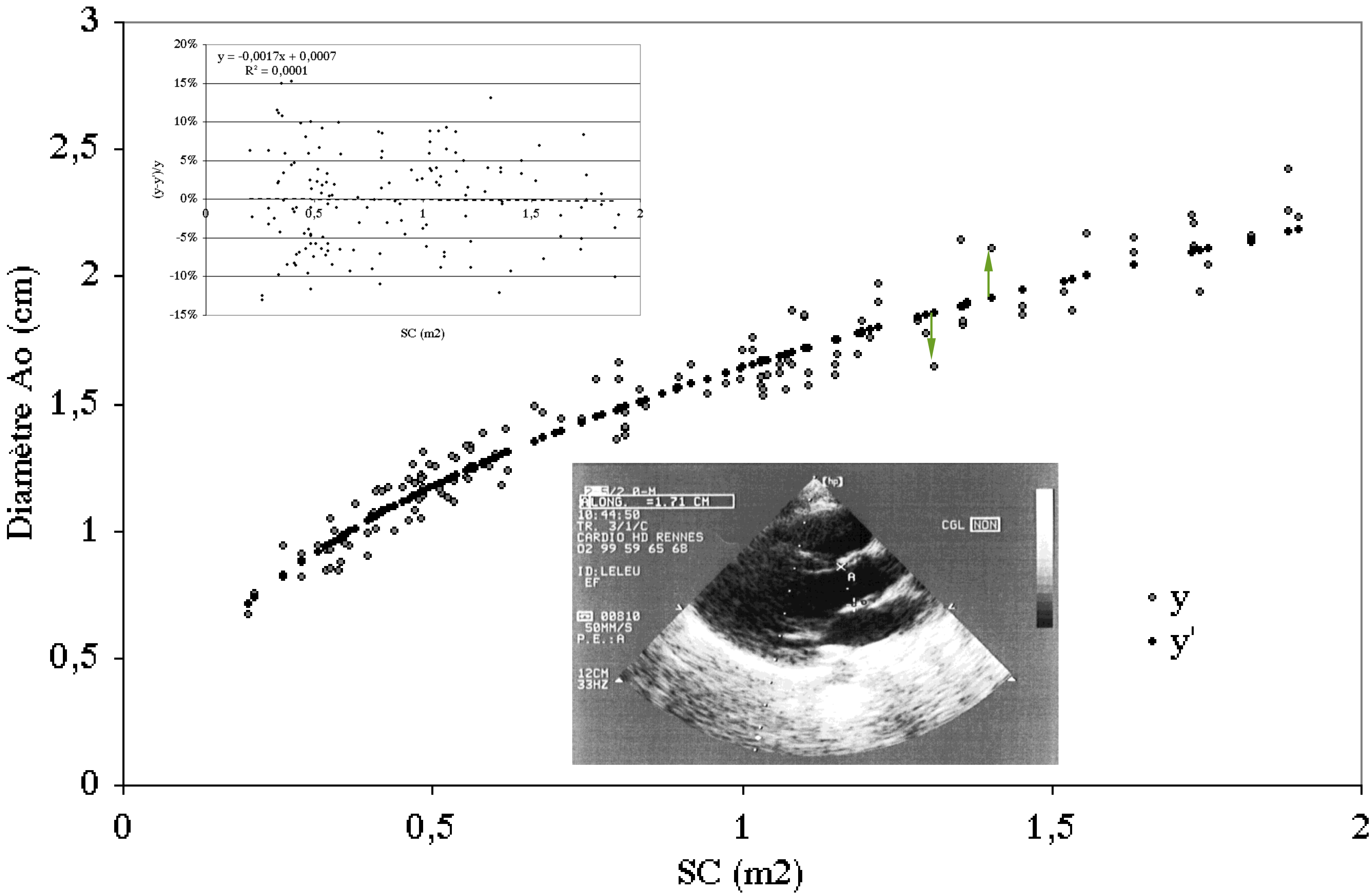
$$\text{(B) } CI\ (l\cdot min^{-1}\cdot m^{-2}) = [AA\ (cm^2) \times MAVF\ (cm\cdot s^{-1}) \times 60]/1000 \times BSA\ (m^2)$$

$$\text{(C) } AA\ (cm^2) = 2.15 \times BSA\ (m^2)$$

$$\text{(D) } CI\ (l\ min^{-1}\cdot m^{-2}) = ([\pi \times \varnothing Ao\ (cm)/4] \times MAVF\ (cm\cdot s^{-1}) \times 60)/1000 \times BSA(m^2)$$

$$\text{(E) } \varnothing Ao = 1.65 \times \sqrt{BSA}$$

Paediatric Anaesthesia 2002 12: 220±226



126 enfants et NN (Age 3 jours à 18 ans).

Paediatric Anaesthesia 2002 12: 220±226

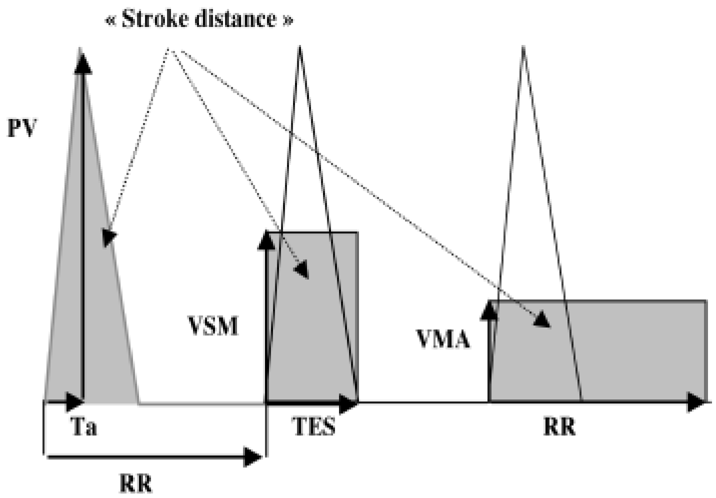
Table 2
Relationship between aortic size and BSA obtained with nonlinear regression method

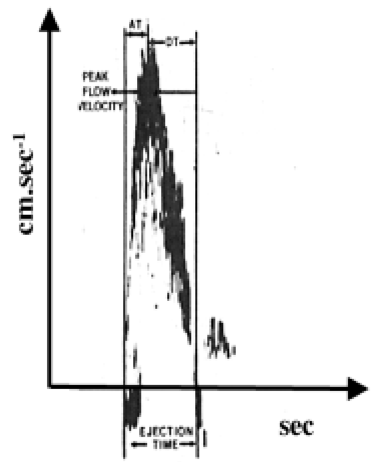
	Model	a	b	c	$y - y'/y$	*SD*	P	r
ØAo								
1	$y = a(x^{1/4}) + b$	2.969	−1.315	–	3.29E−03	6.11E−02	0.999	0.974
2	$y = a(x^{1/3}) + b$	2.280	−0.632	–	3.73E−03	6.11E−02	1	0.974
3	$y = a(x^{c}) + b$	2.208	−0.561	0.345	3.80E−03	6.11E−02	1	0.974
4	$y = a(x^{1/2}) + b$	1.583	0.0519	–	−4.79E−03	6.37E−02	0.999	0.973
5	$y = a(x) + b$	0.84	0.738	–	9.07E−03	8.55E−0.2	0.81	0.962
6	$y = a(x^{1/2})$	1.639	–	–	−5.63E−04	6.27E−02	0.999	0.973
7	$y = a(x^{c})$	1.636	–	0.479	5.26E−03	6.34E−02	0.998	0.974
8	$y = a(x^{1/3})$	1.594	–	–	4.12E−0.2	1.12E−01	0.848	0.974
AA								
9	$y = a(x)$	2.093	–	–	4.25E−03	1.25E−01	0.987	0.970
10	$y = a(x^{c}) + b$	2.228	−0.109	0.894	−1.70E−02	1.26E−01	0.952	0.970
11	$y = a(x) + b$	2.01	0.007	–	−2.19E−02	1.34E−0.1	0.898	0.970
ØAo $_{index}$								
12	$y = a(x^{c}) + b$	3.165	−1.508	−0.286	3.62E−03	6.16E−02	0.991	0.970
13	$y = a(x^{c})$	1.654	–	−0.492	6.5E−03	6.34E−02	0.861	0.968
AA $_{index}$								
14	$y = a(x) + b$	−0.082	2.199	–	−1.55E−02	1.27E−01	0.991	0.131
15	$y = a(x^{c}) + b$	−0.042	2.169	2.12	1.54E−02	1.26E−01	0.998	0.146

(E) $\varnothing Ao = 1.65 \times \sqrt{BSA}$

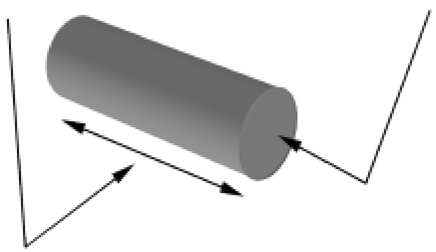
(C) $AA\ (cm^2) = 2.15 \times BSA\ (m^2)$

Paediatric Anaesthesia 2002 12: 220±226





SV (cm3) = « Stroke distance » (cm) x Ao Area (cm2)



SVI (cm ^{3}.m^2) = Stroke distance (cm) x Ao Area Index (cm ^{3}/m^2)

- MAV(cm.sec^{-1}) ⇨ CI

« Estimation en sortie de VG»

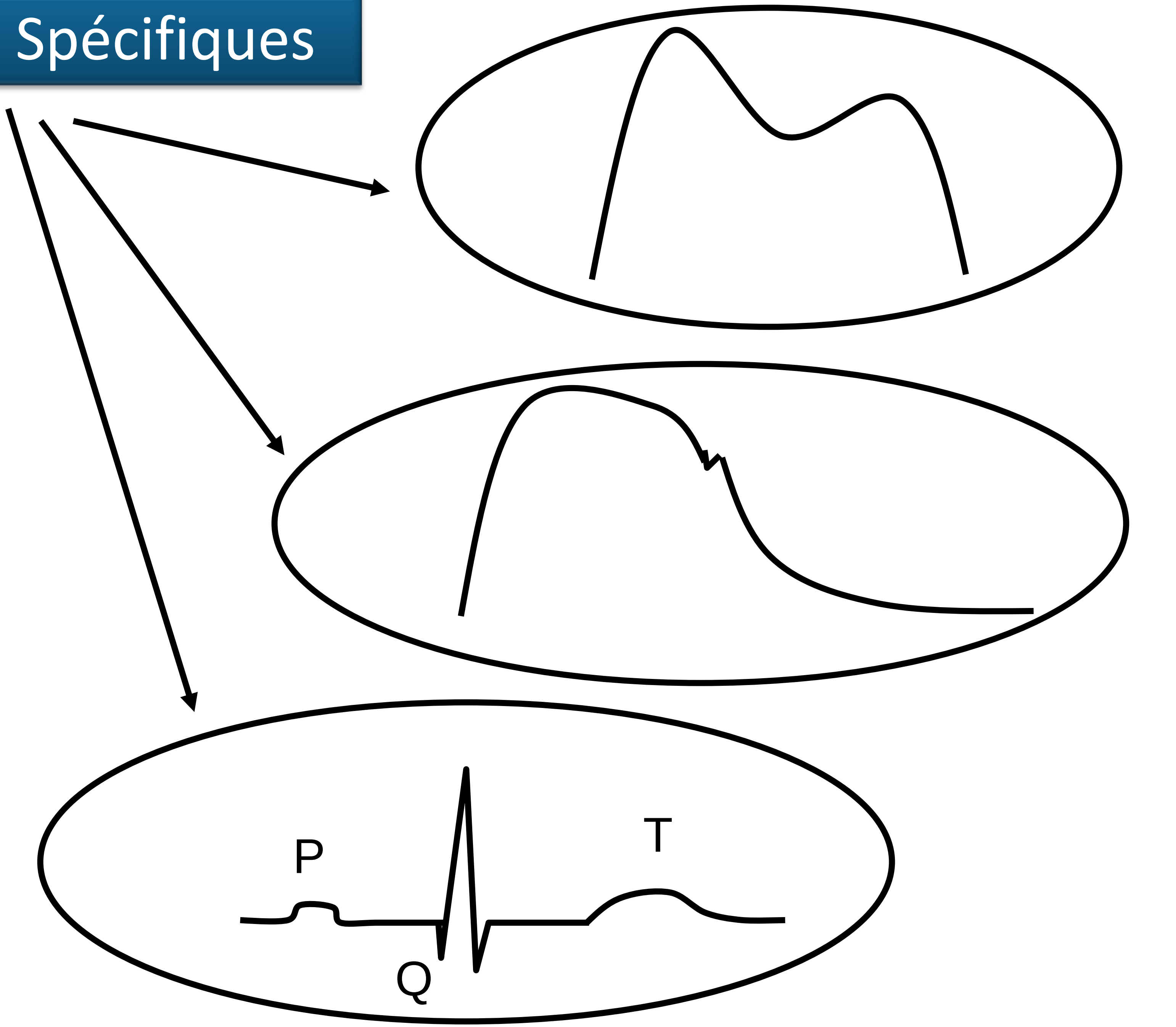
- Stroke D(cm) ⇨ SVI

Origine du signal mesuré ?

