

Alternatives aux mesures invasives du Débit Cardiaque en Réanimation



DESC Réanimation Médicale

Session 12 mars 2008

Toulouse

BARREAU Anthony

Pourquoi le Débit Cardiaque (1)

- ❑ Adéquation besoins cellulaires en O_2 /demandes pour assurer le métabolisme
- ❑ Souvent 1^{er} élément adapté pour augmenter DaO_2
- ❑ Compréhension physopathologique des états instables plus qu'une description
- ❑ Mise en place de thérapies guidées (early goal-directed)
- ❑ Non invasif: sécurité, validité relative des méthodes dites de référence

Pourquoi le Débit Cardiaque (2)

Deux questions fondamentales en Hémodynamique:

- ❑ DC augmente-t-il après remplissage?
Preload responsiveness

- ❑ Cœur assure-t-il un maintien du DC une fois la PA restaurée?

Les nouvelles techniques de monitoring du débit cardiaque : gadgets ou avancées réelles ?

R. Chatti, B. Cholley*

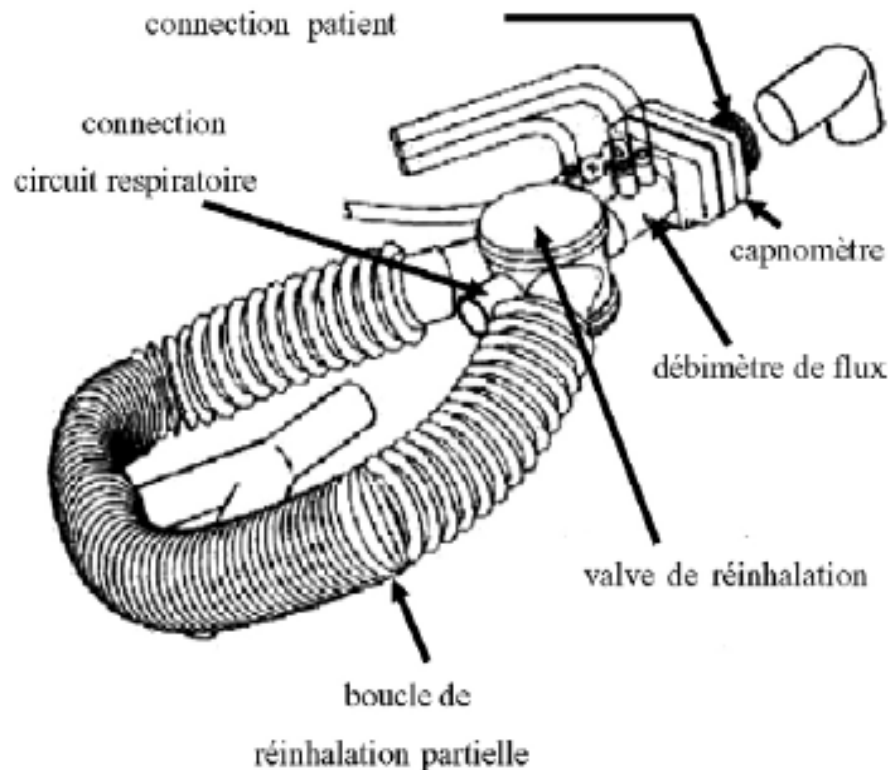
Réanimation 16 (2007) 156-162

- ❑ Principe de Fick appliqué au CO₂
- ❑ Bio-réactance
- ❑ Vélocimétrie doppler
- ❑ Échocardiographie

Méthode utilisant le principe de Fick

$$DC = \frac{VCO_2}{CvCO_2 - CaCO_2}$$

$$DC = \frac{\Delta VCO_2}{S \times \Delta etCO_2}$$



- Technique simple
- Indépendante de l'opérateur
- Ventilation contrôlée
- Mesure discontinue 3mn
- Pathologies pulmonaires
- PRE-requis: stabilité hémodynamique
- shunt

Clinical evaluation of a partial CO₂ rebreathing technique for cardiac output monitoring in critically ill patients

Acta Anaesthesiol Scand 2002; 46: 152–159

Patient characteristics.

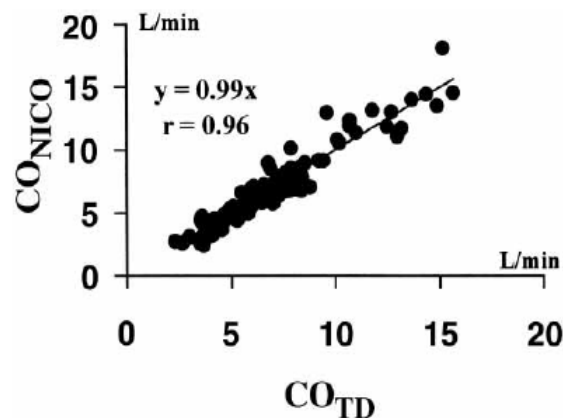
| Patient No. | Sex, M/F | Age, years | BSA, m ² | Diagnosis | CO _{TD} technique | CO _{TD} range, L/min | PEEP cmH ₂ O | FiO ₂ | Maximal pulmonary shunt refraction |
|-------------|----------|------------|---------------------|-----------------------------|----------------------------|-------------------------------|-------------------------|------------------|------------------------------------|
| 1 | M | 56 | 1.70 | Liver cirrhosis | bolus | 4.3–13.0 | 3–4 | 0.31–0.38 | 0.25 |
| 2 | M | 49 | 1.78 | Sepsis | continuous | 5.7–7.5 | 10–13 | 0.40 | 0.19 |
| 3 | M | 74 | 2.20 | Aortic aneurysm | bolus | 2.3–10.1 | 4 | 0.41–0.51 | 0.21 |
| 4 | M | 84 | 1.86 | Sepsis | continuous | 5.0–7.4 | 14–15 | 0.57–0.72 | 0.38 |
| 5 | M | 34 | 1.86 | Liver cirrhosis | bolus | 6.6–12.7 | 3 | 0.27–0.36 | * |
| 6 | M | 84 | 1.79 | Aortic aneurysm | bolus | 3.6–4.7 | 4 | 0.27–0.39 | 0.21 |
| 7 | M | 77 | 1.85 | Aortic aneurysm | continuous | 3.5–6.1 | 4 | 0.35 | * |
| 8 | M | 52 | 1.74 | Liver cirrhosis | bolus | 6.8–15.7 | 3 | 0.34–0.40 | 0.42 |
| 9 | F | 42 | 2.17 | Liver cirrhosis | continuous | 6.6–8.4 | 16–17 | 0.27–0.71 | 0.53 |
| 10 | M | 44 | 2.42 | Liver cirrhosis | bolus | 7.4–14.4 | 10 | 0.30–0.46 | 0.29 |
| 11 | M | 65 | 1.95 | Sepsis | bolus | 4.9–5.8 | 13 | 0.65 | * |
| 12 | F | 58 | 1.82 | Liver cirrhosis | bolus | 5.6–8.6 | 4 | 0.37–0.43 | 0.30 |
| 13 | M | 78 | 1.91 | Aortic aneurysm | bolus | 2.7–4.6 | 14–15 | 0.37–0.43 | 0.31 |
| 14 | M | 59 | 1.98 | Familial amyloid neuropathy | bolus | 3.9–6.4 | 4 | 0.46–0.50 | 0.15 |
| 15 | F | 67 | 1.68 | Adrenal carcinoma | bolus | 3.6–5.9 | 4 | 0.35–0.37 | 0.22 |

