Assistance Publique
Hôpitaux de Marseille

Faculté de Médecine
Université de la Méditerranée
Marseille

Effets de la VM
sur
les interactions cardio-pulmonaires

M.Gainnier
(Marseille)

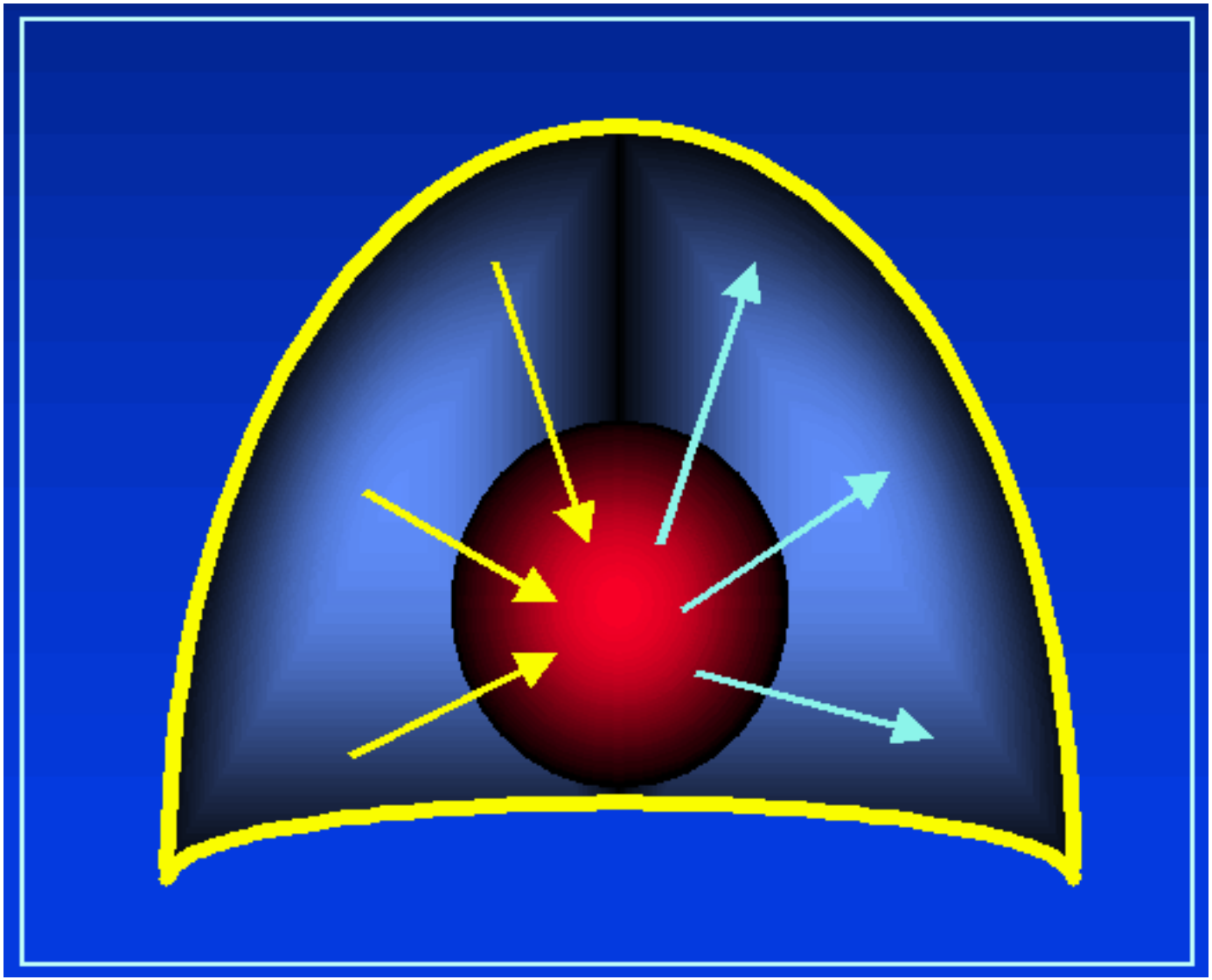
JRUR Avril 2007

Objectifs pédagogiques

Facteurs contribuant aux effets hémodynamiques de la VM et de la PEP

Mieux comprendre les conséquences de ces interactions en clinique

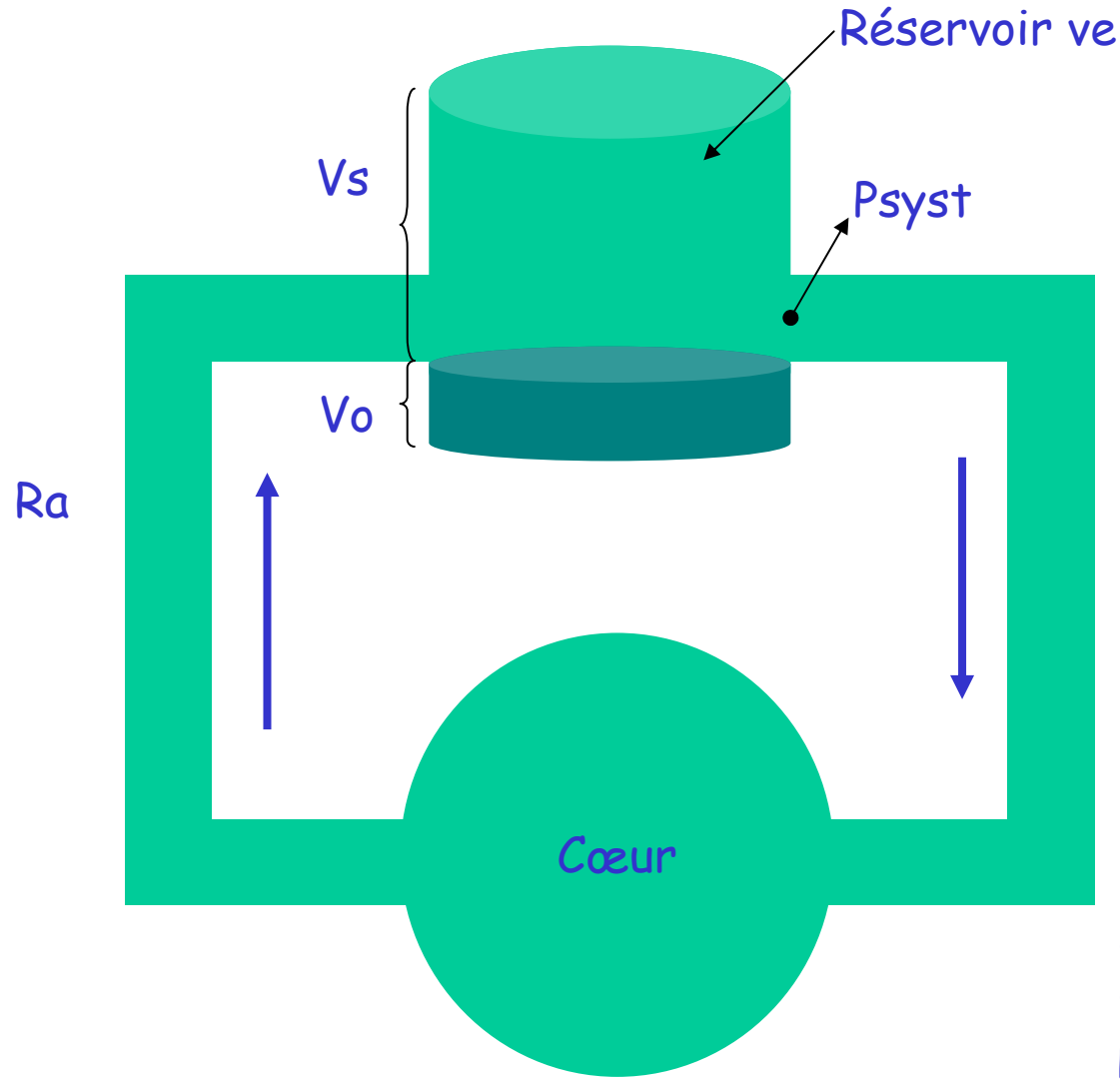
Améliorer l'interprétation des variations hémodynamiques sous VM



« The heart works as a pump within the respiratory pump »