Formes des courbes:

exemple type

Formes Spécifiques



Impédancemétrie Thoracique

- Kubicek WG et al. Aerospace Med 1966

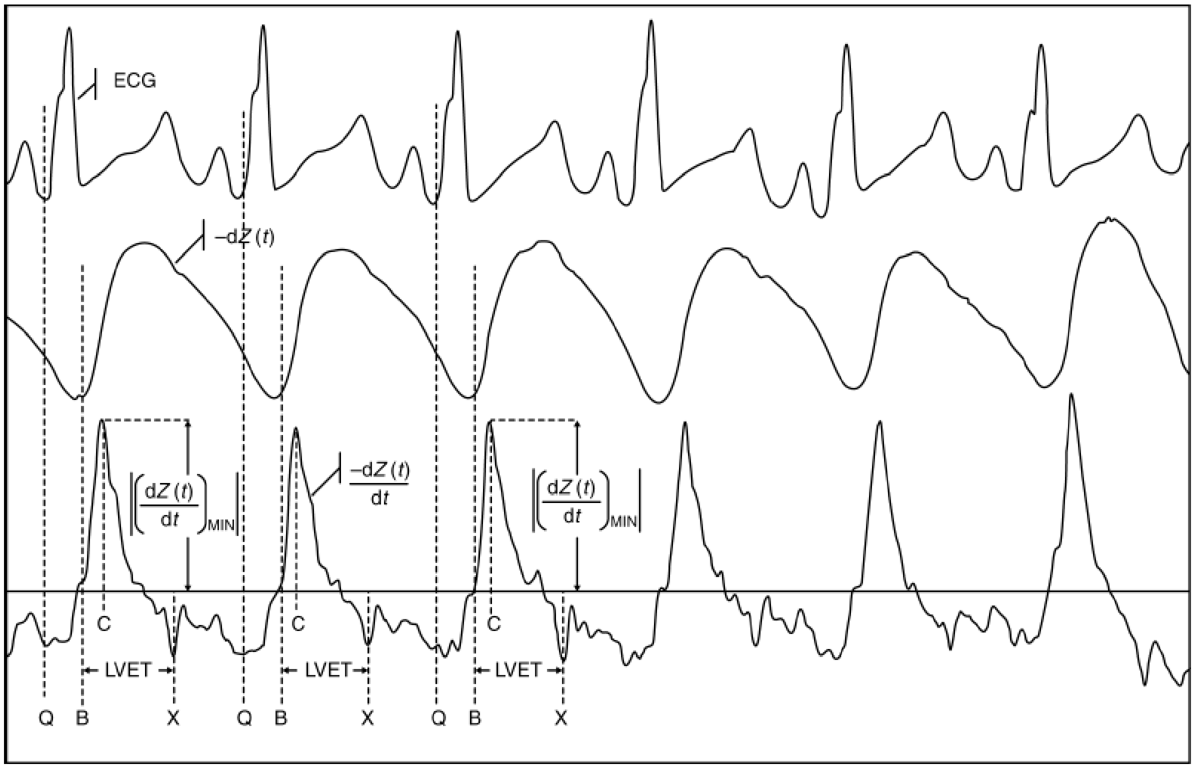
- Wong DH et al. Anesthesiology 1990
- Woltjer HH et al. Eur Heart J 1997

- American Heart Association Congress 1999

  « Acte Remboursé »

Electrical velocimetry for measuring cardiac output in children with congenital heart disease

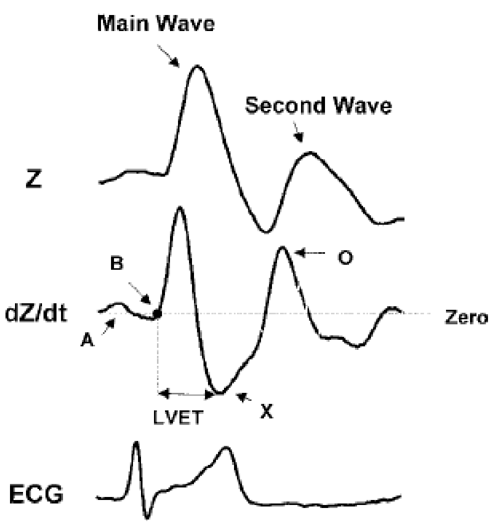
K. Norozi[1*†], C. Beck[1†], W. A. Osthaus[2], I. Wille[1], A. Wessel[1] and H. Bertram[1]



Br J Anaesth 2007

Impedance cardiographic waveforms in children: Involvement in left ventricular ejection time determination during anesthesia

Eric Wodey, MD, PhD; Lotfi Senhadji, PhD; Jean Yves Bansard, PhD; Xavier Beneux, MD; Claude Ecoffey, MD; François Carre, MD, PhD

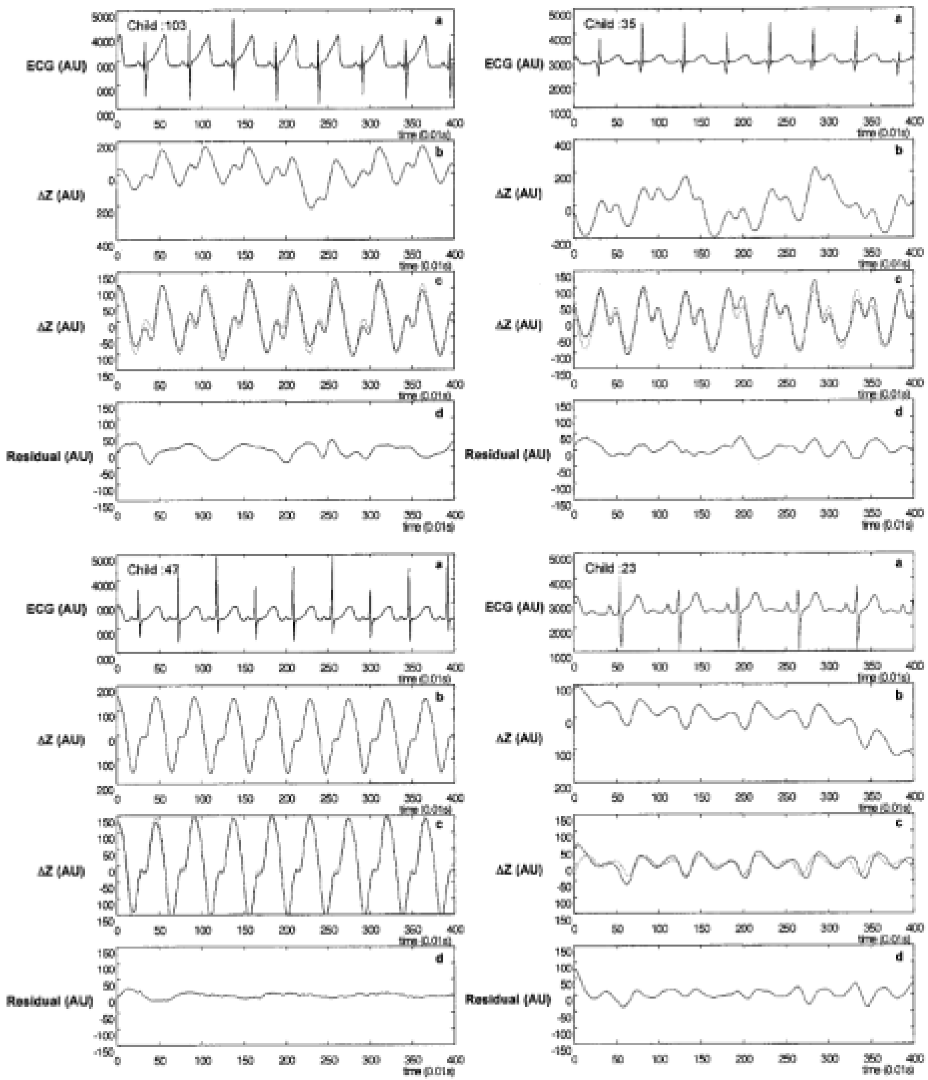


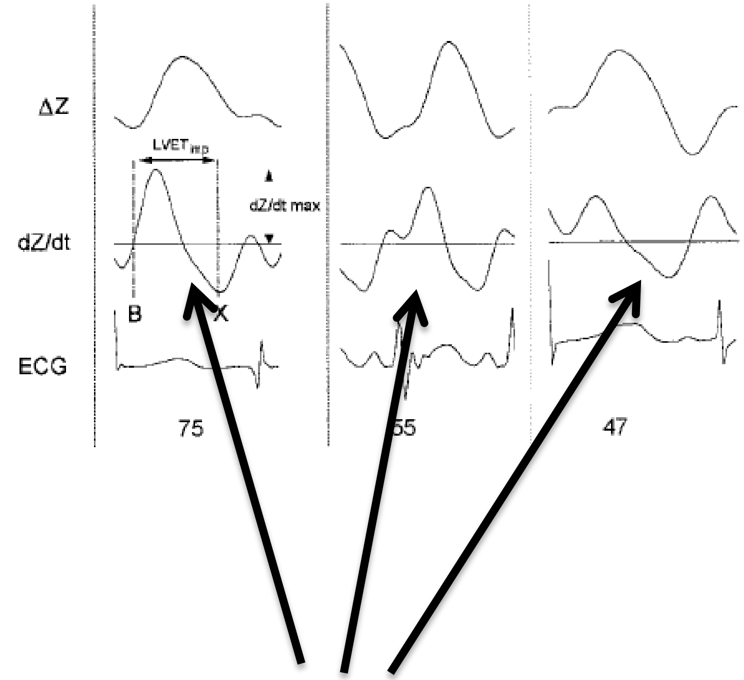
$$SV = \delta \cdot \frac{(0.17 \cdot H)^3}{4.25} \cdot \frac{dZ/dt_{max}}{Z_0} \cdot LVET$$

$$SV = \rho \cdot \frac{L^2}{Z_0^2} \cdot dZ/dt_{max} \cdot LVET$$

- 103 children of ASA physical status I or II who required general anesthesia for elective surgery.
- Children did not have cardiovascular disease