15 patients

12 chir majeure

3 ICU

125 mesures

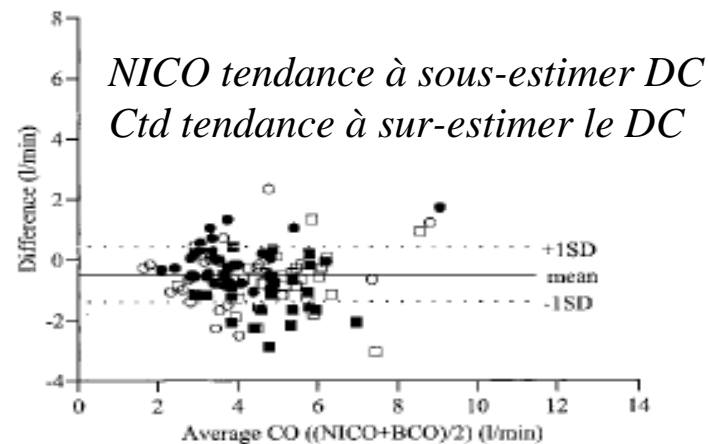
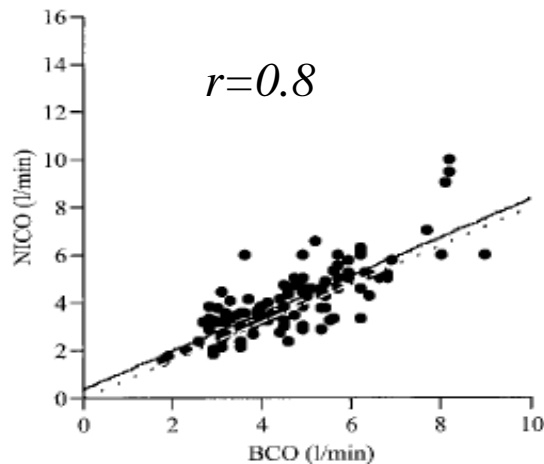


- Sous-estimation du shunt de 11%
- Modification de PvCO₂ lors du rebreathing
- Sous-estimation du VCO₂ sur modèle de poumon artificiel

Performance of Noninvasive Partial CO₂ Rebreathing Cardiac Output and Continuous Thermodilution Cardiac Output in Patients Undergoing Aortic Reconstruction Surgery

Anesthesiology, V 99, No 2, Aug 2003

- Étude prospective en chirurgie de l'Aorte NICO versus CCO/BCO
- 28 patients, 112 mesures
- 4 temps d'évaluation : induction-clampage-déclampage-reperfusion



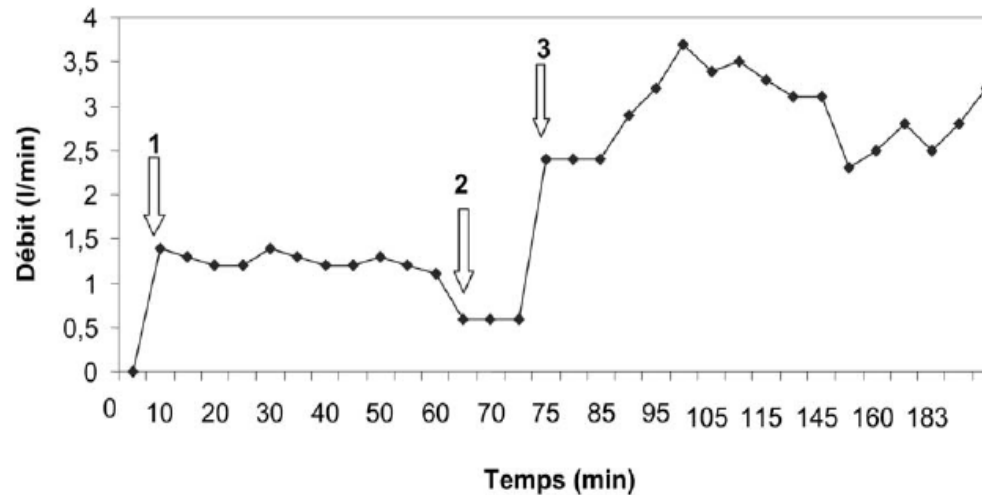
- Bonne estimation du DC en conditions STABLES
- Perte d'exactitude lors des phases de clampage et reperfusion
- Sous estimation constante du DC par le NICO
- Augmentation du biais à cause d'une augmentation brutale de VCO₂ ?
- PAS de renseignement sur le statut volémique

Cas clinique

Intérêt du monitoring du débit cardiaque en situation préhospitalière par la technique de la réinhalation partielle du CO₂ : à propos d'une observation

Interest of prehospital use of cardiac output monitoring with partial CO₂ rebreathing technique: a case report

R. Amathieu ^{a,b,*}, V. Minville ^a, M.-P. Poloujadoff ^b, F. Adnet ^b, N. Smail ^a



Bioreactance: A new technology for non invasive cardiac output monitoring



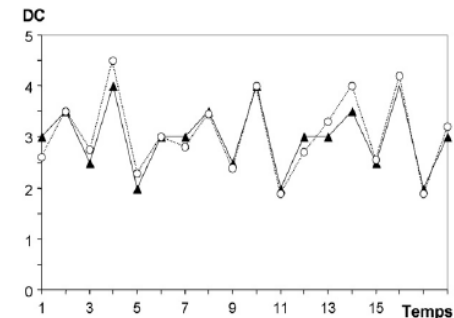
P. Squara

De la bioréactance thoracique au débit cardiaque

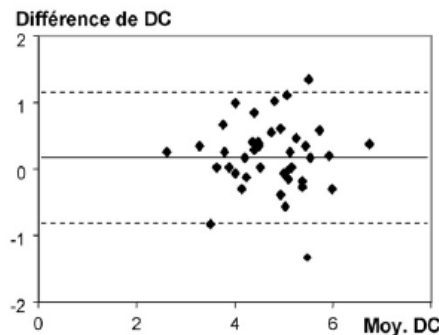
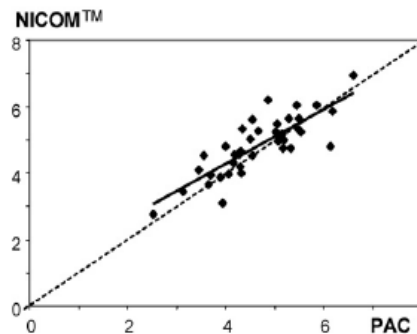
- Application d'un courant de haute fréquence, 4 électrodes
- Mesure des variations de tension
- Bio-impédance mesure la variation d'amplitude
- Bio-Réactance mesure le *décalage de phase* et la modulation de fréquence $\Delta\omega(t)$

Validation expérimentale

- Modèle de porc à thorax ouvert sous CEC
- Modèle de porc à thorax ouvert avec dobutamine et écho