Even P, Pulmonary Circulation, 1980

Modélisation de la circulation

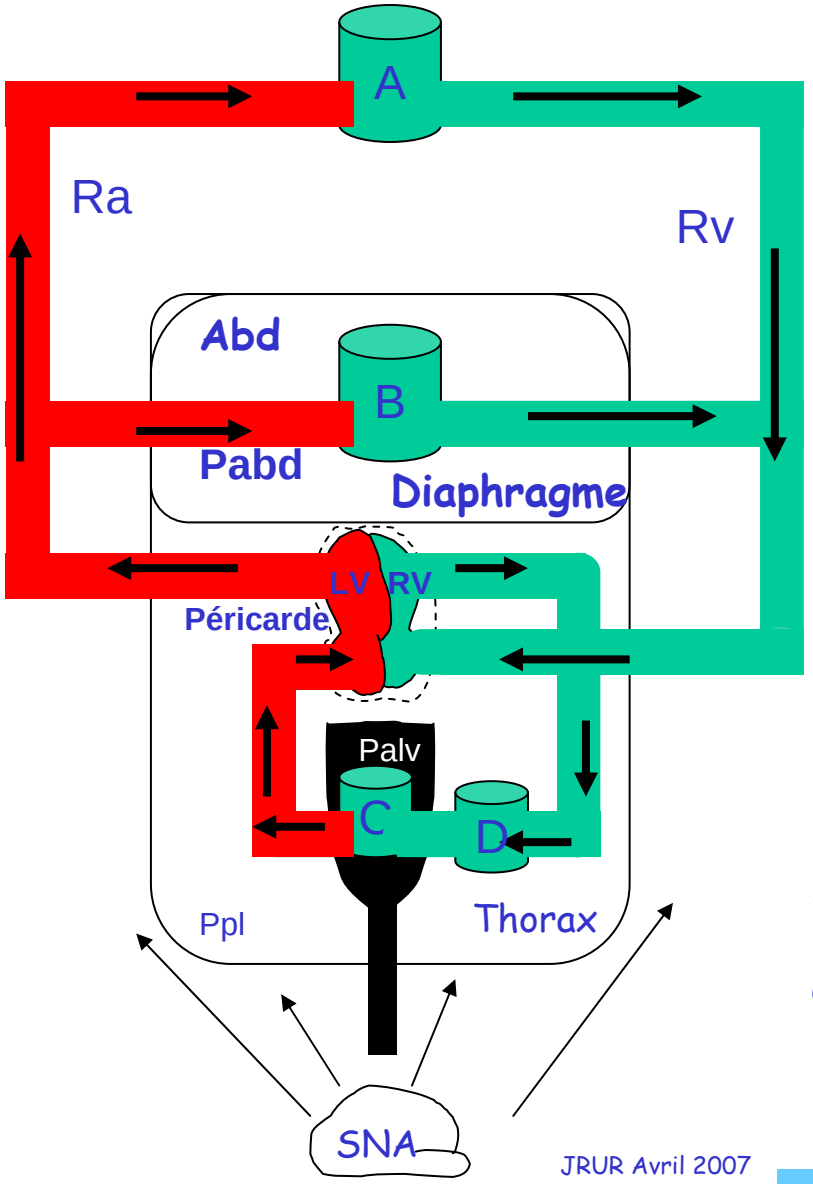


$$Vt = Vs + Vo$$

Vs : stressed volume
Vo : unstressed volume
Psyst : Pression systémique
Rv : Résistances veineuses
Ra : Résistances artérielles

Fessler HE. ERJ 1997;10:226-337

Modélisation de la circulation

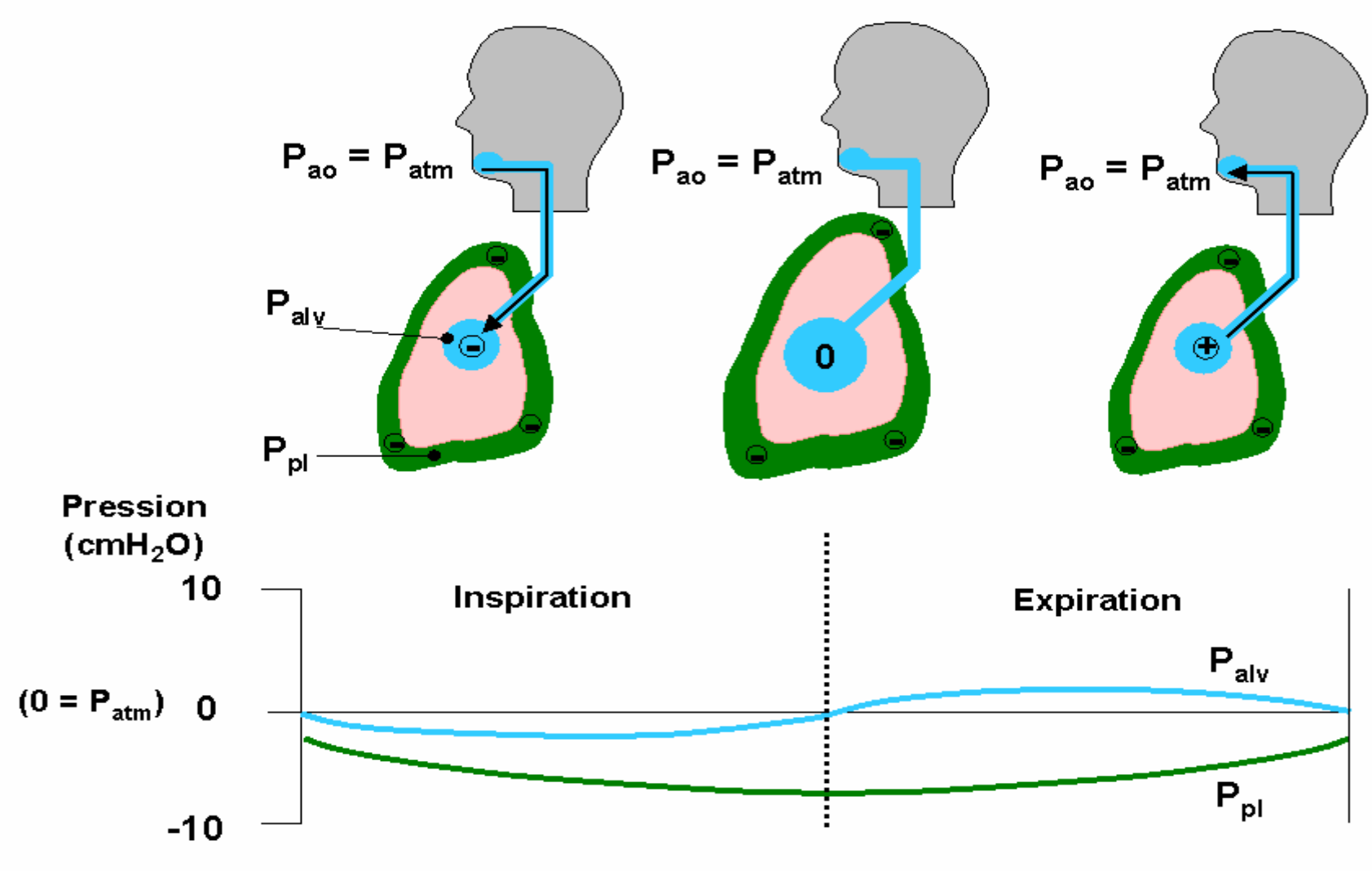


JRUR Avril 2007

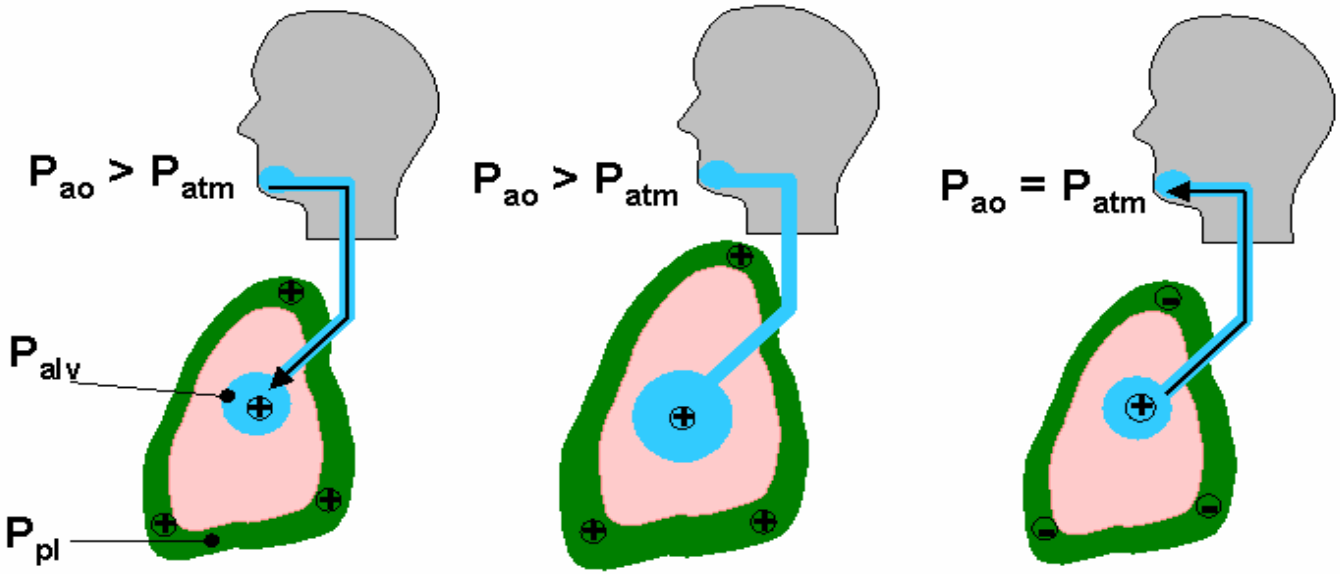
A : compartiment extra-abdominal
B : compartiment abdominal
C : vaisseaux alvéolaires
D : vaisseaux extra-alvéoaires