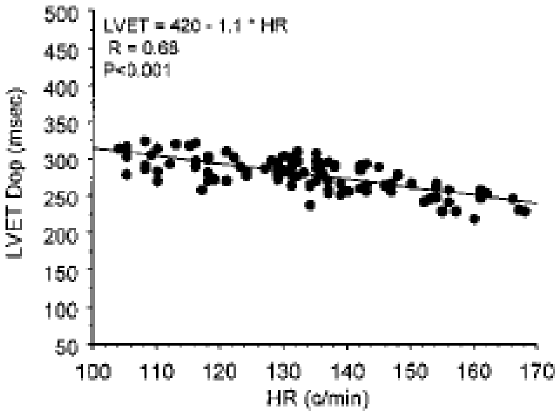
Pediatr Crit Care Med. 2001 Jul;2(3):250-259

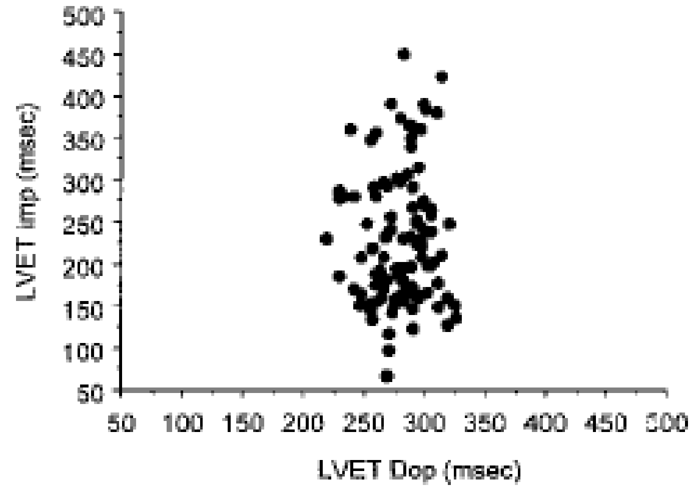


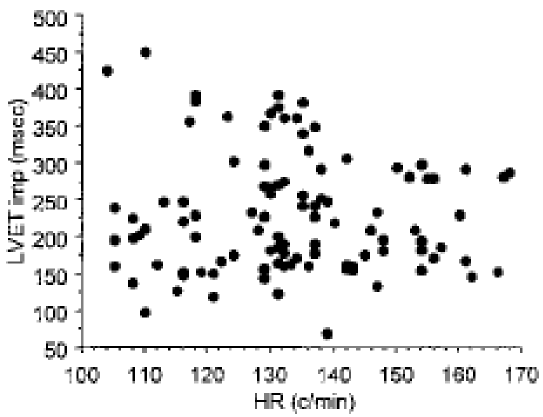


Formes variables

Pediatr Crit Care Med. 2001 Jul;2(3):250-259







Impedance cardiography appears inadequate to always accurately determine LVET, which is needed for SV calculation during general anesthesia in children and infants.

Pediatr Crit Care Med. 2001 Jul;2(3):250-259

$$SV = \delta \cdot \frac{(0.17 \cdot H)^3}{4.25} \cdot \frac{dZ/dt_{max}}{Z_0} \cdot LVET$$

$$SV = \rho \cdot \frac{L^2}{Z_0^2} \cdot dZ/dt_{max} \cdot LVET$$

SV = BSA x SVi

Unité ?

Méthodes (in English)

Invasive

- Dilution techniques
- Dye dilution
- Pulmonary artery thermodilution
- Transpulmonary thermodilution
- Lithium dilution
- Direct Fick

Non-invasive

- Non-invasive Fick using CO2
- Bioimpedance
- Echocardiography
- Trans-oesophageal doppler
- Pulse contour analysis
- Nicom (Bioréactance)

C. Pauli
U. Fakler
T. Genz
M. Hennig
H.-P. Lorenz
J. Hess

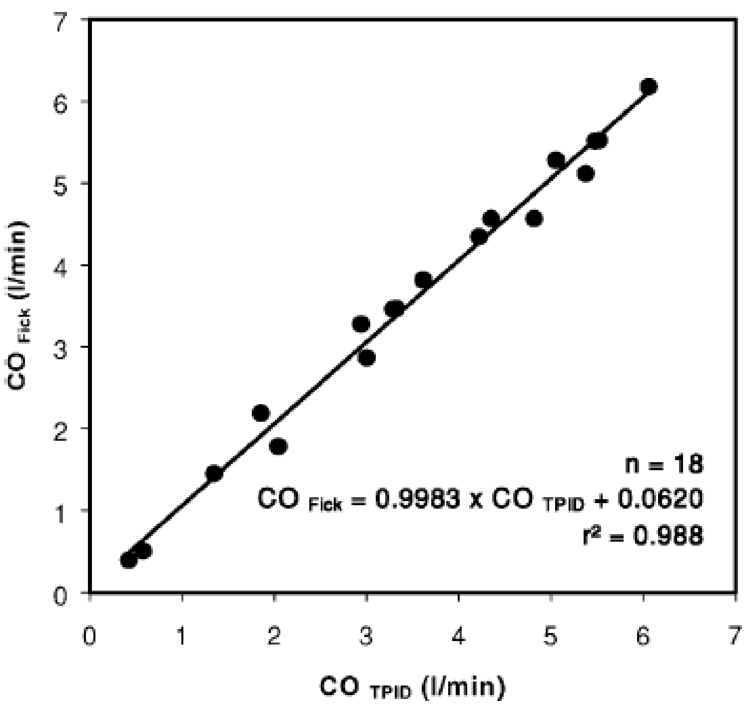
Cardiac output determination in children: equivalence of the transpulmonary thermodilution method to the direct Fick principle

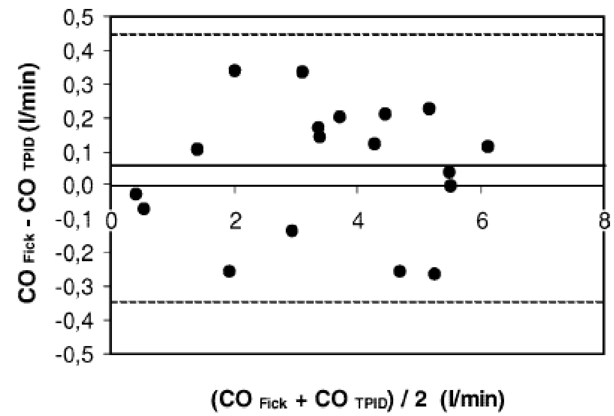
- Prospective study.
- 18 patients (mean age 12.1± 6.4 years) during cardiac catheterisation and after corrective cardiac operation
- No shunt
- Control: Determination of CI by Fick as the clinical “gold standard”

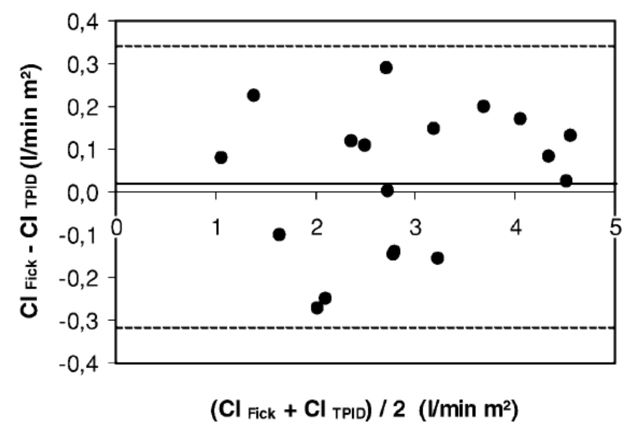
Intensive Care Med (2002) 28:947–952

C. Pauli
U. Fakler
T. Genz
M. Hennig
H.-P. Lorenz
J. Hess

Cardiac output determination in children: equivalence of the transpulmonary thermodilution method to the direct Fick principle







Like a dream !

Intensive Care Med (2002) 28:947–952

C. Pauli
U. Fakler
T. Genz
M. Hennig
H.-P. Lorenz
J. Hess

Cardiac output determination in children: equivalence of the transpulmonary thermodilution method to the direct Fick principle

Patient number	Condition	Weight (kg)	CI_{Fick}(l/min·m²)	CI_{TPID}(l/min·m²)	$CI_{Fick}–CI_{TPID}$(l/min·m²)	Diagnosis
5	Postop	4.3	1.59	1.69	–0.10	Truncus arteriosus repair
10	Cath lab	4.7	1.98	2.23	–0.25	CAVSD repair, severe MI
3	Postop	20.8	4.13	3.96	0.17	ASD repair
11	Cath lab	23.0	3.15	3.30	–0.15	IAA repair, LVOTO
13	Cath lab	25.9	1.88	2.15	–0.27	PS, dilatation of PV
22	Postop	26.6	4.62	4.49	0.13	CoA
18	Postop	27.8	3.78	3.58	0.20	VSD, RVOTO repair
1	Postop	35.0	4.52	4.49	0.03	AS 2°, AI 4°, AVR
7	Cath lab	35.2	2.85	2.56	0.29	TGA, Senning
14	Cath lab	37.3	1.10	1.02	0.08	Hypertrophic CMP
20	Postop	42.0	3.26	3.11	0.15	VSD, AI 4°, repair
2	Cath lab	43.0	2.42	2.30	0.12	Tricuspid atresia, Fontan
19	Postop	48.0	4.38	4.30	0.08	MI 3°
4	Cath lab	49.7	1.49	1.26	0.23	Tricuspid atresia, Fontan
12	Cath lab	53.0	2.70	2.85	–0.15	CCTGA, p.H.
26	Cath lab	70.6	2.72	2.86	–0.14	DORV, RVOTO, Fontan
25	Cath lab	78.0	2.72	2.72	0.00	TGA, LVOTO, Mustard
17	Cath lab	88.0	2.55	2.44	0.11	TGA, Senning

Median of Weight: 35 kg: “Old children”
Steady state

Intensive Care Med (2002) 28:947–952

Pulse Contour Analysis for Cardiac Output Monitoring in Cardiac Surgery for Congenital Heart Disease

Aman Mahajan, MD, Afshin Shabanie, MD, Judi Turner, MD, PhD, Michael J. Sopher, MD, and Jure Marijic, MD

- Prospective study.
- 16 patients undergoing corrective operations for congenital heart disease (median age 7 years)

Anesth Analg 2003;97:1283–8)

Pulse Contour Analysis for Cardiac Output Monitoring in Cardiac Surgery for Congenital Heart Disease

Aman Mahajan, MD, Afshin Shabanie, MD, Judi Turner, MD, PhD, Michael J. Sopher, MD, and Jure Marijic, MD