Validation clinique



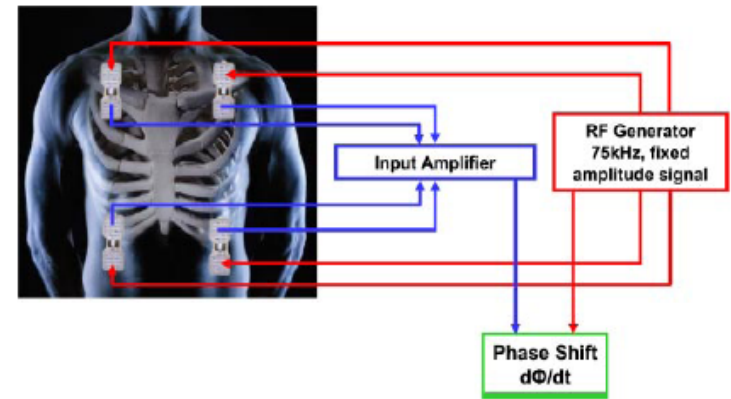
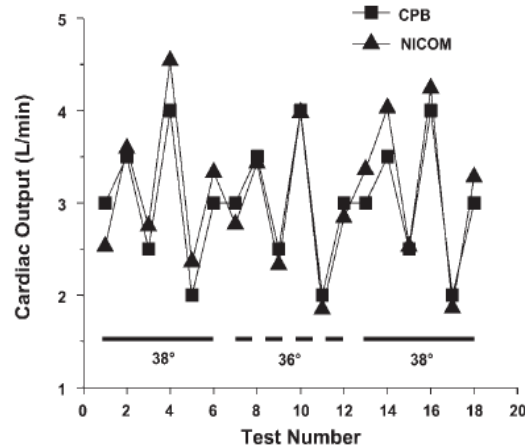
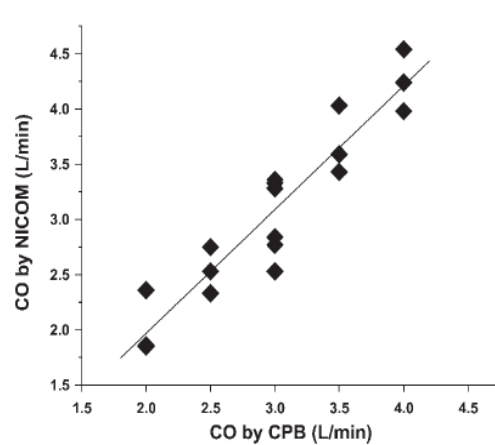
Squara P, Denjean D, Estagnasie P, Brusset A, Dib JC, Dubois C. Noninvasive cardiac output monitoring (NICOM): a clinical validation. *Intensive Care Med* 2007;33:1191-4.

biais moyen = 0.16 l/mn

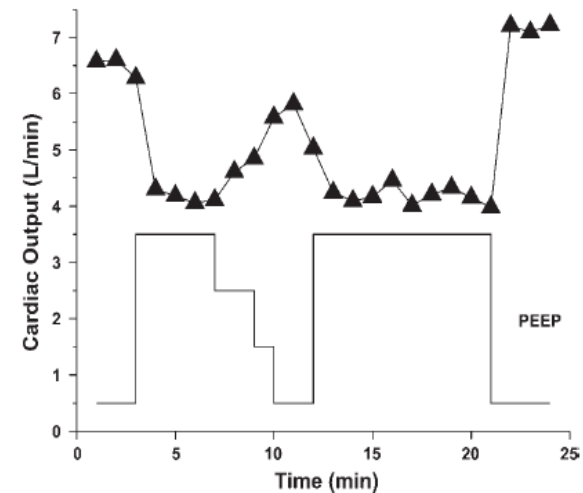
Evaluation of a noninvasive continuous cardiac output monitoring system based on thoracic bioreactance

Am J Physiol Heart Circ Physiol 293: H583–H589, 2007.
First published March 23, 2007; doi:10.1152/ajpheart.00195.2007.

Hanan Keren,¹ Daniel Burkhoff,² and Pierre Squara³



- Pré-requis animal 9 cochons en CEC
- 27 patients de réa cardiaque après chir PAC
- Variations rapides de DC et température
- Effets de la PEEP
- Facteur correctif



Noninvasive cardiac output monitoring (NICOM): a clinical validation

Intensive Care Med (2007) 33:1191–1194
DOI 10.1007/s00134-007-0640-0

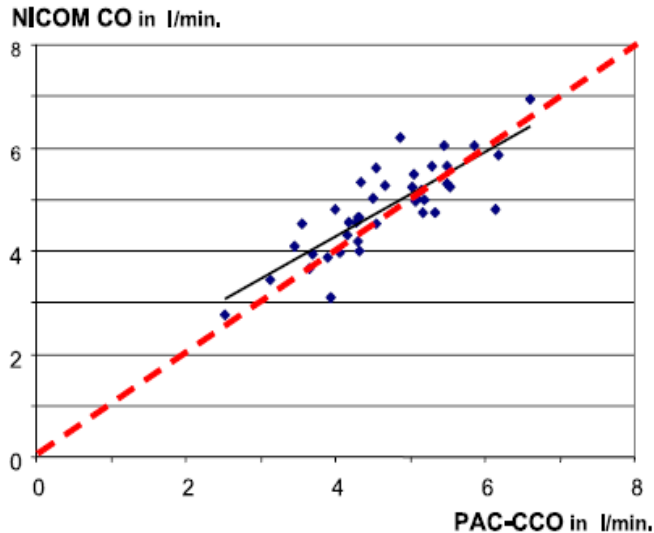


Fig.1 Regression PAC-CCO vs. NICOM (each point represents the mean CO value during a period of stable CO). $R=0.82$. Slope = 0.82 (95%CI=0.64–1.0) not significantly different from the identity line (red dotted line)

| | NICOM | PAC-CCO | <i>p</i> |
|---------------------------------------|------------|------------|----------|
| 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 |

- ❑ 119 patients de chirurgie cardiaque PAC, 65 888 paires de valeurs 65% pendant ventilation
- ❑ calcul du biais par méthode de Bland & Altman
- ❑ Biais moyen 0.06 l/mn +/- 0.71 acceptable (<20%) dans 80% des cas
- ❑ Biais non corrélé à durée expérimentation ni ventilation mécanique
- ❑ Réponse rapide

Notions de mesures doppler (1)

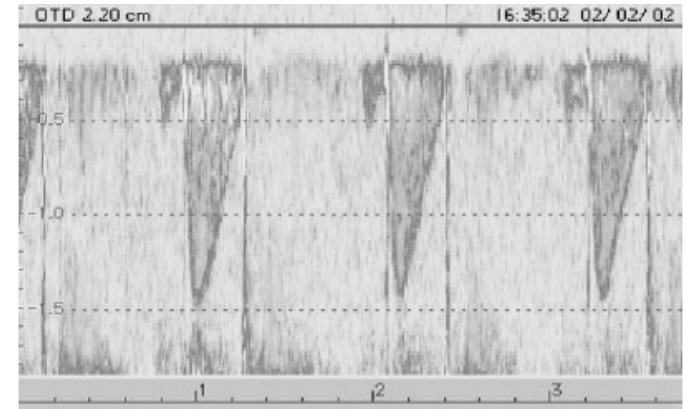
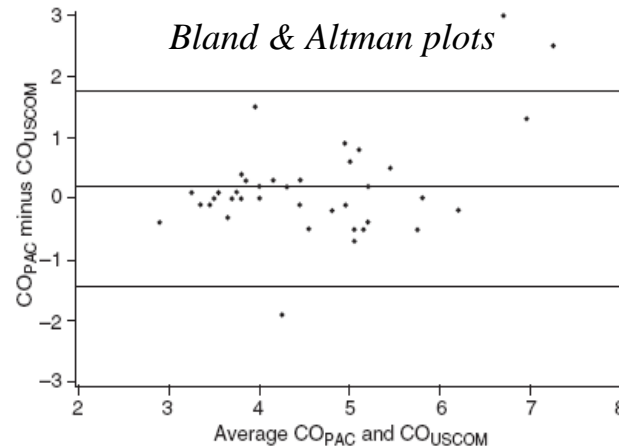
- $S^2 = \Pi \times \text{diamètre}^2 / 4$
- ITV = distance en cm parcourue par la colonne de sang
= Intégrale Temps x Vitesse = sec x cm/s = cm
- Volume Ejection = ITV x S^2
- DC = Volume x Fc = ITV x S^2 x Fc