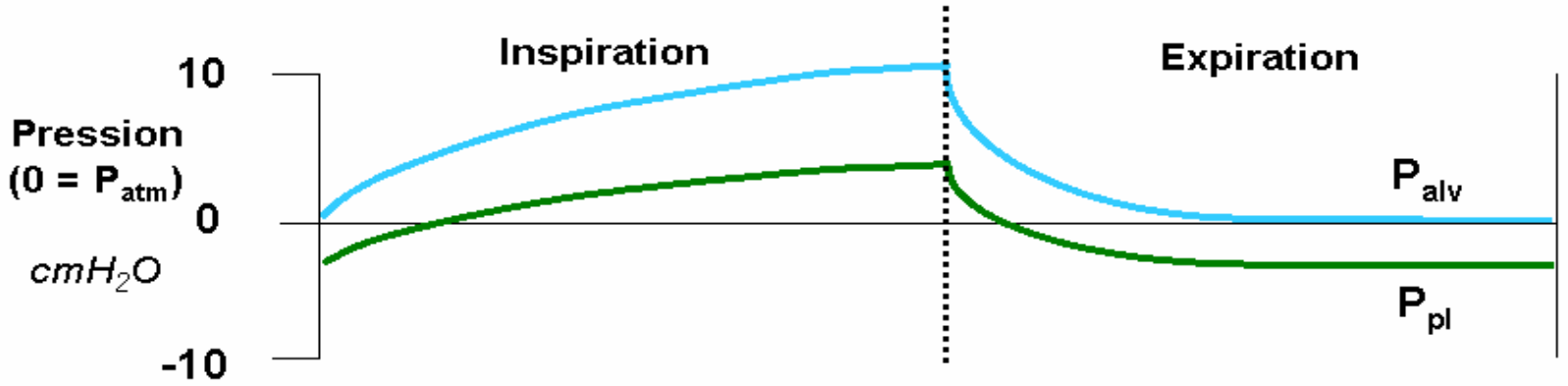
Fessler HE. ERJ 1997;10:226-337

Variations des pressions intra-thoraciques en ventilation spontanée



Variations des pressions intra-thoraciques en ventilation en pression positive

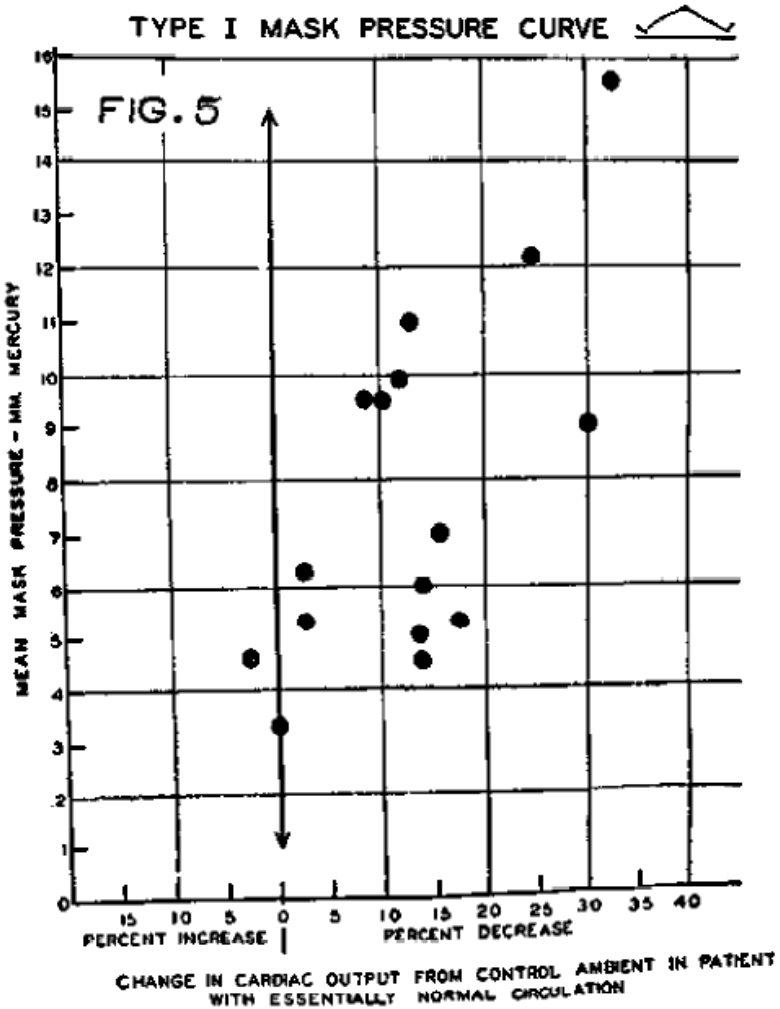




Effets comparés de la VS et de la VM sur les pressions intra-thoraciques et intra-abdominales lors de l'inspiration

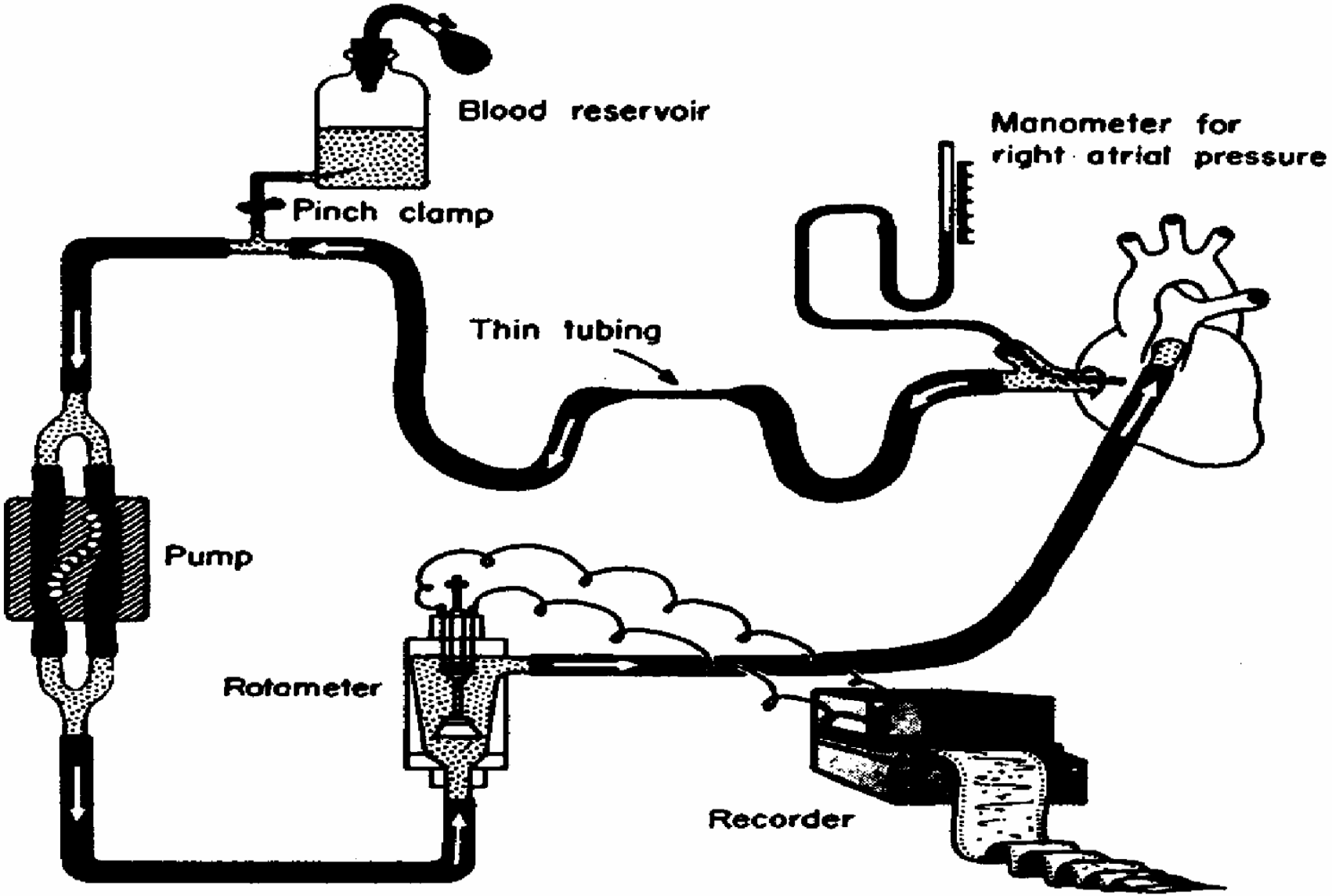
VPN (VS) Augmentation Volume Pulmonaire	VPP Augmentation Volume Pulmonaire
↘ Pression Pleurale ↗ P alv par rapport à la Ppl ↗ Ptdi ↗ P abd	↗ Pression Pleurale ↗ Palv par rapport à la Ppl ↗ P abd