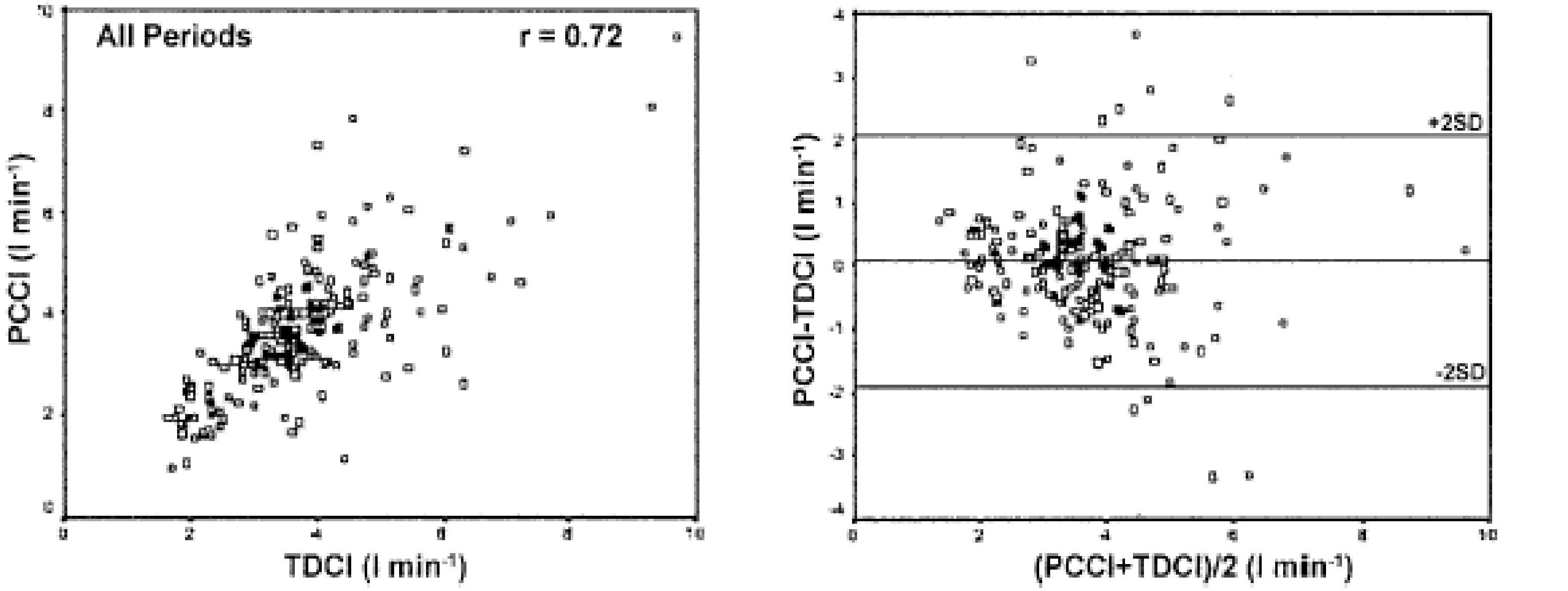


Figure 1. Top panels) Pre-cardiopulmonary bypass (CPB) period. (Middle panels) Post-CPB and intensive care unit (ICU). (Lower panels) All periods linear correlation (left) and mean difference between pulse contour analysis (PCCI) and transpulmonary thermodilution (TDCI) using Bland-Altman analysis (right). Each point represents the mean of three consecutive measures of TDCI and the respective PCCI_lag values. The right panels represent the bias between the two different techniques of cardiac output monitoring.

- CI « index » < ? > $l.min^{-1}$

Anesth Analg 2003;97:1283–8

Pulse Contour Analysis for Cardiac Output Monitoring in Cardiac Surgery for Congenital Heart Disease

Aman Mahajan, MD, Afshin Shabanie, MD, Judi Turner, MD, PhD, Michael J. Sopher, MD, and Jure Marijic, MD

Table 1. Accuracy of Pulse Controls analysis (PCCI) Compared with Transpulmonary Thermodilution (TDCI) During Different Time Periods of Congenital Cardiac Surgery

Group	Patient group/time period	mean bias ± SD	*r*	*n*
1	OR, before bypass (pre-CPB)	−0.13 ± 0.93	0.61	61
2	OR, after bypass (post-CPB)	0.05 ± 0.94	0.72	69
3	ICU	0.24 ± 1.04	0.73	61
4	All data after correction (post-CPB + ICU)	0.08 ± 0.99	0.73	130
5	All patients, all periods	0.10 ± 0.97	0.72	191

r = Pearson's correlation coefficient; Mean bias = (TDCI-PCCI); OR = operating room; ICU = intensive care unit; CPB = cardiopulmonary bypass.

- DS à 0,97 (Limites d'agrément – 1,84 to 2,04 $L.min^1.m^2$)
- soit 50 à100% d'erreur

Mauvais r = 0.7
Correspond à r^2= 0,49

Anesth Analg 2003;97:1283–8

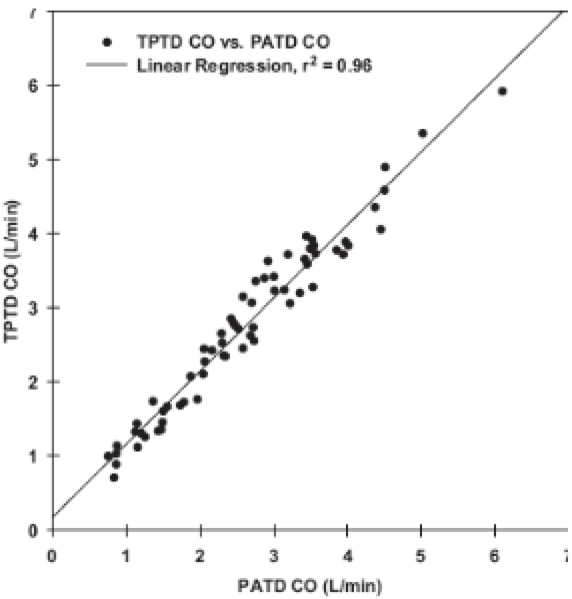
conclusion :

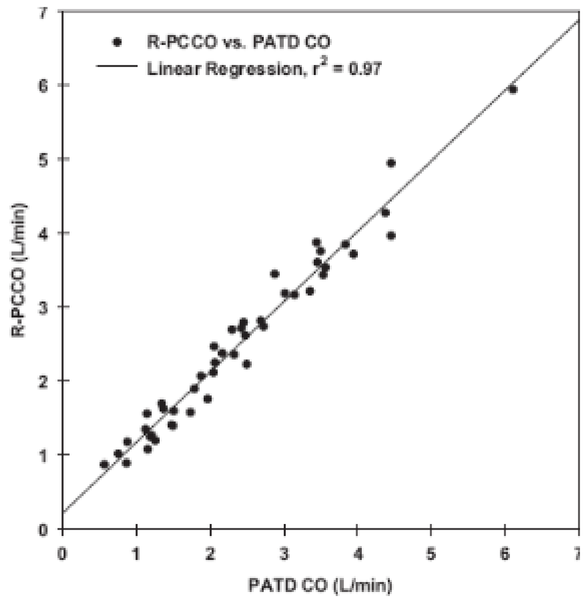
…range as wide as that obtained in our series can limit the clinical utility of the monitor because most anesthesiologists will treat a CI of 1.0 differently from a CI of 3.0 …

Anesth Analg 2003;97:1283–8

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





Crit Care Med 2008; 36:1189–1195

"…this study demonstrates that PCCO analysis, when recalibrated by TPTD CO during major hemorrhage and acute changes in MAP, correlates extremely well with PATD CO in a piglet model of hemorrhagic shock".

"In the setting of large (20%) changes in blood pressure and intravascular volume, PCCO readings can be markedly inaccurate if not recalibrated…"

Crit Care Med 2008; 36:1189–1195

Question : Quels délais ?

Cardiac index monitoring by pulse contour analysis and thermodilution after pediatric cardiac surgery

U. Fakler, MD,[a] Ch. Pauli, MD,[a] G. Balling, MD,[a] H. P. Lorenz, MD,[a] A. Eicken, MD,[a] M. Hennig, Dr,[b] and J. Hess, MD[a]

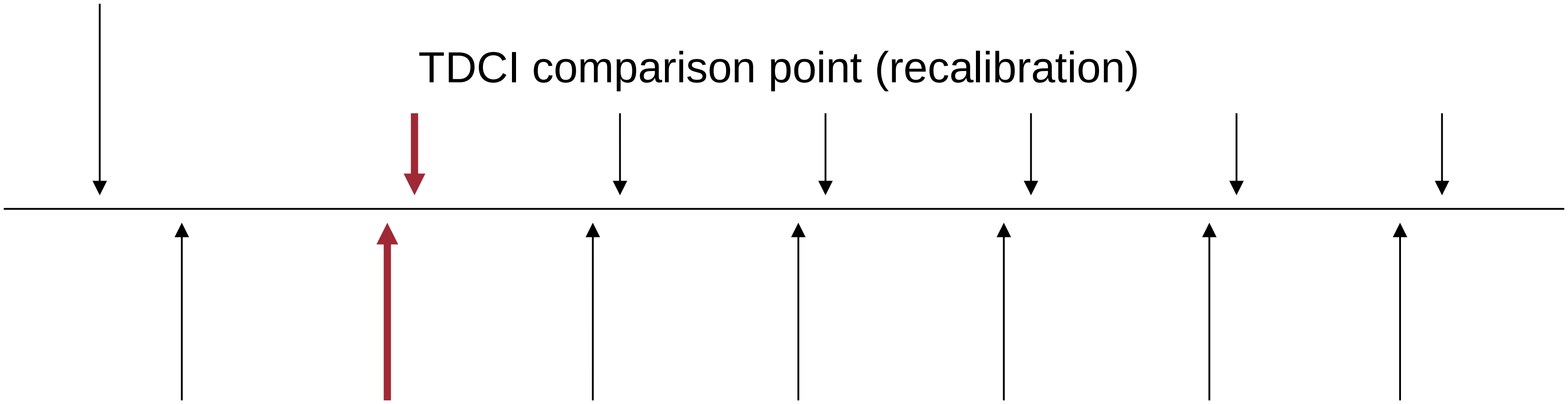
- Prospective study.
- 24 patients undergoing corrective operations for congenital heart disease (median age 4.2 years)
- Patients with intracardiac shunts were excluded by transesophageal or transthoracic echocardiography.

J Thorac Cardiovasc Surg 2007;133:224-8

- Central venous line in the jugular vein
- 3F catheter with a thermistor at the tip (PiCCO system) in the femoral artery

Initial calibration Transpulmonary thermodilution (TDCI)

TDCI comparison point (recalibration)



PCCI: cardiac index derived from pulse contour analysis (just before recalibration with TDCI and self-calibrating

1 - 4 - 8 - 12 -16 - 20 – 24H

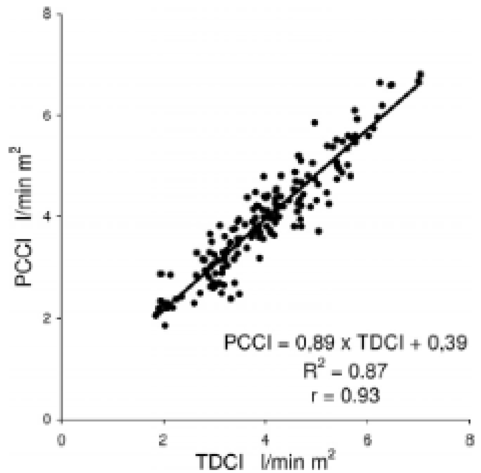


Figure 1. Comparative plot showing the correlation of TDCI and PCCI.