Clinical evaluation of USCOM ultrasonic cardiac output monitor in cardiac surgical patients in intensive care unit

H. L. Tan,

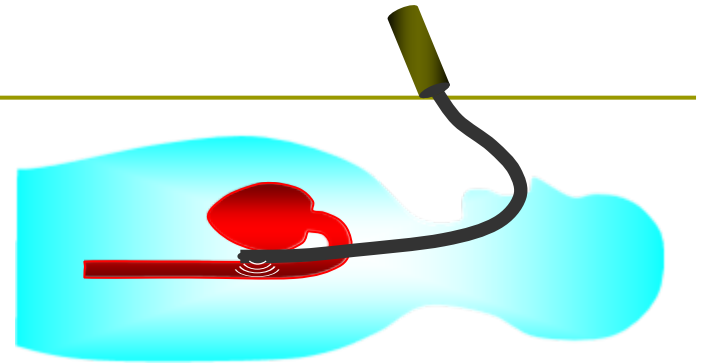
Br J Anaesth 2005; 94: 287–91

BJA



- ❑ 22 patients 40 paires de mesures
- ❑ Échec de pose pour 2 malades
- ❑ Biais de 0,18 l/mn
- ❑ Limite S² valvulaire calculée pas mesurée
- ❑ Augmentation du biais avec le débit cardiaque
- ❑ 1^{ère} étude en ventilation mécanique
- ❑ Avantages: sécurisé, patients éveillées, bien toléré
- ❑ 40 000 \$

Doppler oesophagien



- ❑ Non invasif
- ❑ Estimation fiable et précise du débit cardiaque
estimation de la S² Aortique ou mesure directe
- ❑ Utilisation simple
- ❑ Apprentissage facile
- ❑ Réponse au remplissage vasculaire
- ❑ PAS d'estimation des pressions de remplissage

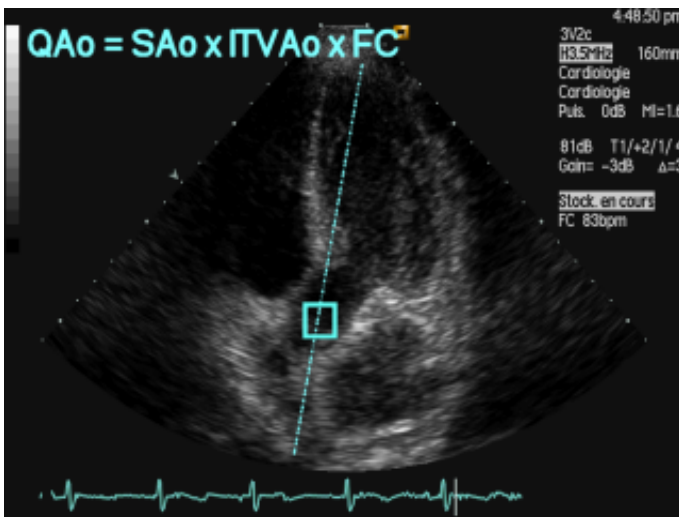
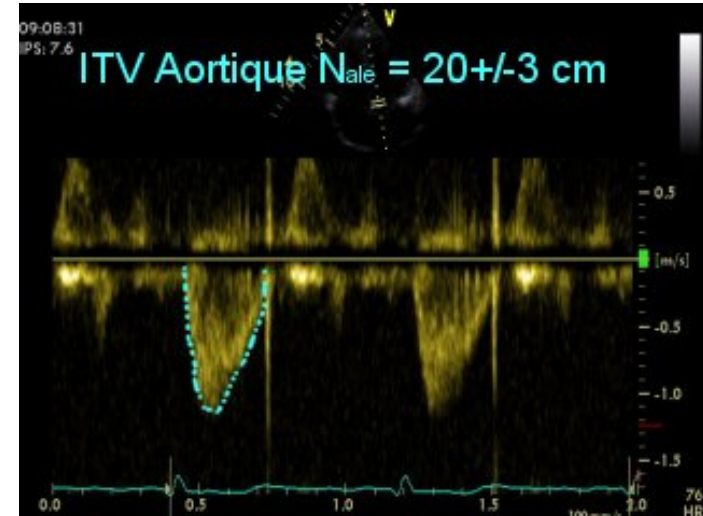
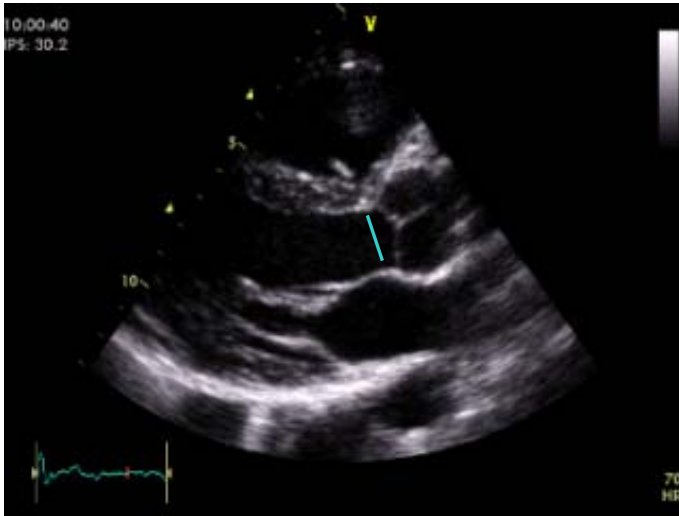
The validity of trans-esophageal Doppler ultrasonography as a measure of cardiac output in critically ill adults

Intensive Care Med (2004)

- ❑ Méta-analyse 1989-2003
- ❑ 422 études prospectives avec paires de mesures Doppler oeso/PAC
- ❑ 11 publications CardioQ et 2 HémoSonic
- ❑ 314 patients et 2400 paires de mesures pour CardioQ
46 patients 462 paires HémoSonic
- ❑ Méthodes Bland & Altman
- ❑ Critères évalués: 1) biais moyen « poolé »
 2) pourcentage acceptabilité clinique

| | | |
|-----------|---|-------------------------------|
| CardioQ | | |
| | biais poolé 0,19 l/mn | acceptabilité 50% des valeurs |
| | meilleurs résultats pour monitoring des tendances | |
| HémoSonic | | |
| | biais poolé ?l/mn | acceptabilité 40% des valeurs |

Notions de mesures doppler (2)



$$\begin{aligned} DC &= \text{Débit Ao} \\ &= ITVAo \times S^2Ao \times Fc \end{aligned}$$