« with an increase in pressure in the thorax during expiration, the right heart filling pressure from the large veins was reduced and the stroke volume decreased »



Cournand et al. Am J Physiol 1947;152:152-174

Le Modèle de Guyton



Guyton et al. Am J Physiol 1957;189:609-615

Les courbes de Retour veineux

Guyton et al. Am J Physiol 1957;189:609-615

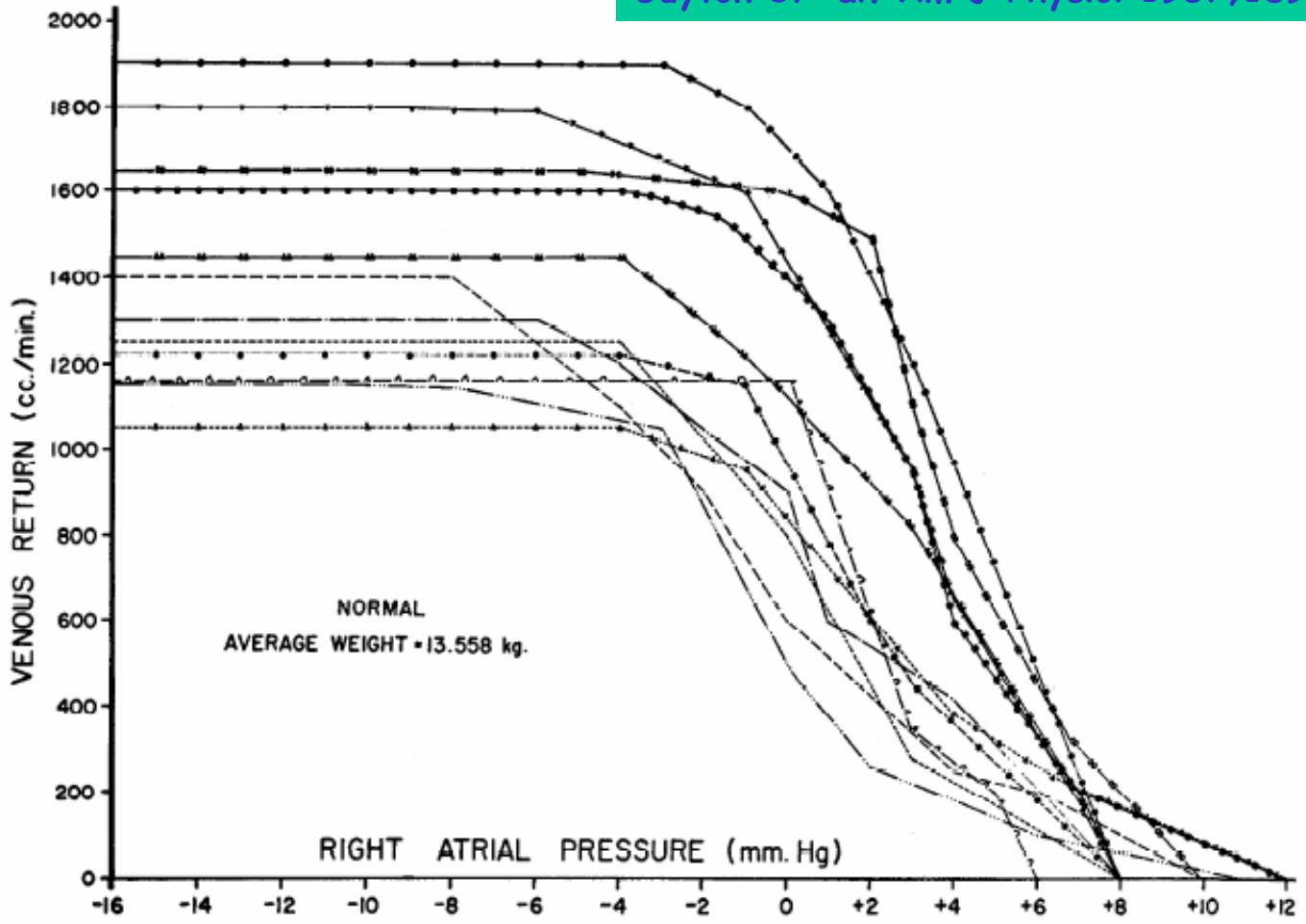


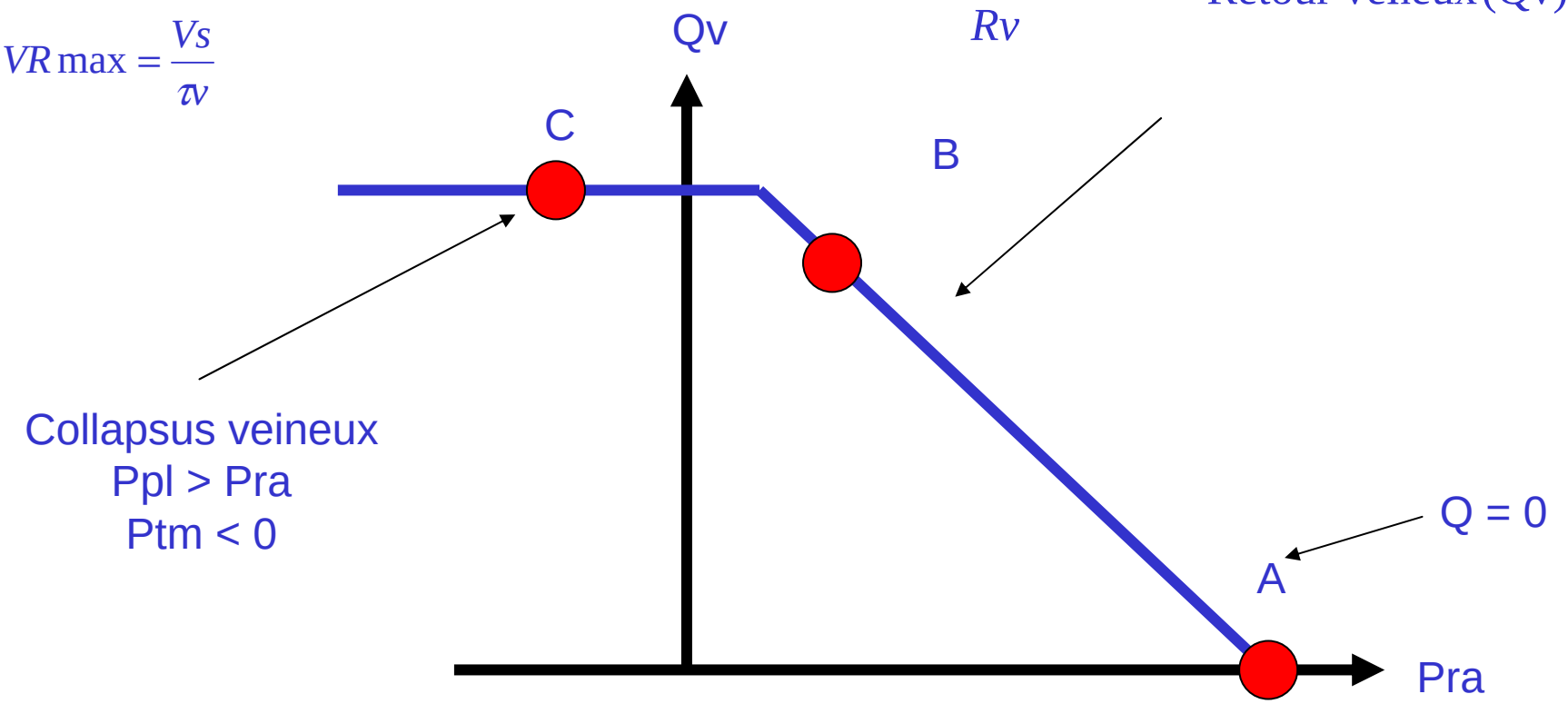
FIG. 2. Venous return curves recorded from 12 normal open-chest dogs.