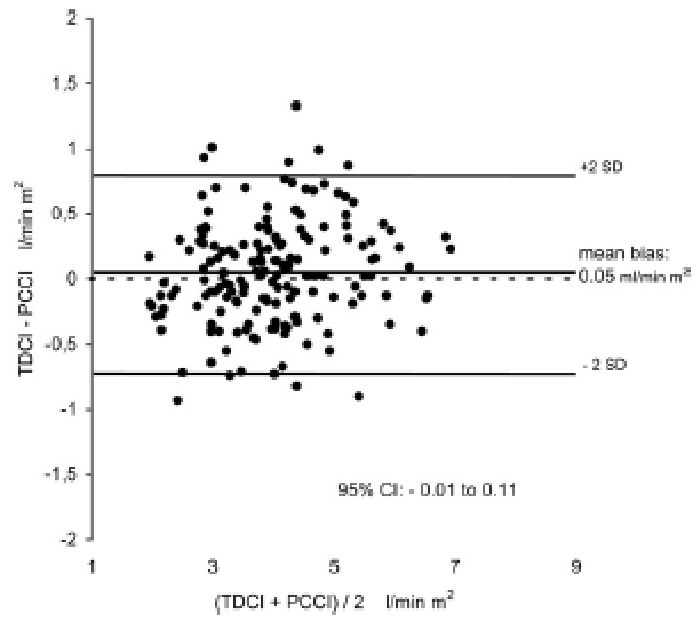


Figure 2. Bland–Altman plot showing the comparison of TDCI and PCCI, expressed by mean bias and limits of agreement and 95% confidence interval *(CI)*. *SD*, Standard deviation.

- Meilleurs limites d'agrément
- Meilleur corrélation

Do not validate the accuracy of the PiCCO method... (vs independent method)

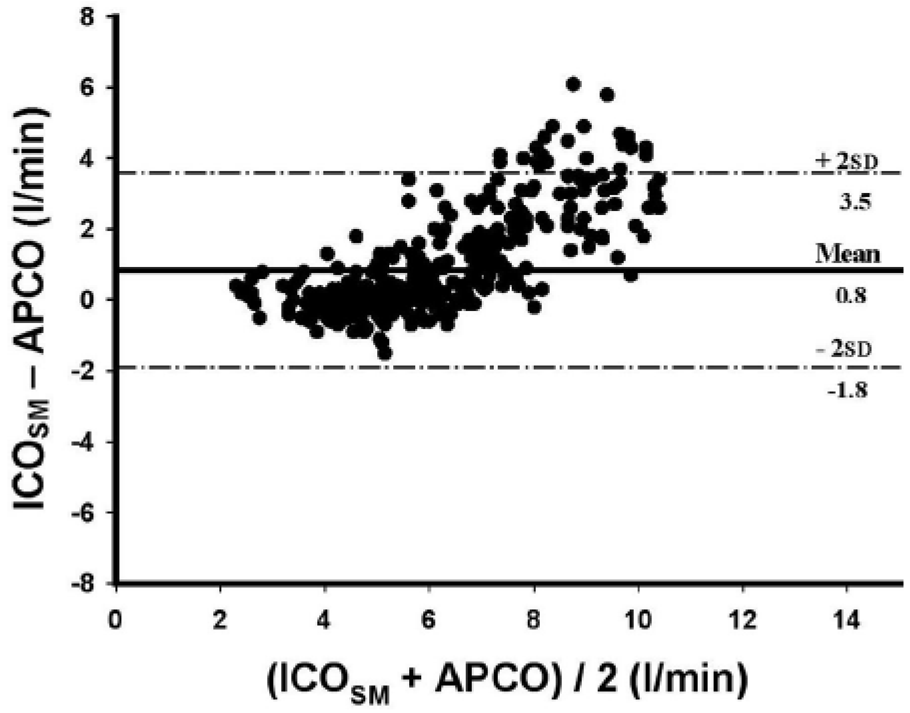
But validate the delay of 4 H to give similar information to TPTD

J Thorac Cardiovasc Surg 2007;133:224-8

Cardiac Output Measurement in Patients Undergoing Liver Transplantation: Pulmonary Artery Catheter Versus Uncalibrated Arterial Pressure Waveform Analysis

« Pulse contour » seul

Biais Matthieu, MD
Nouette-Gaulain Karine, MD, PhD
Cottenceau Vincent, MD
Vallet Alain, MD
Cochard Jean François, MD
Revel Philippe, MD
Sztark François, MD, PhD

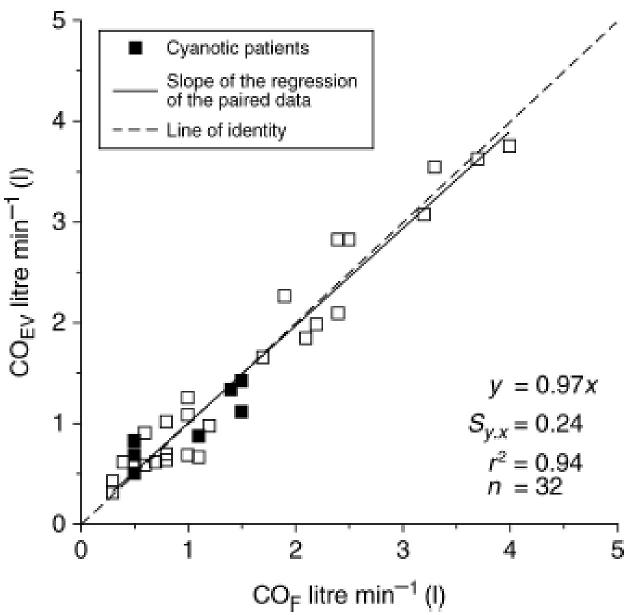


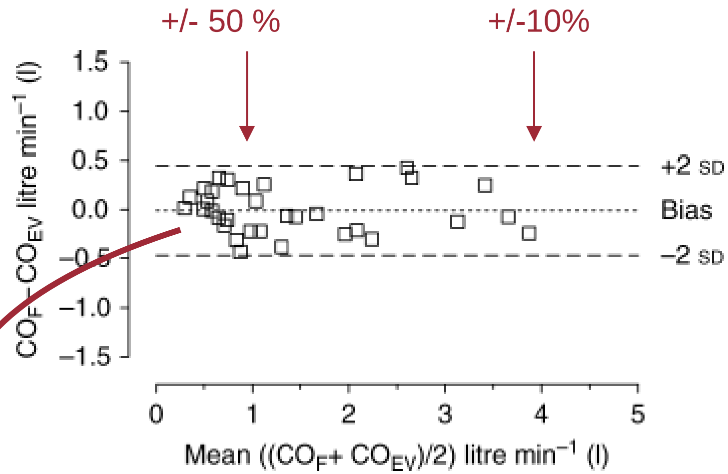
Doesn't run in adult
Doesn't run in children

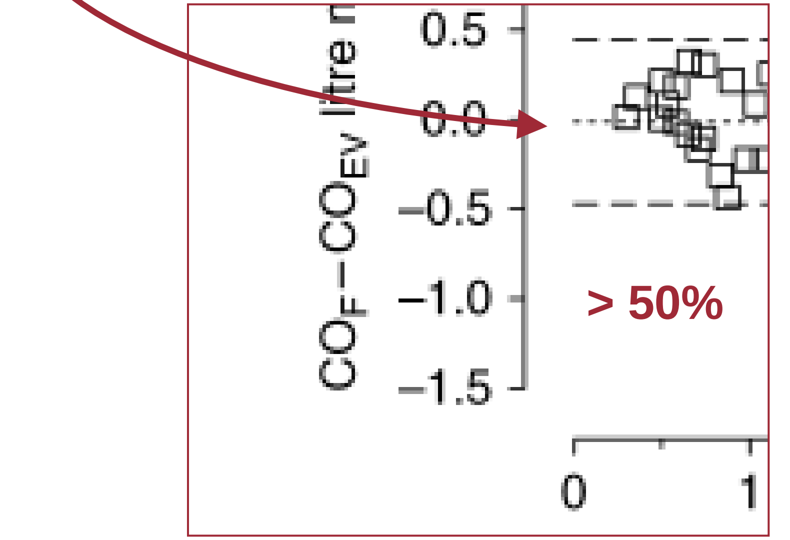
Anesth Analg 2008;106:1480 –6

Electrical velocimetry for measuring cardiac output in children with congenital heart disease

K. Norozi[1*†], C. Beck[1†], W. A. Osthaus[2], I. Wille[1], A. Wessel[1] and H. Bertram[1]







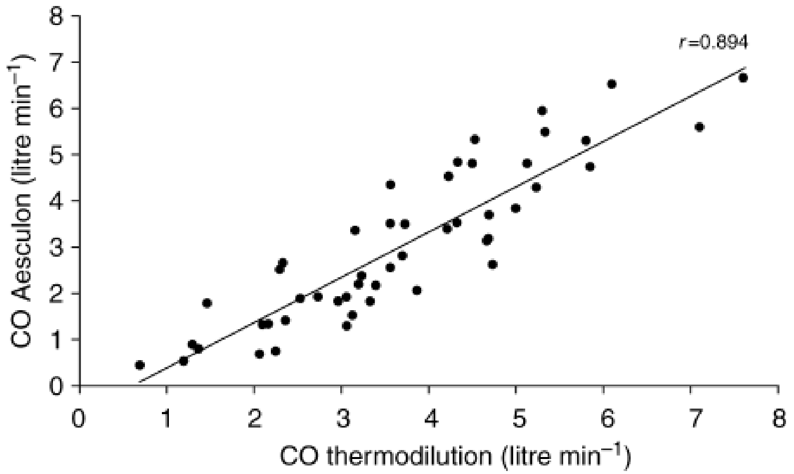
IMPEDANCE

Br J Anaesth 2008; 100(1) 88-94

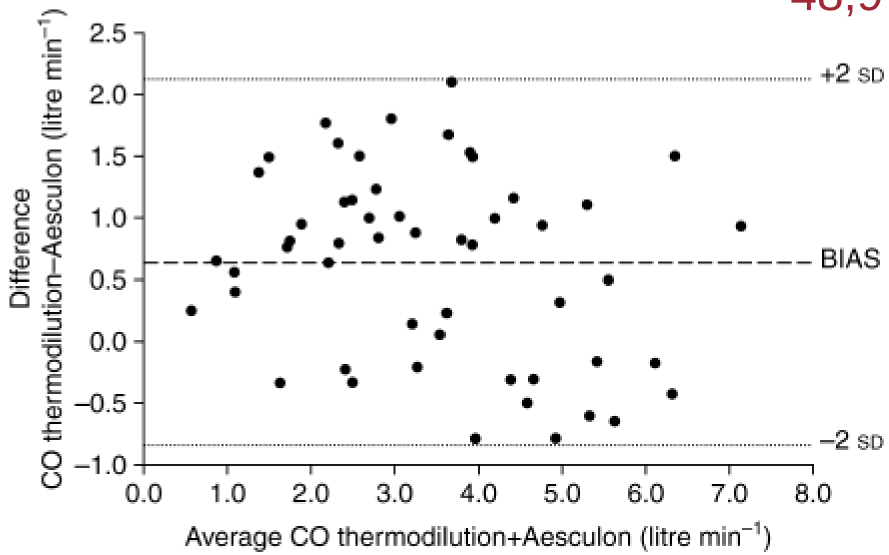
Cardiac output measurement in children: comparison of Aesculon® cardiac output monitor and thermodilution

M. Tomaske[1]*, W. Knirsch[1], O. Kretschmar[1], K. Woitzek[1 2], C. Balmer[1], A. Schmitz[2], U. Bauersfeld[1], M. Weiss[2] and on behalf of the Working Group on Non-invasive Haemodynamic Monitoring in Paediatrics