ELSEVIER

Available online at www.sciencedirect.com



Réanimation 13 (2004) 255–263

Réanimation

www.elsevier.com/locate/reaurg

Recommandations

Recommandations d'experts de la SRLF

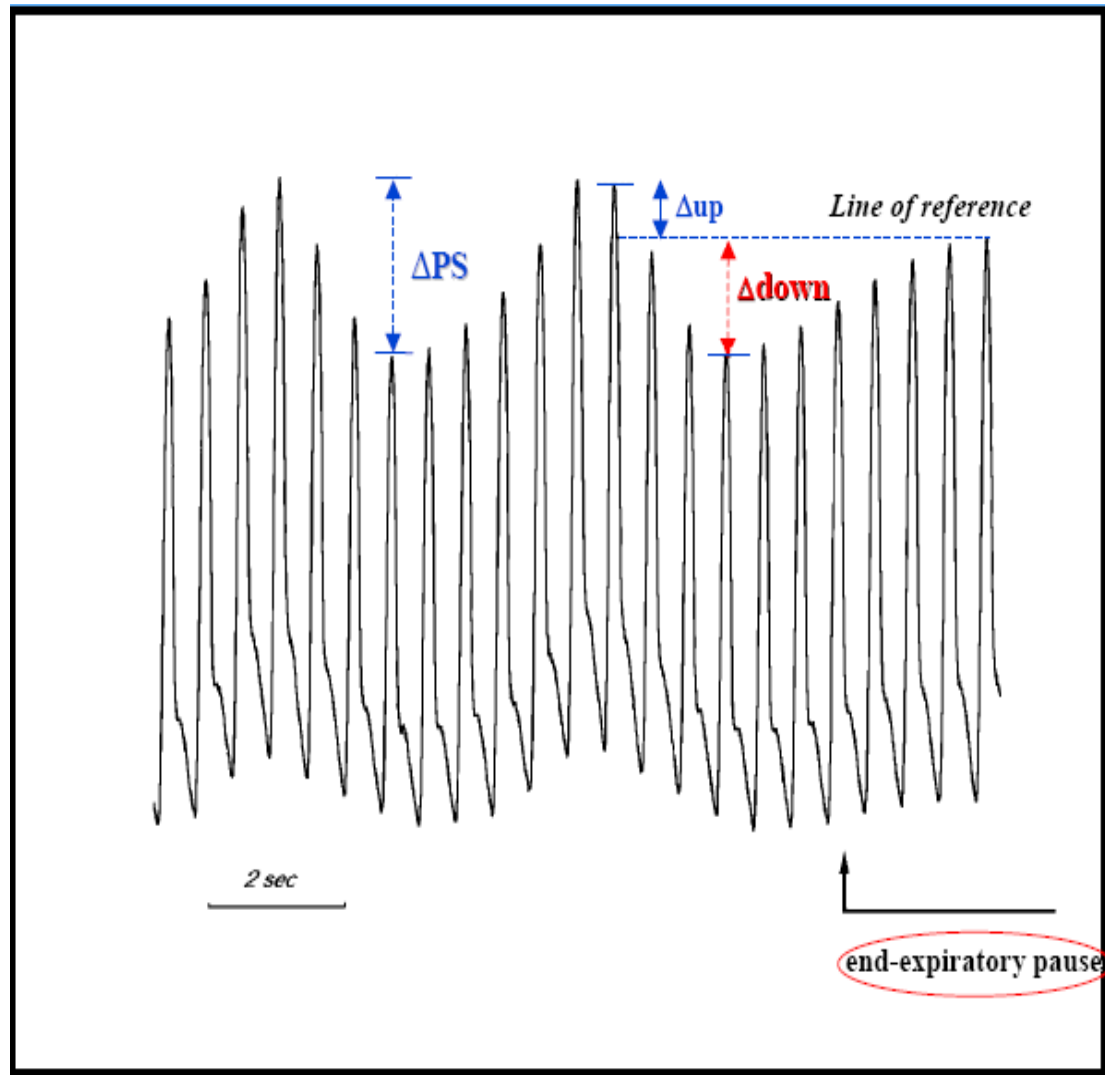
« Indicateurs du remplissage vasculaire
au cours de l'insuffisance circulatoire »

SRLF experts recommendations

Indicators of volume resuscitation during circulatory failure

J.-L. Teboul, et le groupe d'experts de la SRLF

Paramètres dynamiques liés à l'onde de pouls

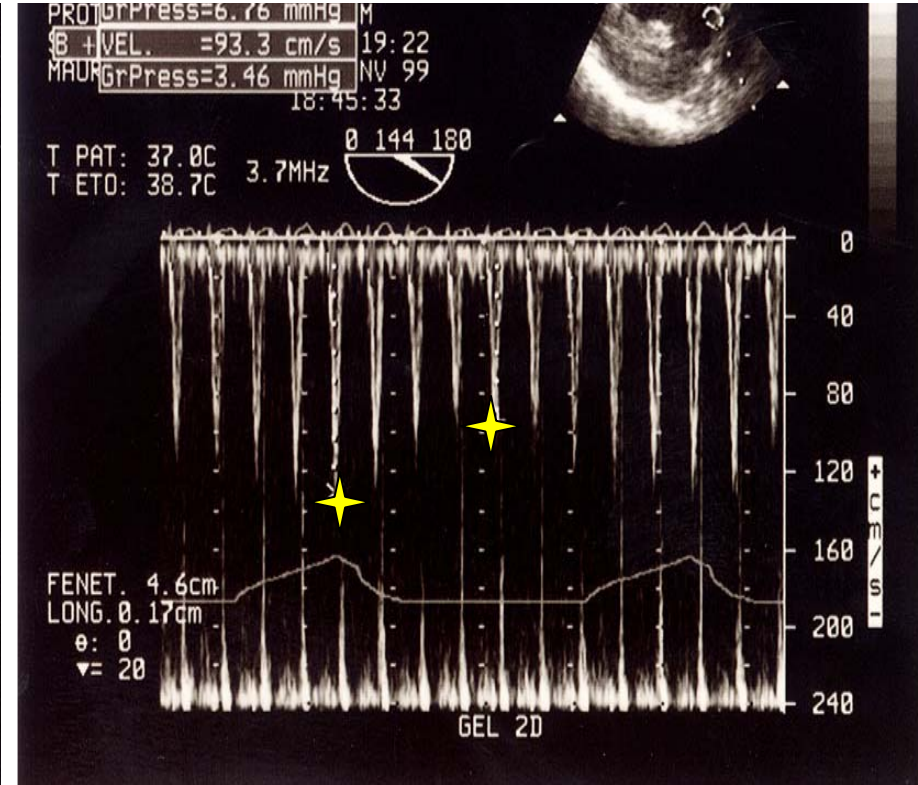
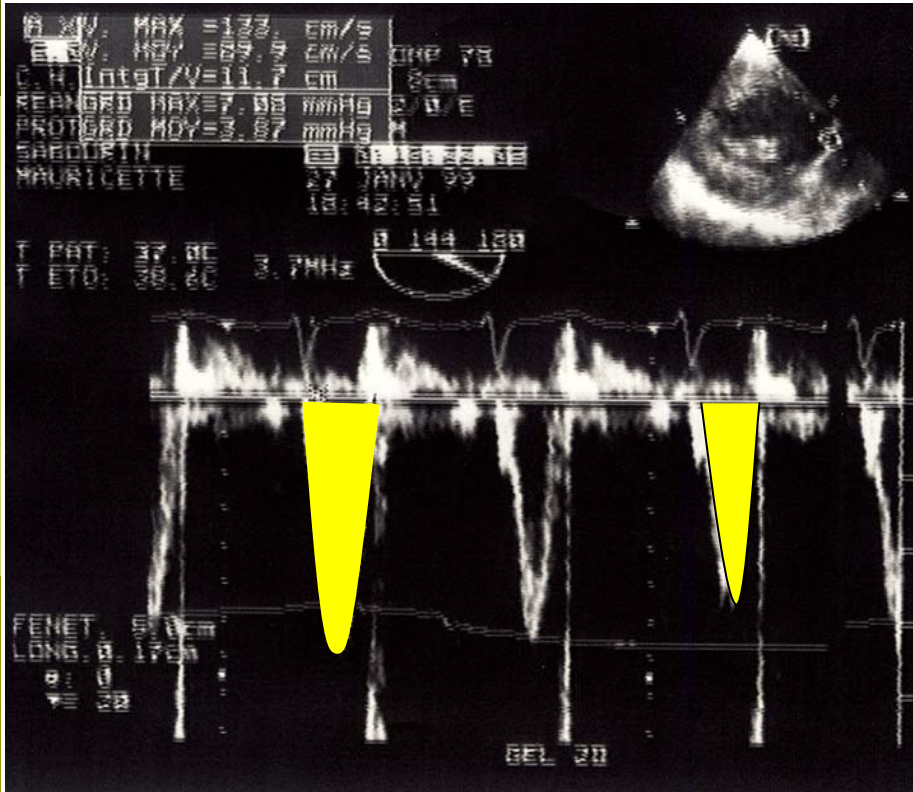