$$VR\max = \frac{MCFP}{Rv}$$

$$VR\max = \frac{Vs}{Cv \times Rv}$$

$$VR\max = \frac{Vs}{\tau v}$$

$$\frac{MCFP(Psys) - P_{ra}}{Rv} = \text{Retour veineux (Qv)}$$

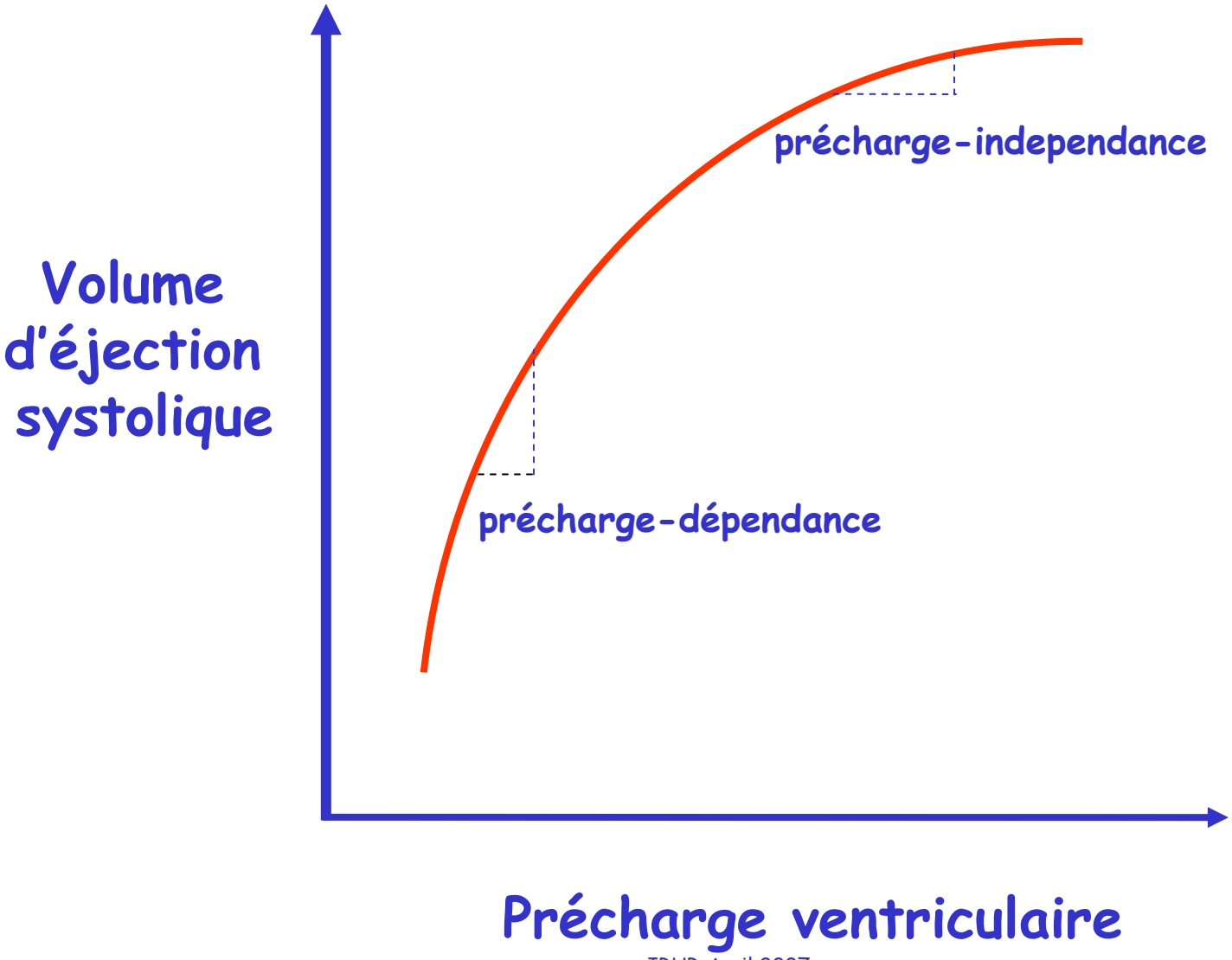


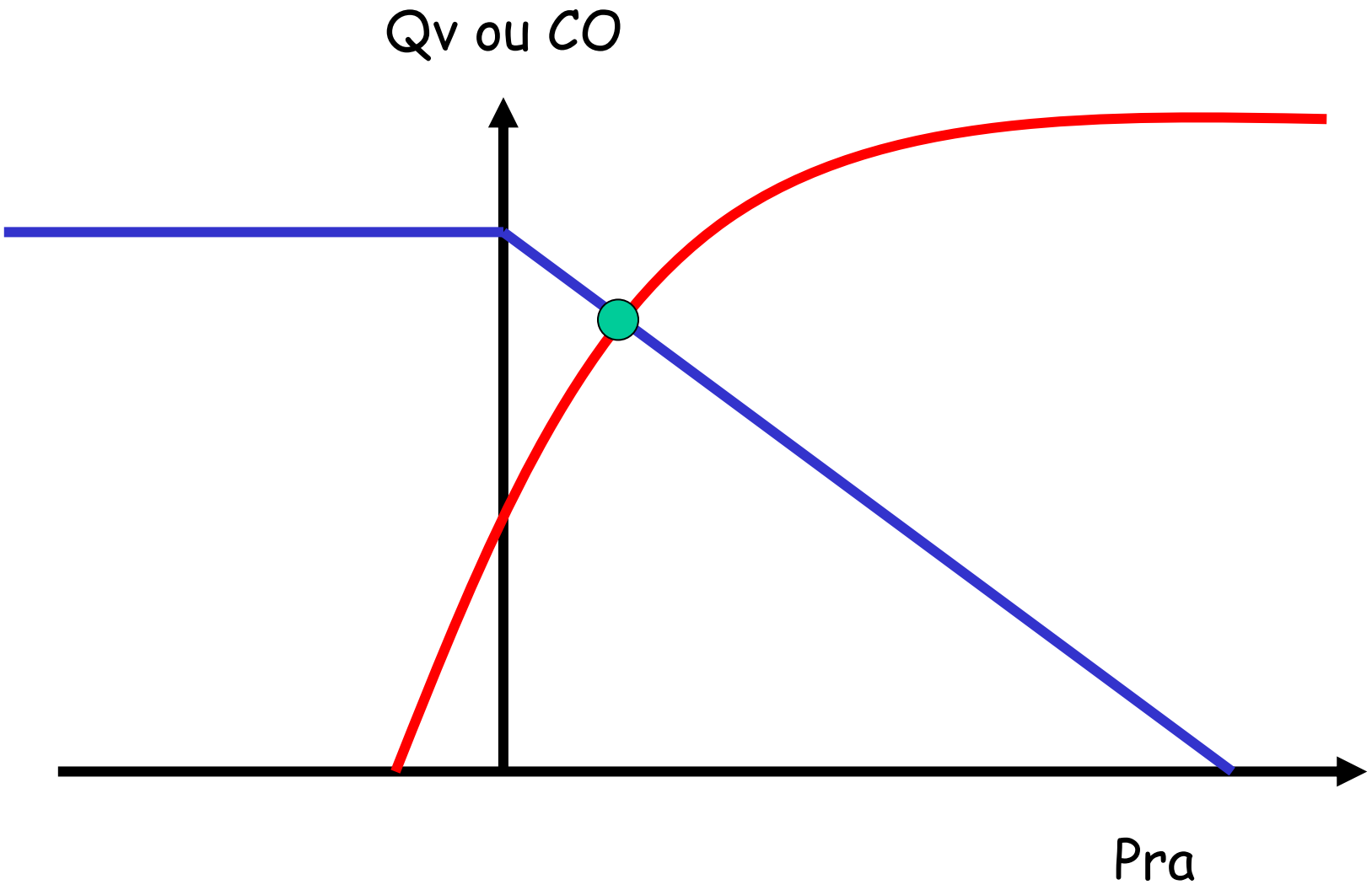
MCFP = Psys = 7-10 mmHg (animal)

Guyton et al. Am J Physiol 1957;189:609-615

Déterminants du retour veineux

- ✓ Vs = Volume total – Vus
- ✓ Compliance veineuse
- ✓ Résistance veineuse
- ✓ Pra


Volume
d'éjection
systolique
précharge-independance
précharge-dépendance
Précharge ventriculaire