50 patients
median (range) age of 7.5 (0.5–16.5) yr

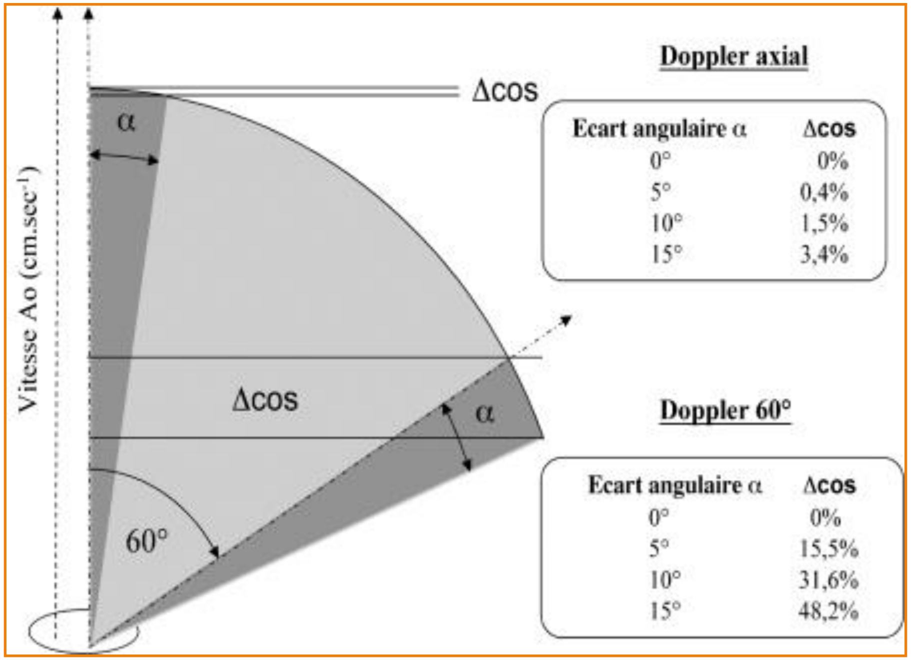


48,9%



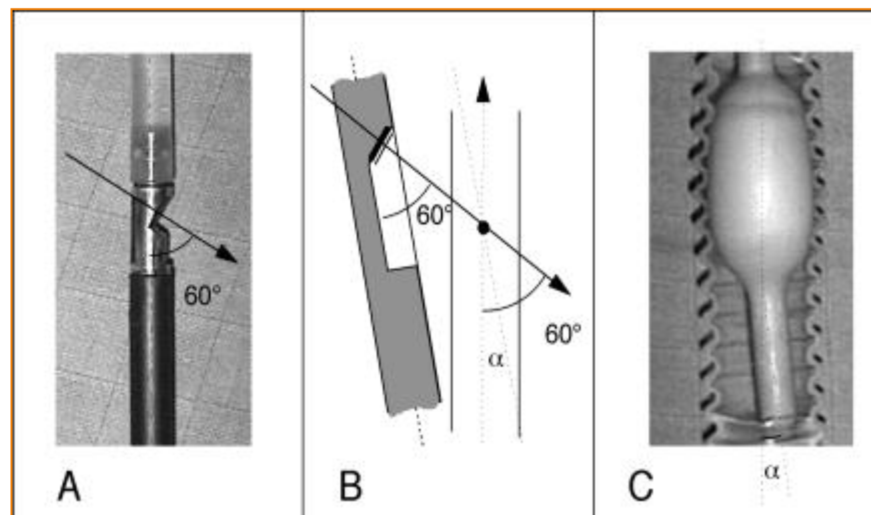
… electrical velocimetry using the Aesculon monitor did not provide reliable CO values in children with congenital heart diseases when compared with PAC thermodilution

Br J Anaesth 2008 Epub



Angle 60°

Doppler Oesophagien



Wodey et al. Paediatric Anaesthesia 2001

Walter Knirsch
Oliver Kretschmar
Maren Tomaske
Kathrina Stutz
Nicole Nagdyman
Christian Balmer
Achim Schmitz
Dominique Béttex
Felix Berger
Urs Bauersfeld
Markus Weiss

Cardiac output measurement in children: comparison of the Ultrasound Cardiac Output Monitor with thermodilution cardiac output measurement

24 patients aged 0.1–16.7 years (median 7.6) and weighing 3.4–51.0 kg (23.0 kg).

……were excluded a residual shunt following device closure or a residual pulmonary valve regurgitation by transesophageal echocardiography and/or angiography.

USCOM device

Intensive Care Med 2008 Feb 23 (Epub)

Walter Knirsch
Oliver Kretschmar
Maren Tomaske
Kathrina Stutz
Nicole Nagdyman
Christian Balmer
Achim Schmitz
Dominique Béttex
Felix Berger
Urs Bauersfeld
Markus Weiss

Cardiac output measurement in children: comparison of the Ultrasound Cardiac Output Monitor with thermodilution cardiac output measurement

34%

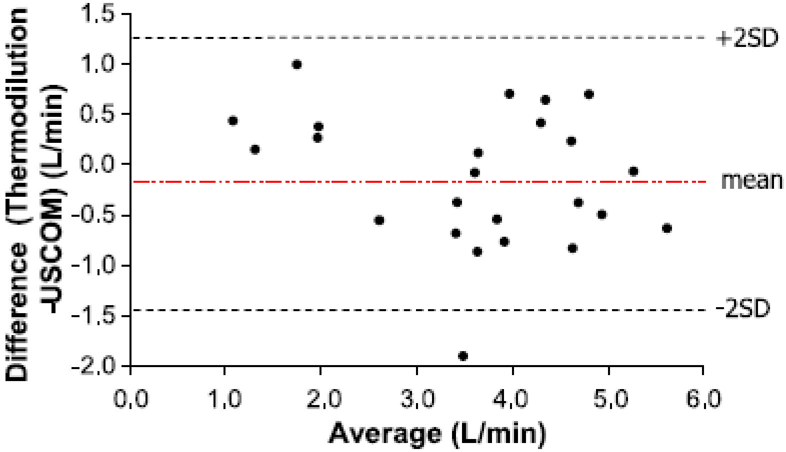


Fig. 2 Bland–Altman analysis to compare cardiac output values obtained by the USCOM and the thermodilution technique in 24 cardiac pediatric patients

- The CO value is calculated using the flow integral, and the aortic valve diameter as given by the USCOM internal algorithm based on height and gender.

- Use blind Doppler probe (continuous Doppler)

Author's conclusion……USCOM cannot be recommended for the assessment of absolute CO values in pediatric cardiac patients

Intensive Care Med 2008 Feb 23 (Epub)

Plus récemment !

Philippe Durand
Laurent Chevret
Sandrine Essouri
Vincent Haas
Denis Devictor

Respiratory variations in aortic blood flow predict fluid responsiveness in ventilated children

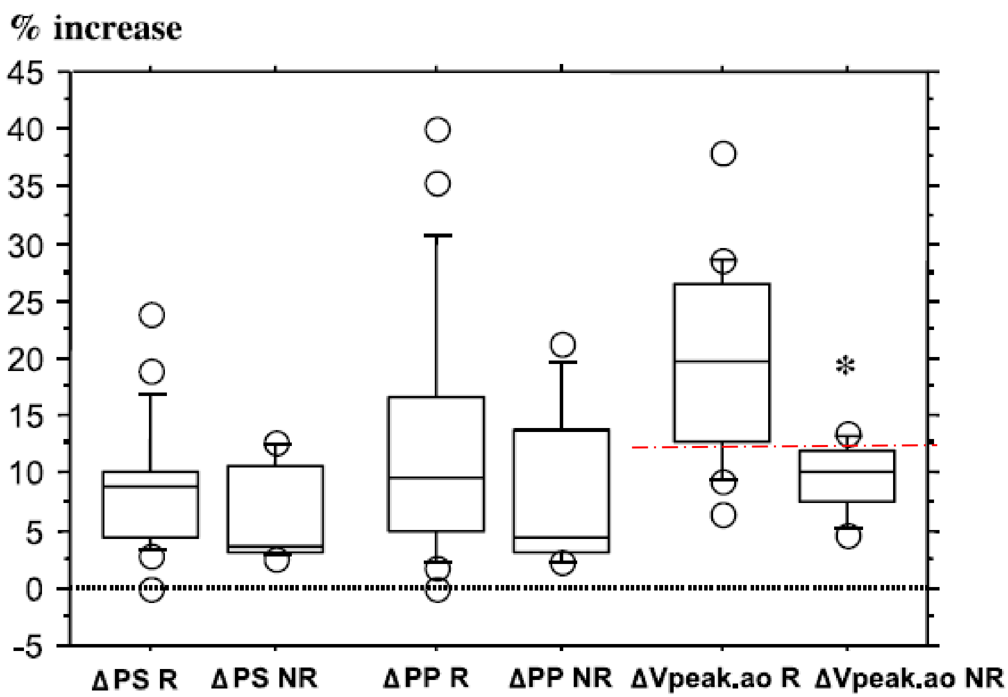
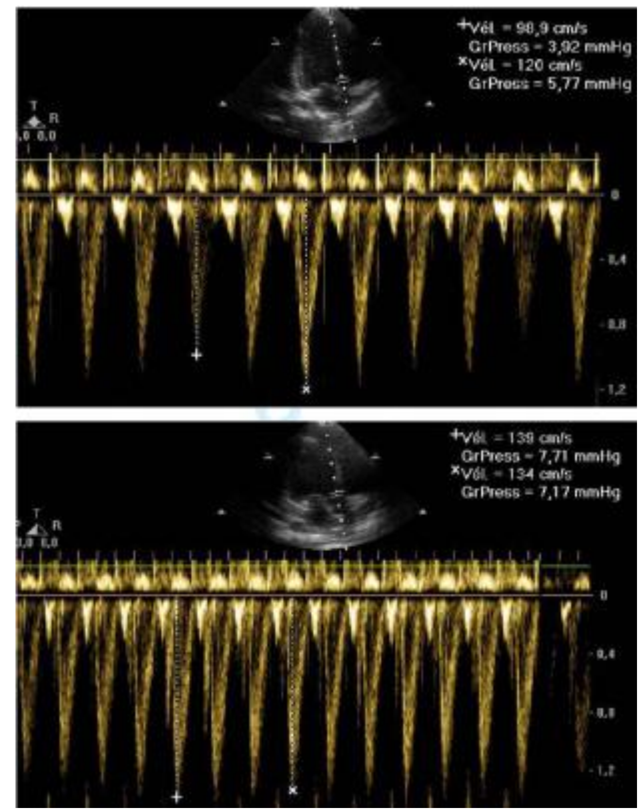


Fig. 1 ΔPS, ΔPP and ΔVpeak ao at baseline expressed in plot box form (median, interquartile range) in volume expansion-responders (*R*, $n = 18$) and non-responders (*NR*, $n = 8$). Values expressed in percent; * $p < 0.001$



Intensive Care Med (2008) 34:888–894

Pierre Squara
Dominique Denjean
Philippe Estagnasie
Alain Brusset
Jean Claude Dib
Claude Dubois

Noninvasive cardiac output monitoring (NICOM): a clinical validation

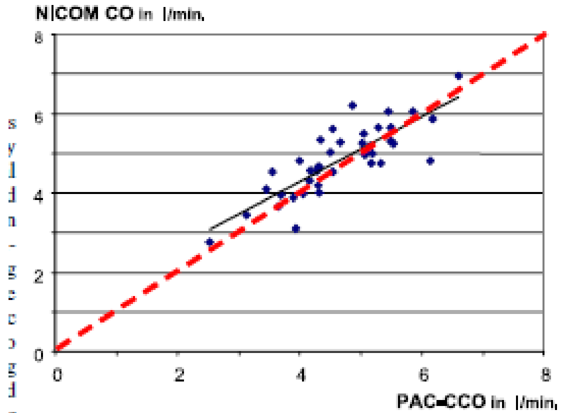


Fig. 1 Regression PAC-CCO vs. NICOM (each point represents the mean CO value during a period of stable CO). $R = 0.82$. Slope = 0.82 (95%CI = 0.64–1.0) not significantly different from the identity line (*red dotted line*)

Table 1 CO changes after hemodynamic challenges

	NICOM	PAC-CCO	*p*
Negative CO challenge ($n = 14$)			
Lag time (min)	3.4 ± 1.3	7.1 ± 3.1	0.01
Amplitude (l/min)	-1.7 ± 1.0	-1.7 ± 1.2	0.25
Amplitude (%)	-28 ± 14	-34 ± 20	0.25
Positive CO challenge ($n = 23$)			
Lag time (min)	4.0 ± 2.2	6.8 ± 3.2	0.003
Amplitude (l/min)	1.5 ± 0.9	1.7 ± 1.3	0.07
Amplitude (%)	40 ± 26	50 ± 33	0.07

Adulte : Ca marche !