Critères dynamiques en échocardiographie

Validation: malades ventilés en VAC, $V_t > 7 \text{ ml/kg}$, en rythme sinusal

- Variabilité respiratoire du V_{éj} VG :
 - { $\Delta V_{\text{maxAo}} > 12\%$ en ETO
 - { $\Delta \text{ITV Ao}$
 - { diminution des critères à LJP
- Variabilité respiratoire du diamètre des Veines Caves:
 - { $\Delta \text{diamètre VCI} > 12\%$
 - { indice de collapsibilité de VCS en ETO 60%

Paramètres dynamiques en écho-doppler



Une littérature exhaustive....

- Cyclic changes in arterial pulse during respiratory support revisited by Doppler echocardiography.
Vieillard-Baron A and al.
Am J Respir Crit Care Med 2003
- Respiratory changes in aortic blood velocity as an indicator of fluid responsiveness in ventilated patients with septic shock.
Feissel M and al.
Chest 2001
- Respiratory variations of aortic VTI: a new index of hypovolemia and fluid responsiveness.
Slama M and al.
Am J Heart Circ Physiol 2002
- The respiratory variation in the inferior vena cava diameter as a guide to fluid therapy.
Feissel M and al.
Intensive Care Med 2004
- Superior vena caval collapsibility as a gauge of volume status in ventilated septic patients.
Vieillard-Baron A and al.
Intensive Care Med 2004



Place de l'échocardiographie en Réanimation

- ❑ évaluation non invasive du DC et plus...(pressions)
- ❑ discontinue
- ❑ reproductible
- ❑ intérêt diagnostique complet, prédictif et évolutif

- ❑ malgré coût et formation préalable

Place de l'échocardiographie en Réanimation

NCBI PubMed A service of the U.S. National Library of Medicine and the National Institutes of Health My NCBI [Sign In] [Register]

Intensive Care Med (2008) 34:243-249
DOI 10.1007/s00134-007-0923-5

CLINICAL COMMENTARY

Search
Lim
Displa
All:
Antoine Vieillard-Baron
 1: Michel Slama
Bernard Cholley
All i Gérard Janvier
Sep Philippe Vignon

Echocardiography in the intensive care unit: from evolution to revolution?

[Crit Care Med. 2007]

- ▶ Specific skill set and goals of focused echocardiography for critical care clinicians. [Crit Care Med. 2007]
- ▶ Critical care medicine in the Western Pacific region.

Department of Intensive Care Medicine, University of Sydney, Nepean Hospital, Sydney, NSW, Australia. seppelt@med.usyd.edu.au

The value of echocardiography to the intensivist has been well recognised in the past two decades. Regular reviews of the subject can be found in all major journals. Most intensivists surveyed feel that echocardiography is the way of the future. Yet, despite the undisputed advantages of echocardiography, uptake of the technique into the intensive care unit has been slow. Reasons for this are multiple, and include conservatism among senior clinicians and limited availability of equipment. Above all, the lack of a consistent and widely available education program has limited the opportunities for intensive care trainees to learn echocardiography. There is a need for a "three-tier" program, where all intensivists learn the basic skills to perform a focused examination on a patient whose condition is unstable, while those with a special interest develop more comprehensive skills or go on to lead a critical care echocardiography program.

PMID: 17767457 [PubMed - indexed for MEDLINE]

Les limites de l'hémodynamique globale

Table 3. Physiologic variables on the first and last day of shock in survivors and patients dying after resolution of shock in multiple-organ failure (death MOF) and patients dying in acute circulatory failure (death in shock)