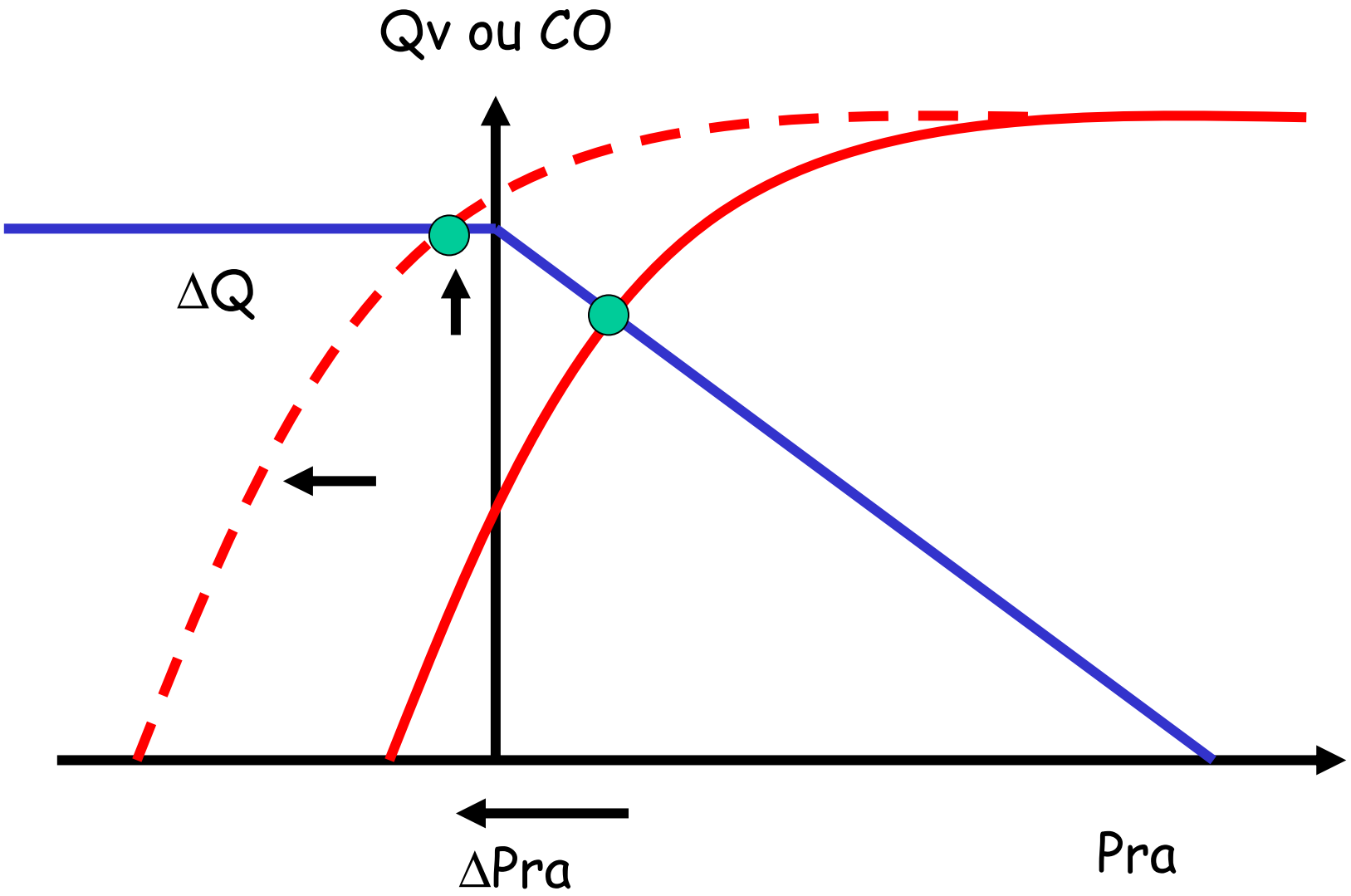


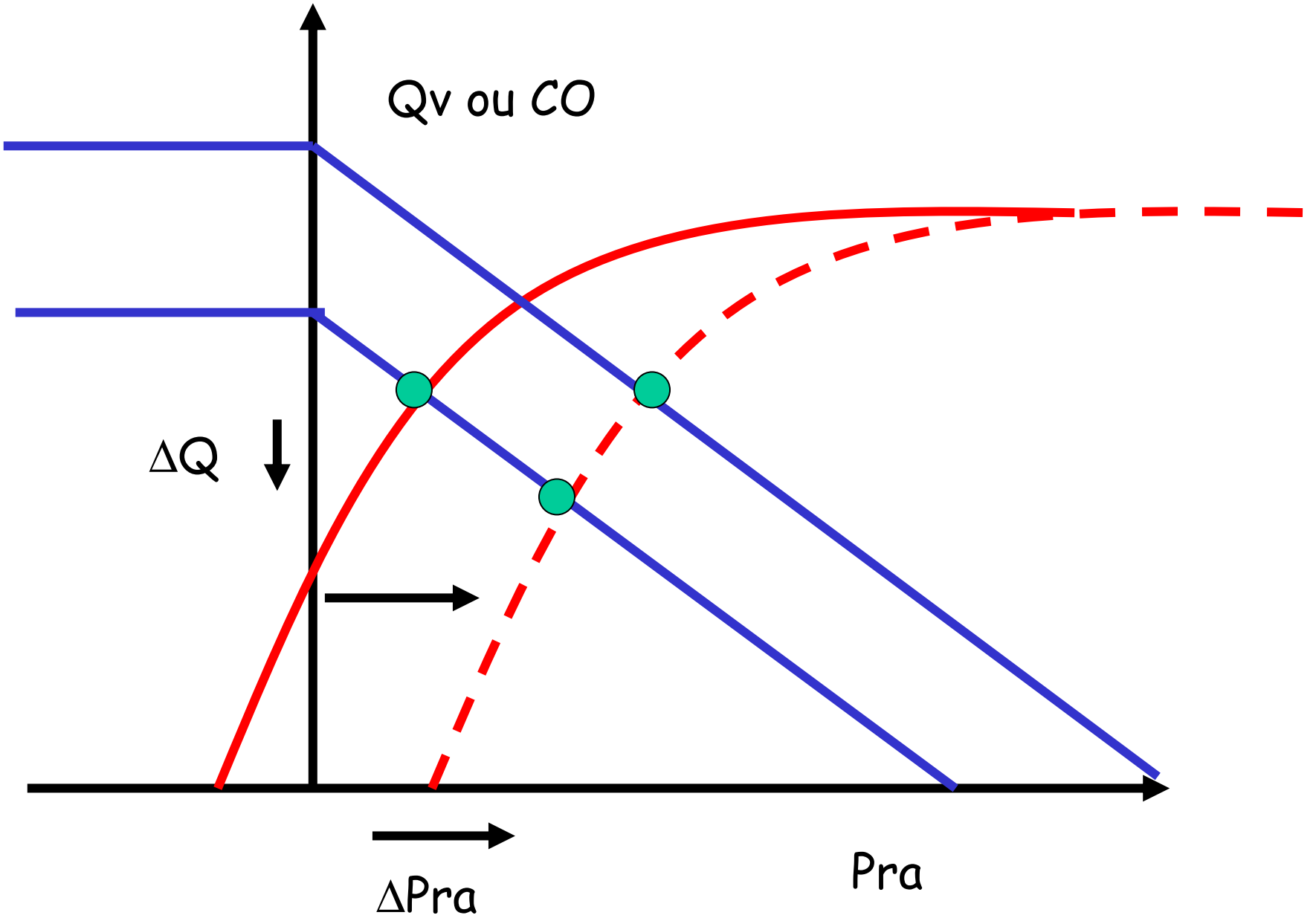
Guyton et al. Am J Physiol 1957;189:609-615