Intensive Care Med 2007; 33:1191–1194

Cardiac output measurements using the bioreactance technique in critically ill patients

David Fagnoul, Jean-Louis Vincent and Daniel De Backer*

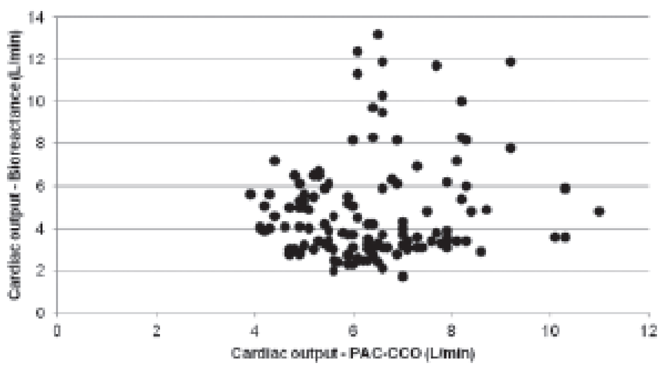


Figure 1. Correlation between pulmonary artery catheter semi-continuous cardiac output by thermodilution and bioreactance cardiac output. A total of 141 measurements in 11 patients, r = 0.1455. PAC-CCO, pulmonary artery catheter semi-continuous cardiac output by thermodilution.

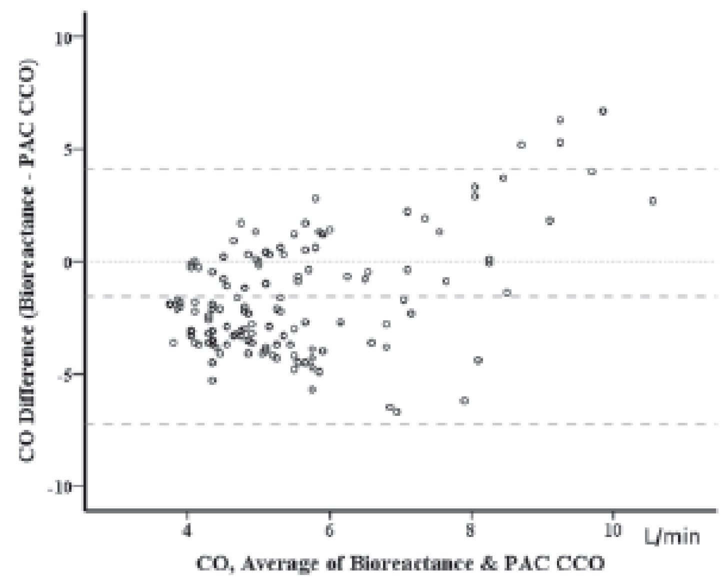


Figure 2. Pulmonary artery catheter semi-continuous cardiac output by thermodilution and bioreactance cardiac output: bias and agreement. A total of 141 pairs of measurements in 11 patients. Bias -1.6 L/min and limits of agreement 5.7 L/min. CO, cardiac output; PAC-CCO, pulmonary artery catheter semi-continuous cardiac output by thermodilution.

Adulte : Ca marche plus !

Critical Care 2012, **16**:460

Experimental paper

Pulmonary arterial thermodilution, femoral arterial thermodilution and bioreactance cardiac output monitoring in a pediatric hemorrhagic hypovolemic shock model☆

Yolanda Ballestero[a,c], Javier Urbano[a,c], Jesús López-Herce[a,c,*], Maria J. Solana[a,c], Marta Botrán[a,c], Diego Vinciguerra[a,c], Jose M. Bellón[b,d]

Modèle enfant = Cochon

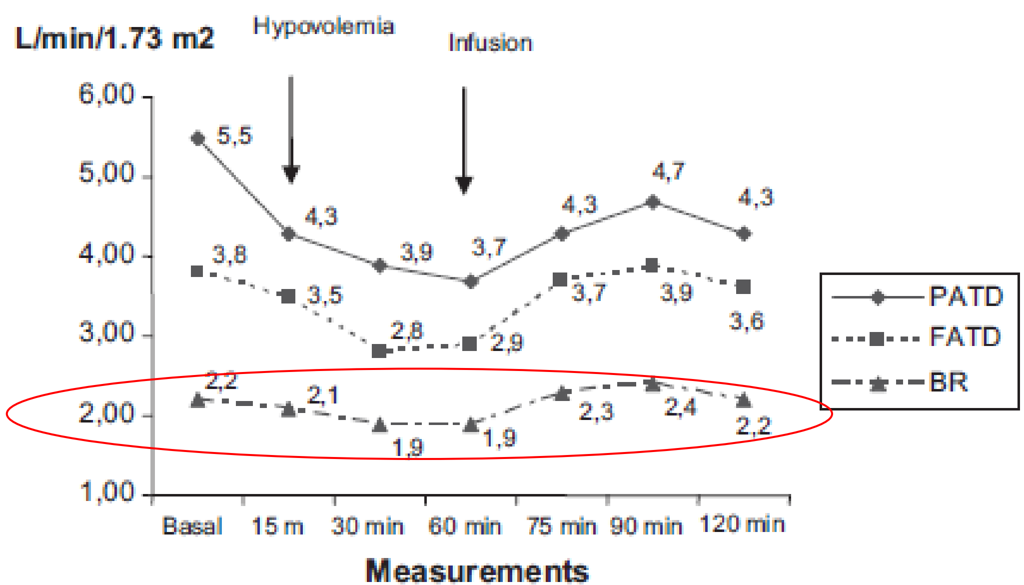


Fig. 4. Changes in the CI measured by pulmonary artery thermodilution (PATD), femoral artery thermodilution (FATD) and bioreactance (BR).

Resuscitation 2012; 83 :125– 129

Display Settings: Abstract Send to:

Br J Anaesth. 2013 Aug 28. [Epub ahead of print]

Bioreactance is not reliable for estimating cardiac output and the effects of passive leg raising in critically ill patients.

Kupersztych-Hagege E, Teboul JL, Artigas A, Talbot A, Sabatier C, Richard C, Monnet X.

Hôpitaux universitaires Paris-Sud, Hôpital de Bicêtre, service de réanimation médicale, 78, rue du Général Leclerc, F-94270 Le Kremlin-Bicêtre, France.

Abstract

BACKGROUND: /st>Bioreactance estimates cardiac output in a non-invasive way. We evaluated the ability of a bioreactance device (NICOM®) to estimate cardiac index (CI) and to track relative changes induced by volume expansion.

METHODS: /st>In 48 critically ill patients, we measured CI estimated by the NICOM® device (CI_{Nicom}) and by transpulmonary thermodilution (CI_{td}, PiCCO$_2$™ device) before and after a 500 ml saline infusion. Before volume expansion, we performed a passive leg raising (PLR) test and measured the changes it induced in CI_{Nicom} and in pulse contour analysis-derived CI.

RESULTS: /st>Considering the values recorded before PLR and before and after volume expansion (n=144), the bias (lower and upper limits of agreement) between CI_{td} and CI_{Nicom} was 0.9 (-2.2 to 4.1) litre min^{-1} m^{-2}. The percentage error was 82%. There was no significant correlation between the changes in CI_{td} and CI_{Nicom} induced by volume expansion (P=0.24). An increase in CI estimated by pulse contour analysis >9% during the PLR test predicted fluid responsiveness with a sensitivity of 84% (95% confidence interval 60-97%) and a specificity of 97% (95% confidence interval 82-100%). The area under the receiver operating characteristic curve constructed to test the ability of the PLR-induced changes in CI_{Nicom} in predicting fluid responsiveness did not differ significantly from 0.5 (P=0.77).

CONCLUSIONS: /st>The NICOM® device cannot accurately estimate the cardiac output in critically ill patients. Moreover, it could not predict fluid responsiveness through the PLR test.

Adulte : Ca marche plus !

Measurement of Cardiac Output in Children by Bioreactance

Yolanda Ballestero · Jesús López-Herce ·
Javier Urbano · Maria José Solana ·
Marta Botrán · Jose M. Bellón · Angel Carrillo

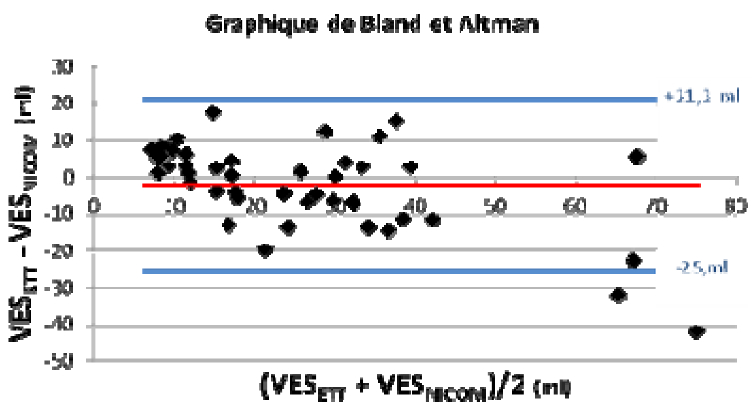
…These data suggest that this method is not useful for evaluating CI in small children.

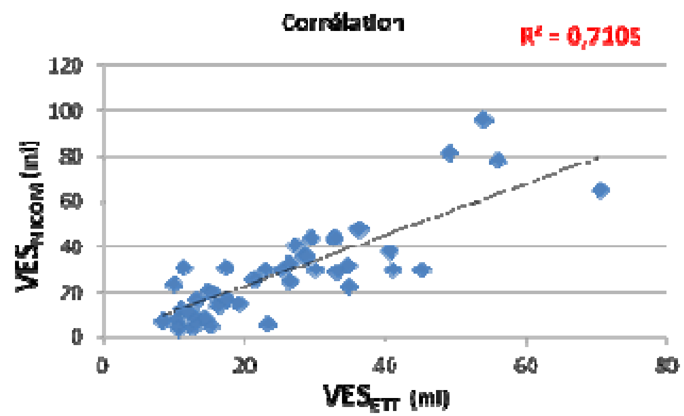
Enfant : Ca marche pas !

Pediatr Cardiol 2010; 32:469–472

R076

Comparaison de deux méthodes de mesure du volume d'éjection systolique (VES) chez l'enfant : bioréactance thoracique par NICOM® et échocardiographie trans-thoracique





Matériel et Méthodes: Il s'agit d'
enfants âgés de 0 à 16 ans, néce
neurochirurgie pouvaient être incl

Comment est calculé le VES (en bioréactance ?)