| | Survivors (n = 26) | | Death MOF (n = 7) | | Death in Shock (n = 13) | |
|---|--------------------|----------------------------------|-------------------|----------------------------|-------------------------|------------------|
| | Baseline | Last | Baseline | Last | Baseline | Last |
| Temperature, °C | 37.3 (36.5–38.0) | 37.2 (36.8–37.6) | 37.2 (36.6–38.8) | 37.0 (36.7–37.9) | 36.7 (36.3–37.9) | 37.2 (36.7–37.5) |
| Mean arterial pressure, mm Hg | 72 (66–80) | 78 (71–94) ^a | 78 (70–82) | 76 (66–80) | 66 (61–71) | 63 (56–83) |
| Heart rate, beats/min | 109 (94–121) | 95 (81–116) ^a | 100 (99–128) | 101 (93–117) | 101 (99–119) | 99 (83–128) |
| Central venous pressure, mm Hg | 12 (8–15) | 12 (11–14) | 16 (10–19) | 16 (12–19) | 11 (8–16) | 16 (13–21) |
| Mean pulmonary artery pressure, ^b mm Hg | 27 (21–33) | 30 (24–40) | 29 (23–33) | 30 (29–36) | 28 (21–31) | 29 (26–32) |
| Pulmonary artery occlusion pressure, ^b mm Hg | 14 (11–18) | 16 (13–19) | 18 (14–24) | 17 (13–22) | 15 (10–18) | 20 (14–26) |
| Cardiac index, ^b L/min·m ² | 3.7 (2.8–4.5) | 3.3 (2.7–4.1) | 4.0 (3.6–4.5) | 3.6 (2.9–4.3) | 3.0 (2.4–3.3) | 2.9 (2.2–4.1) |
| pH | 7.39 (7.32–7.44) | 7.39 (7.35–7.42) | 7.37 (7.29–7.40) | 7.36 (7.22–7.36) | 7.39 (7.25–7.42) | 7.37 (7.20–7.41) |
| Paco ₂ , mm Hg | 38 (33–41) | 37 (34–45) | 37 (35–39) | 39 (37–41) | 36 (31–41) | 41 (29–44) |
| PaO ₂ , mm Hg | 85 (74–110) | 91 (77–122) | 114 (101–134) | 93 (91–111) | 91 (71–120) | 73 (68–108) |
| Mixed venous oxygen saturation, ^b % | 67 (63–72) | 70 (67–74) | 73 (69–74) | 70 (55–76) | 70 (61–77) | 70 (69–76) |
| Hemoglobin concentration, g/dL | 8.7 (7.8–10.8) | 8.8 (8.0–10.0) | 8.8 (8.0–9.1) | 9.0 (7.5–10.9) | 9.8 (8.1–11.3) | 8.7 (7.6–10.0) |
| Arterial lactate, mEq/L | 1.7 (1.2–2.4) | 1.0 (1.0–1.9) ^a | 1.7 (1.3–4.0) | 2.1 (1.1–4.0) | 2.9 (2.3–3.9) | 2.2 (1.8–4.1) |
| Oxygen delivery, ^b mL/min·m ² | 394 (317–481) | 397 (292–485) | 482 (424–520) | 402 (369–639) | 336 (308–467) | 402 (227–448) |
| Oxygen consumption, ^b mL/min·m ² | 114 (103–153) | 116 (93–140) | 125 (113–150) | 165 (101–169) | 99 (75–140) | 80 (62–126) |
| Oxygen extraction ratio, ^b % | 31.5 (26.5–33.3) | 28.1 (24.7–31.6) | 26.0 (25.4–30.4) | 29.4 (21.8–42.5) | 29 (20–37) | 26 (23–28) |
| Initial adrenergic dose | | | | | | |
| Dopamine ^c | 22, 11.5 (5.8–20) | 20, 5 (4–11) ^a | 6, 16.5 (8.8–20) | 5, 7 (4–20) ^a | 13, 20 (12–20) | 7, 20 (17–20) |
| Norepinephrine ^c | 6, 0.2 (0.1–0.5) | 6, 0.05 (0.04–0.05) ^a | 3, 0.1 (0.1–0.3) | 1, 0.05 | 6, 0.3 (0.2–0.6) | 6, 0.5 (0.4–0.9) |
| Dobutamine ^c | 8, 5 (3.5–17.5) | 9, 8 (3.5–20) | 3, 5 (5–10) | 3, 10 (10–14) ^a | 7, 8 (6–20) | 6, 10 (5–20) |

Conclusion

- ❑ Débit cardiaque vs PA régulée
- ❑ Peu intérêt à avoir une valeur absolue
- ❑ Mesures directes de CO ou indirectes via V_{\max} ITV, Δ ITV
- ❑ Early gold-directed therapies
- ❑ Intérêt du suivi sous thérapeutique (remplissage, amines, PEEP)
- ❑ Intérêt des indices prédictifs de réponse (doppler oeso et écho)
- ❑ Notion d'hémodynamique globale
- ❑ Echo outil indispensable au 21st century

FIN

Artérioles
+
Capillaires
(7%)

Volume
contraint

Volume
non
contraint

Réservoir
veineux
(65%)

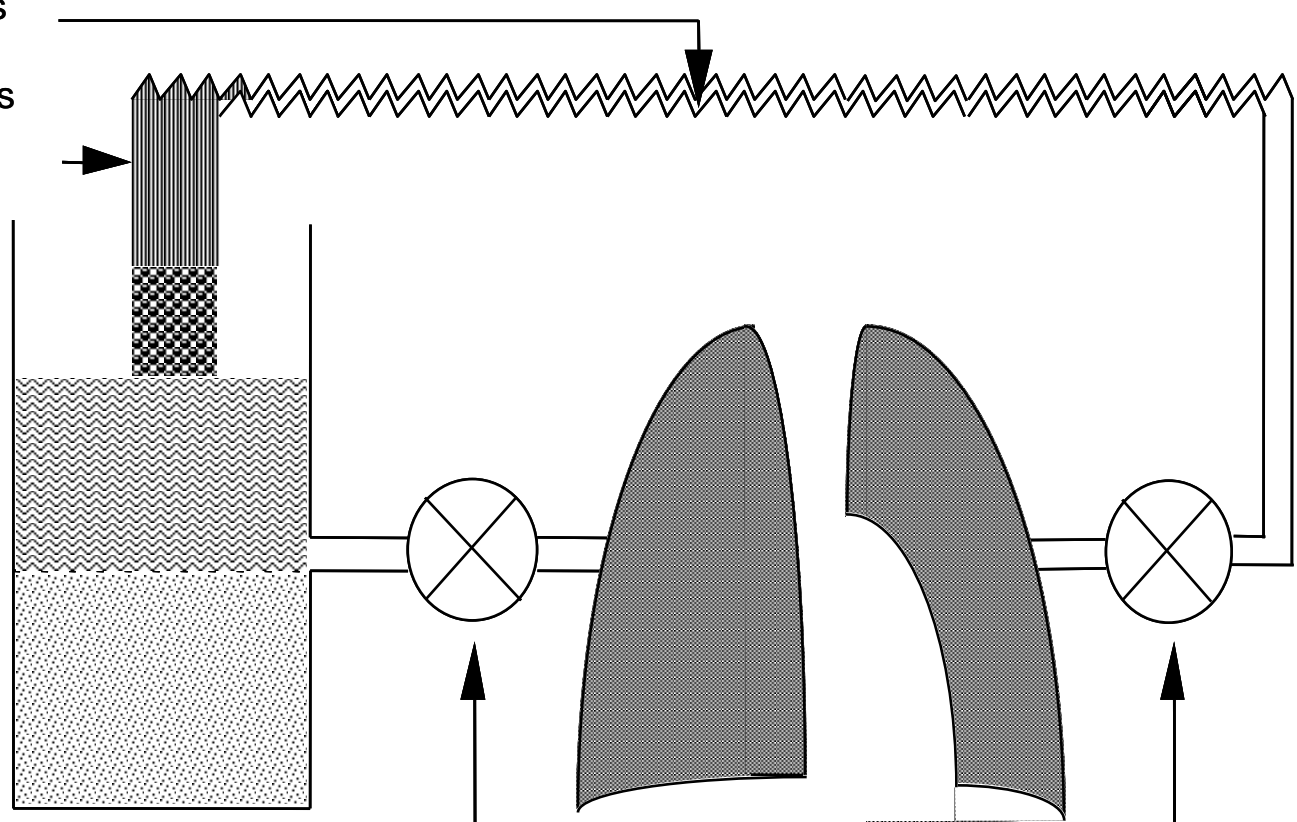
Cœur
droit
(3%)

Poumons
(9%)