Effets de la VM en PP sur le VD

Effets de la VM en PP sur le VD

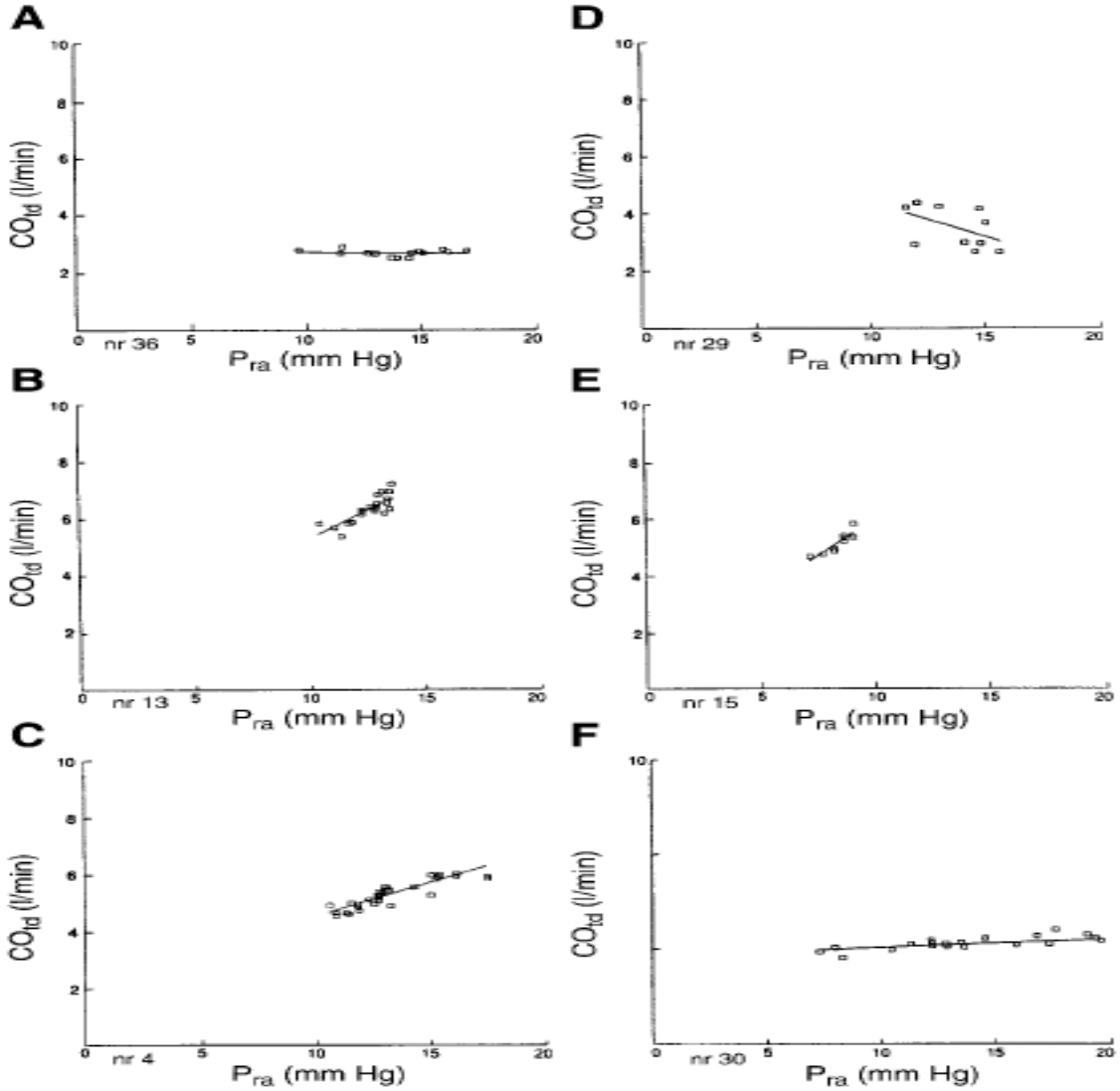
Pré-charge VD
Retour veineux


Qv ou CO
ΔQ
ΔPra
Pra


Qv ou CO
ΔQ
ΔPra
Pra

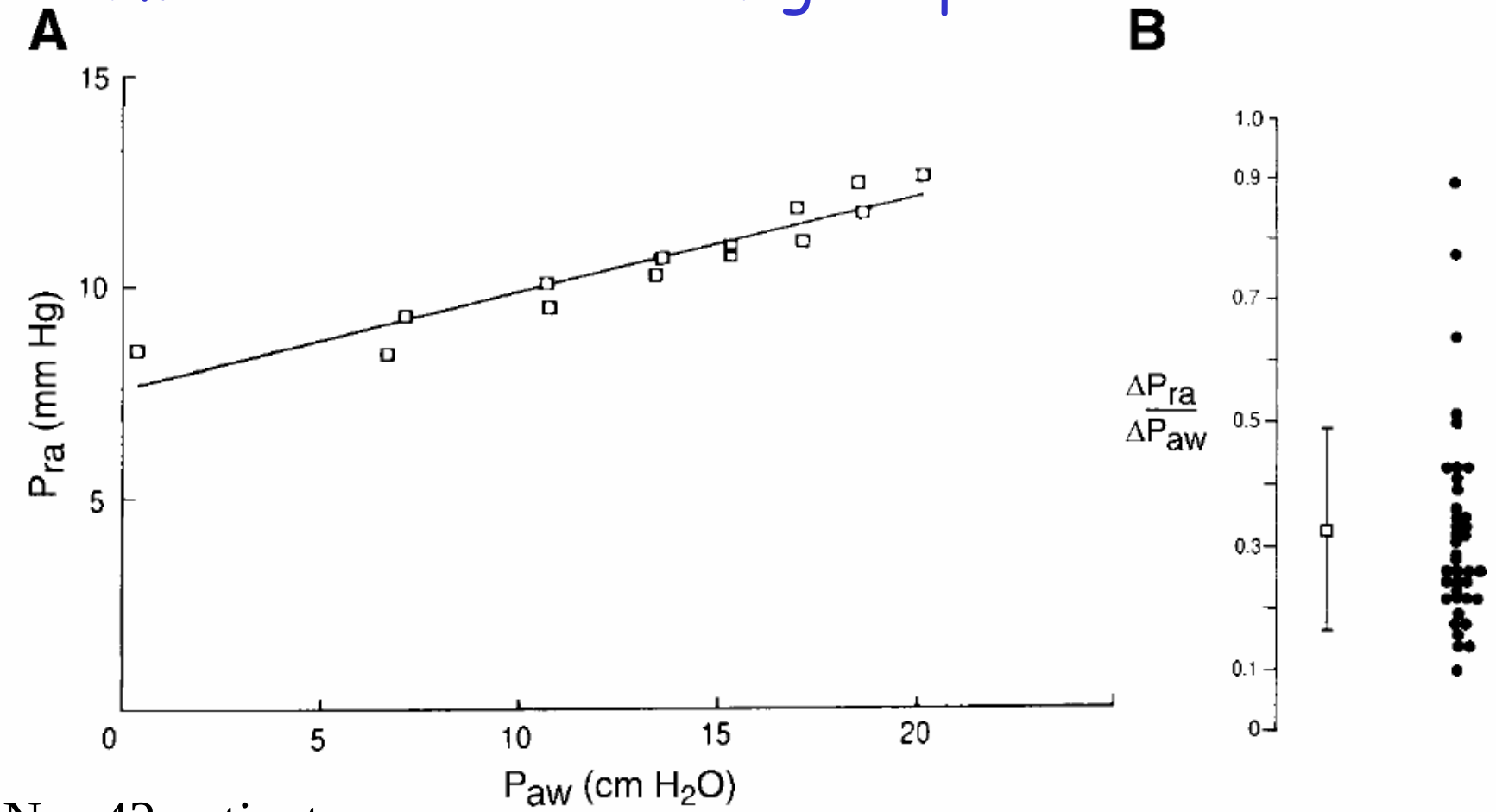
Effect of positive pressure on venous return in volume-loaded cardiac surgical patients

N = 42 patients
Chirurgie cardiaque
Paw de 0 à 20



Van den Berg et al. J Appl Physiol 92: 1223-1231, 2002.

Effect of positive pressure on venous return in volume-loaded cardiac surgical patients



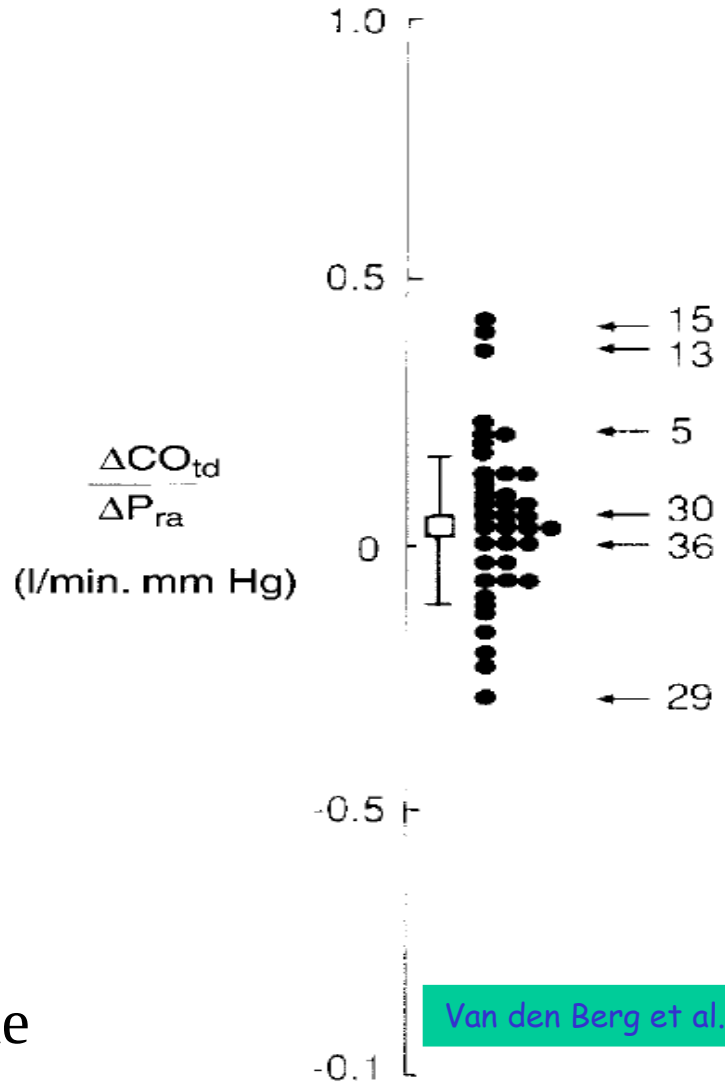
N = 42 patients

Chirurgie cardiaque

Paw de 0 à 20

Van den Berg et al. J Appl Physiol 92: 1223-1231, 2002.