La bioreactance : une nouvelle technologie pour le monitorage non invasif du débit cardiaque

Bioreactance: A new technology for non invasive cardiac ouput monitoring

P. Squara

individuellement à une erreur significative. Pour résoudre ce problème, un facteur de calibration (CF) multivarié à été déterminé basé sur l'âge, le sexe, la taille, le poids, la surface cutanée, le body mass index (BMI) et si disponibles, la pression artérielle pulmonaire estimée qualitativement et la taux d'hémoglobine. La formule finale du débit cardiaque par bioréactance est donc :

$$DC = FC \cdot \frac{CF}{Z_0^2} \cdot VET \cdot \frac{dX}{dt} \max .$$

$$VES = \frac{CF}{Z_0^2} \cdot VET \cdot \frac{dX}{dt} \max .$$

= BSA x VESI

Réanimation (2008) **17**, 111—119

Noninvasive cardiac output measurement using bioreactance in postoperative pediatric patients

Estelle Vergnaud, Charles Vidal, Juliette Montmayeur Verchere, Hanna Taright, Philippe G. Meyer, Pierre A. Carli & Gilles A. Orliaguet

Service d'Anesthésie Réanimation, Hôpital Universitaire Necker – Enfants Malades, Université Paris Descartes, Assistance Publique-Hôpitaux de Paris, Paris, France

$$CO_{\mathrm{Nicom}} = \mathrm{HR} \times (\Delta X/\Delta t_{\mathrm{max}}) \times (k'/Z_0^2)$$

with ΔX: system reactance variation, Δt_{max}: left ventricular ejection time, k': correction factor taking into account the sex and the size of the patient, and Z_0: initial thoracic impedance.

Pediatric Anesthesia 25 (2015) 160–166

Noninvasive cardiac output measurement using bioreactance in postoperative pediatric patients

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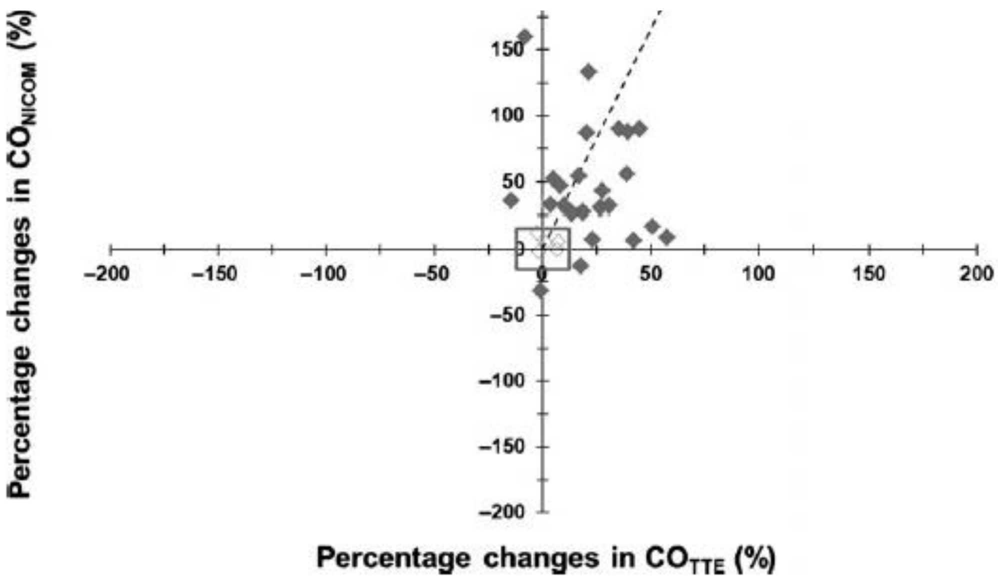


Variations de Q dans le même sens, mais variations de VES ? (Effect FC ?)

Pediatric Anesthesia 25 (2015) 160–166

Peut être un synthèse ?

Where do we go from here? Cardiac output determination in pediatrics*

Brian D. Hanna, MD, PhD
Division of Cardiology
Children's Hospital of Philadelphia
The School of Medicine
University of Pennsylvania
Philadelphia, PA

Transpulmonary thermodilution uses central venous (not pulmonary arterial) and arterial catheters (4F) and gives cardiac output ….

…thoracic bioimpedance estimates of cardiac output are not robust under all loading conditions.

Transthoracic echo Doppler evaluation has been standard in pediatrics for several years and, in experienced hands, can also give excellent cardiac anatomical data.

The transesophageal echo Doppler technique has been adapted in the pediatric intensive care unit for more continuous CO measurements since the probe position is more stationary and probe sizes are now small enough for most children. But with changes in load and/or contractility, there is a change in the aortic diameter that limits the trend analysis without remeasurement.

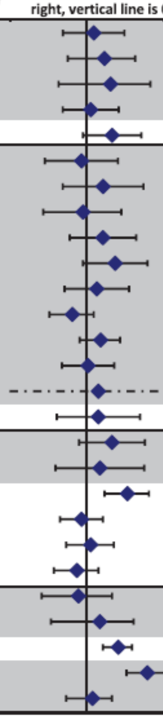
Crit Care Med 2008 Vol. 36, No. 4

Predicting Fluid Responsiveness in Children: A Systematic Review

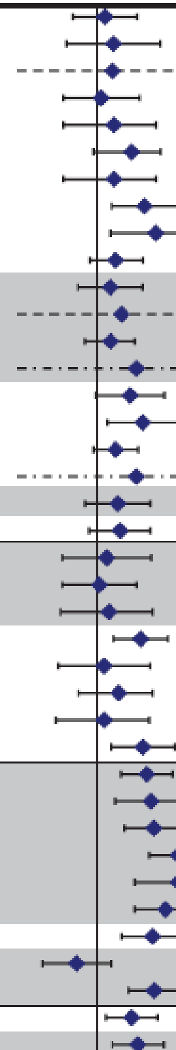
Heng Gan, MBBCh, MRCPCH, FRCA,*† Maxime Cannesson, MD, PhD,‡
John R. Chandler, MBBCh, FCARCSI, FDSRDS,§ and
J. Mark Ansermino, MBBCh, MSc (Inf), FFA (SA), FRCPC*†

CONCLUSIONS: Respiratory variation in aortic blood flow peak velocity was the only variable shown to predict fluid responsiveness in children. Static variables did not predict fluid responsiveness in children, which was consistent with evidence in adults. Dynamic variables based on arterial blood pressure did not predict fluid responsiveness in children, but the evidence for dynamic variables based on plethysmography was inconclusive. (Anesth Analg 2013;117:1380–92)

Anesth Analg 2013;117:1380–92



	Potential predictor	Area under ROC with 95% CI (numerical value on right, vertical line is 0.5)	Fluid bolus, *n*	Setting	Study
Clinical	HR	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]
	SAP	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]



	Potential predictor	Area under ROC with 95% CI (numerical value on right, vertical line is 0.5)	Fluid bolus, *n*	Setting	Study
Arterial pressure	PPV	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]
Plethysmography	ΔPOP	0.56	19	Cardiac cath	Chandler[5]
		0.51	19	Neuro OR, 0-6 yrs	Pereira de Souza Neto[6]
		0.57	11	Neuro OR, 6-14 yrs	Pereira de Souza Neto[6]
	PVI	0.77	33	Neuro OR	Byon[24]
		0.54	19	Cardiac cath	Chandler[5]
		0.63	19	Neuro OR, 0-6 yrs	Pereira de Souza Neto[6]
		0.54	11	Neuro OR, 6-14 yrs	Pereira de Souza Neto[6]
		0.78	27	Cardiac OR	Renner 2011[8]
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]

Anesth Analg 2013;117:1380–92

SYSTEMATIC REVIEW

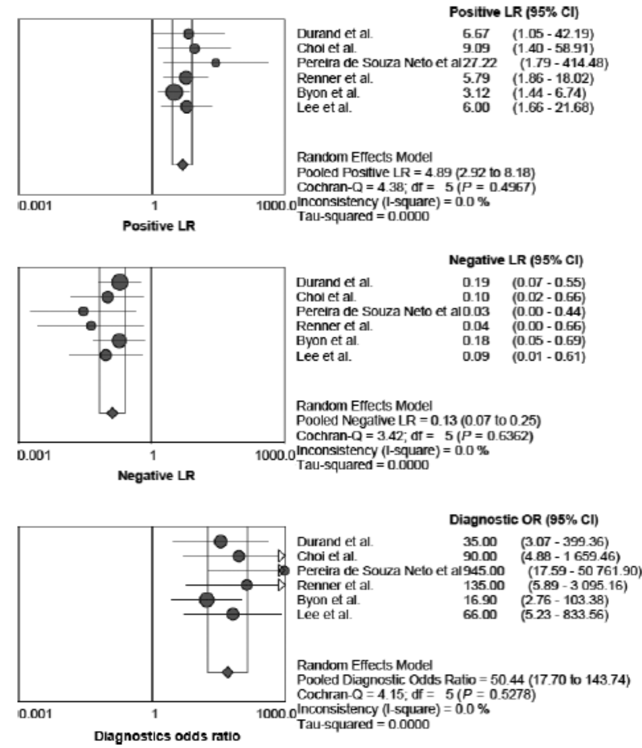
Respiratory variation in aortic blood flow peak velocity to predict fluid responsiveness in mechanically ventilated children: a systematic review and meta-analysis

François-Pierrick Desgranges[1], Olivier Desebbe[2], Edmundo Pereira de Souza Neto[3,4,5]
Darren Raphael[6] & Dominique Chassard[1]

Table 3 Results of the studies included in the systematic review

References	Sample size (*n*)	Percentage of responders (%)	Best threshold value (%)
Durand *et al.* (17)	26	69.2	12
Choi *et al.* (18)	21	52.4	20
Pereira de Souza Neto *et al.* (19)	30	56.7	10
Renner *et al.* (20)	27	48.1	7
Byon *et al.* (21)	33	45.5	11
Lee *et al.* (22)	26	50.0	14

ROC, receiver operating characteristic; CI, confidence interval.



6

Pediatric Anesthesia 2015 (NOV)

Les moyens pour réfléchir

- Facteurs influençant le VES (précharge, etc…)
- Débit cardiaque, PAM, etc…
- Transport d'oxygène (Q, Sao2, Hb)
- Extraction (SvO2, etc…)
- Oxygénation
  - Sao2 main D et G (réouverture CA)
  - Tissulaire (NIRS)
- Marqueurs terminaux « simple » : Lactate

Peripheral Muscle Near-Infrared Spectroscopy in Neonates: Ready for Clinical Use? A Systematic Qualitative Review of the Literature

Nina Höller Berndt Urlesberger Lukas Mileder Nariae Baik
Bernhard Schwaberger Gerhard Pichler

Division of Neonatology, and Research Unit for Neonatal Micro- and Macrocirculation, Department of Pediatrics, Medical University, Graz, Austria

Neonatology 2015;108:233–245

Sevoflurane anesthesia and brain perfusion

Ossam Rhondali[1,2], Agnès Pouyau[1], Aurélie Mahr[1], Simon Juhel[1], Mathilde De Queiroz[1], Khalid Rhzioual-Berrada[1], Sylvain Mathews[2] & Dominique Chassard[1]

1 Department of Pediatric Anesthesia, Hôpital Mère-Enfant, Lyon, France
2 Department of Pediatric Anesthesia, Hôpital Sainte Justine, Montréal, QC, Canada

Nourrissons de moins de 6 mois, 1 MAC sevoflurane

- PAM > 45mmHg : CBF et rSO2c ok
- PAM 45 et 35 mmHg : CBF↘ mais balance O2 , variation + de rSO2c (car CMRO2 ↘)
- PAM < 35 mmHg: CBF ↘ et peu de variation+ de rSO2c (état limite ?)

Pediatric Anesthesia 25 (2015) 180–185

Conclusion

Dans tous les cas

Restez curieux

Comme un enfant !