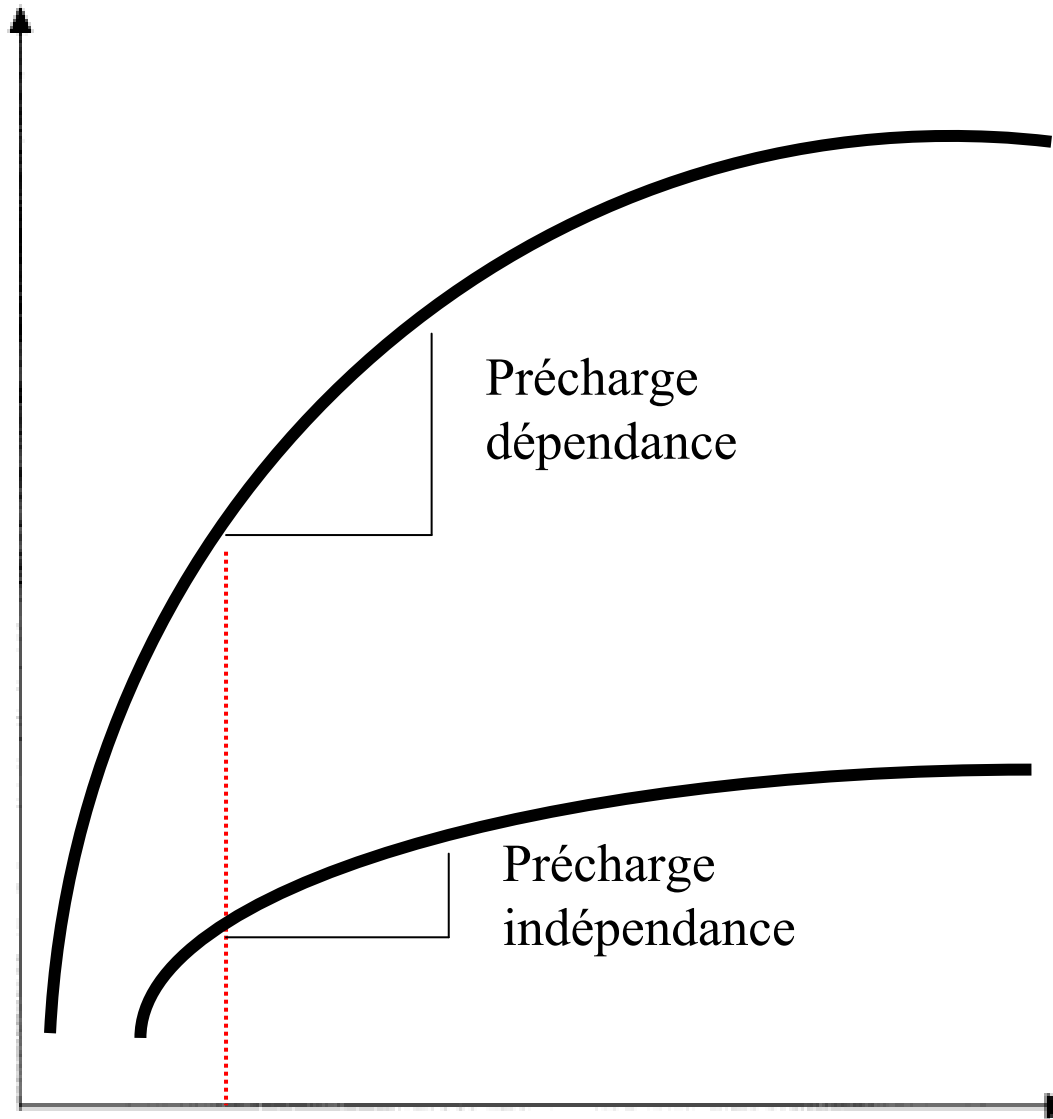
Cœur
gauche
(3%)

Artères
(13%)

Cholley, 2002



**Volume
d'éjection
systolique**



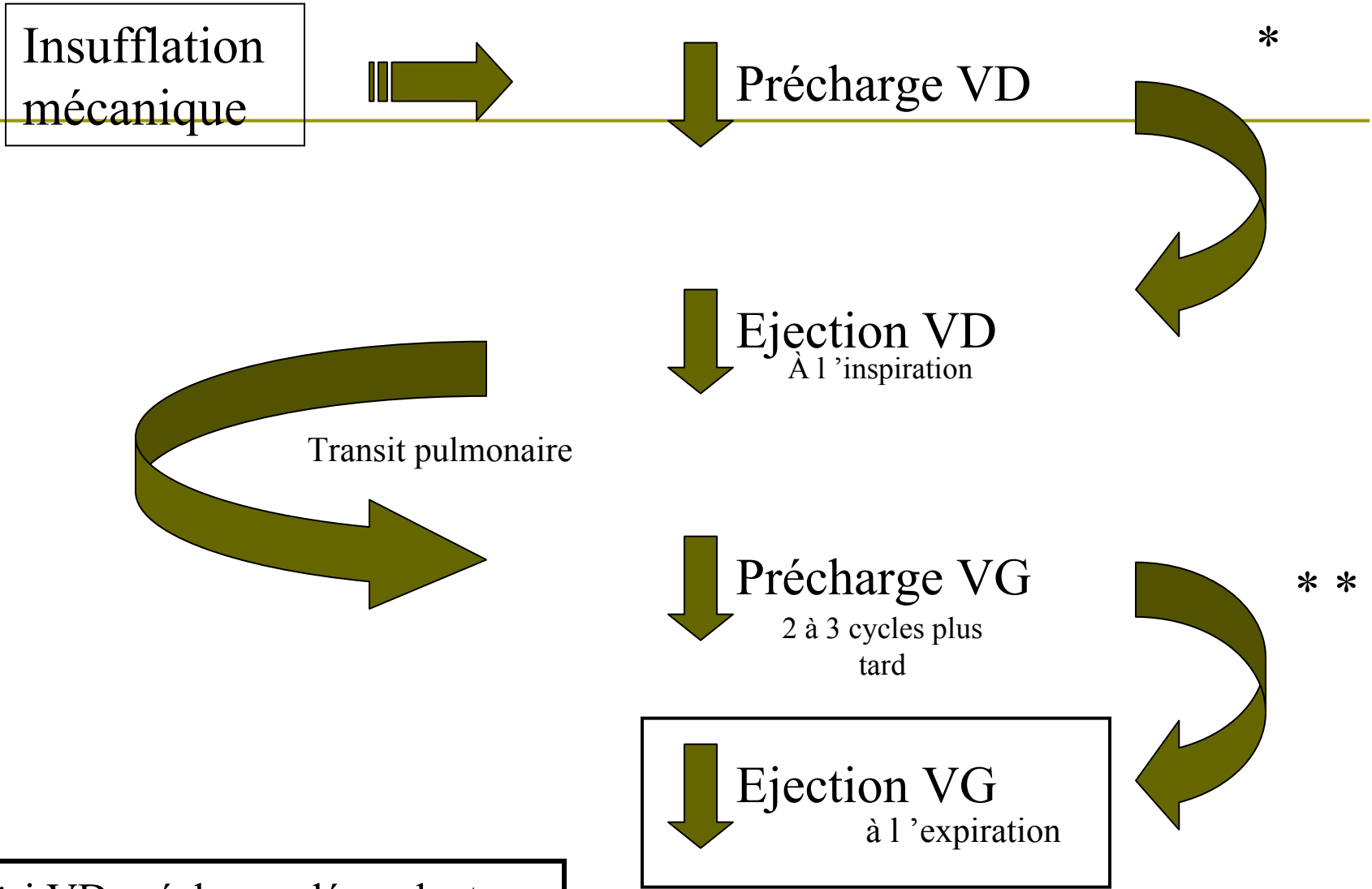
Précharge
dépendance

Cœur
défaillant

Précharge
indépendance

LOI de Frank-Starling

Précharge ventriculaire



*si VD précharge dépendant
* *si VG précharge dépendant