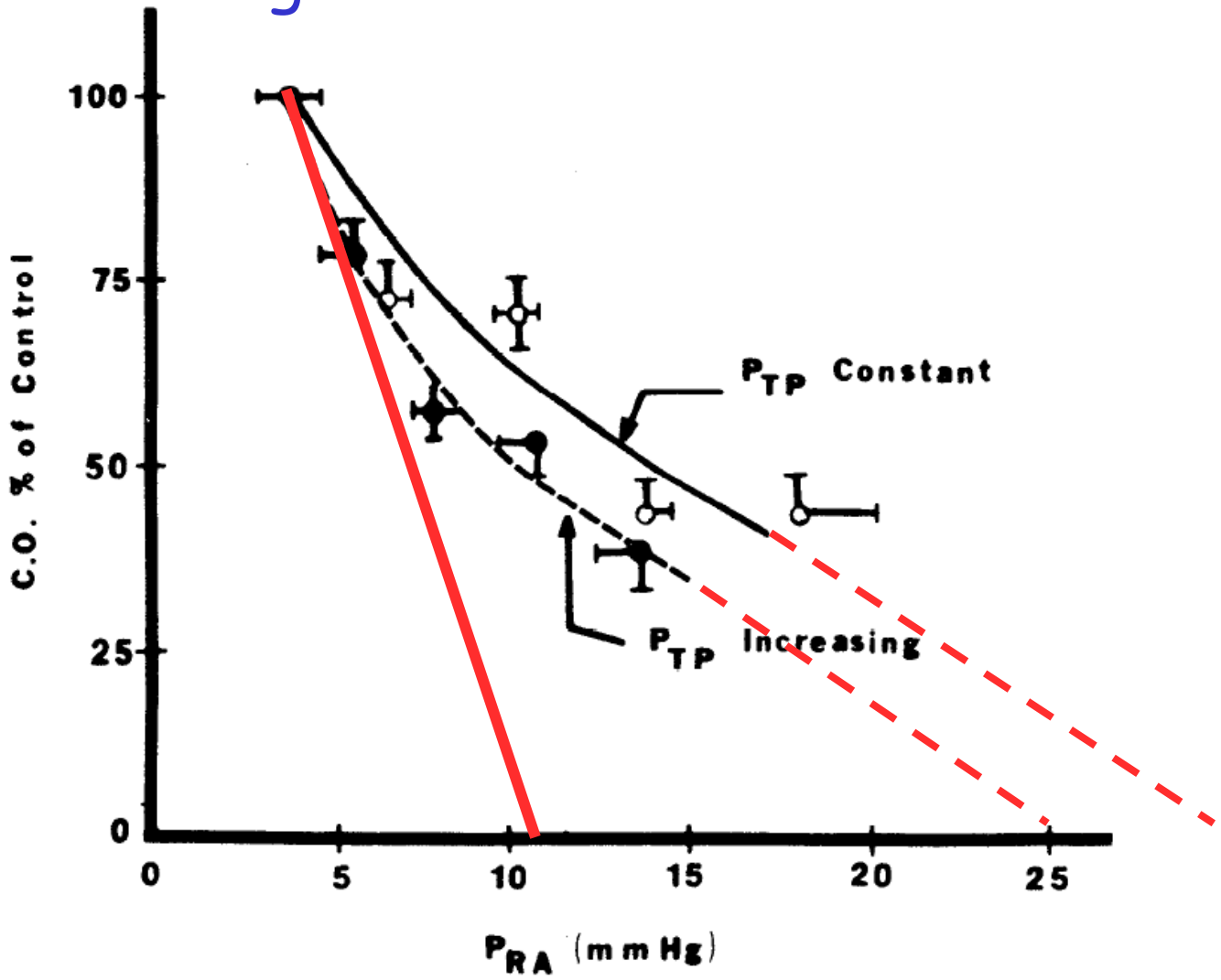
Effect of positive pressure on venous return in volume-loaded cardiac surgical patients



N = 42 patients
Chirurgie cardiaque
Paw de 0 à 20

Van den Berg et al. J Appl Physiol 92: 1223-1231, 2002.

Cardiovascular effects of increasing airway pressure in the dog



JRUR Avril 2007

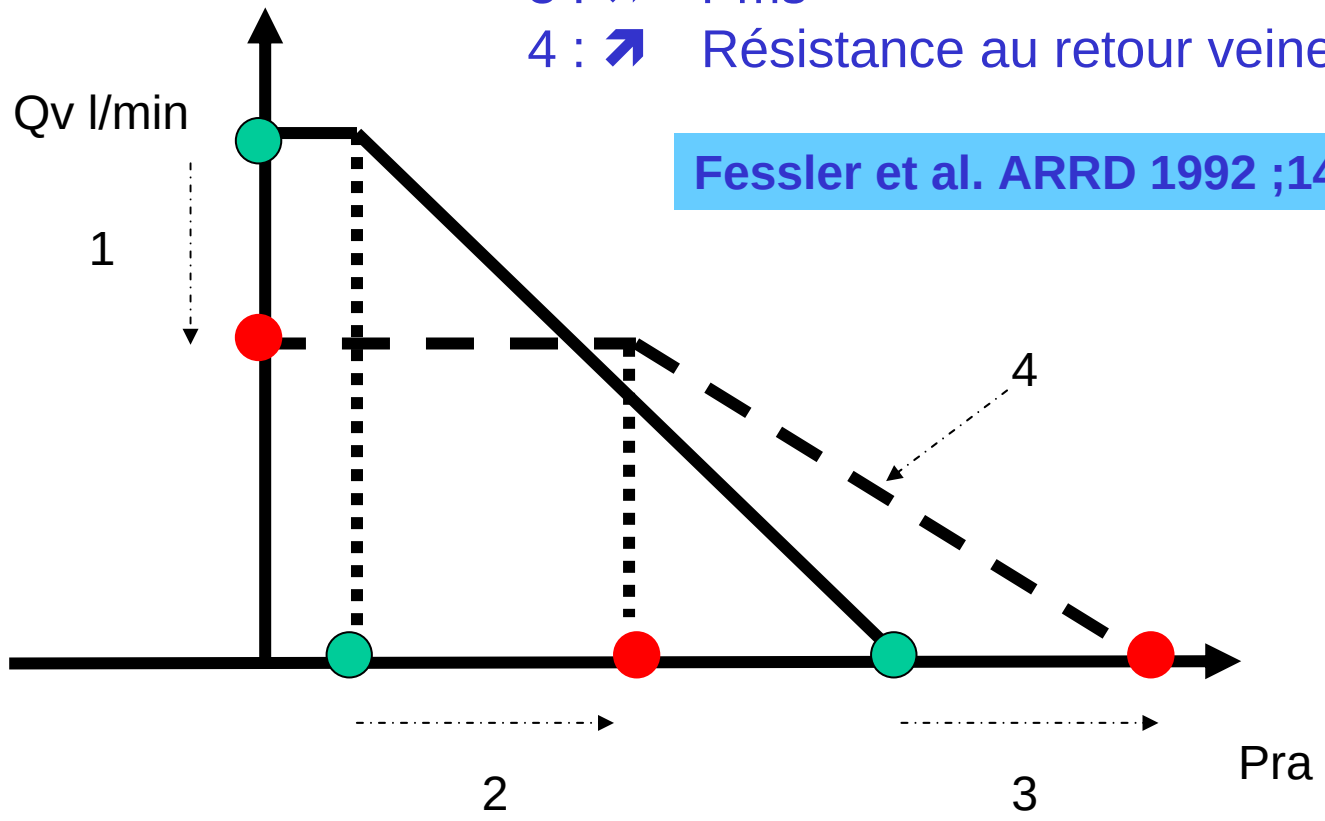
Scharf et al. Am J Physiol 1977;232:H35-H43

Effet de la PEP sur le Retour veineux

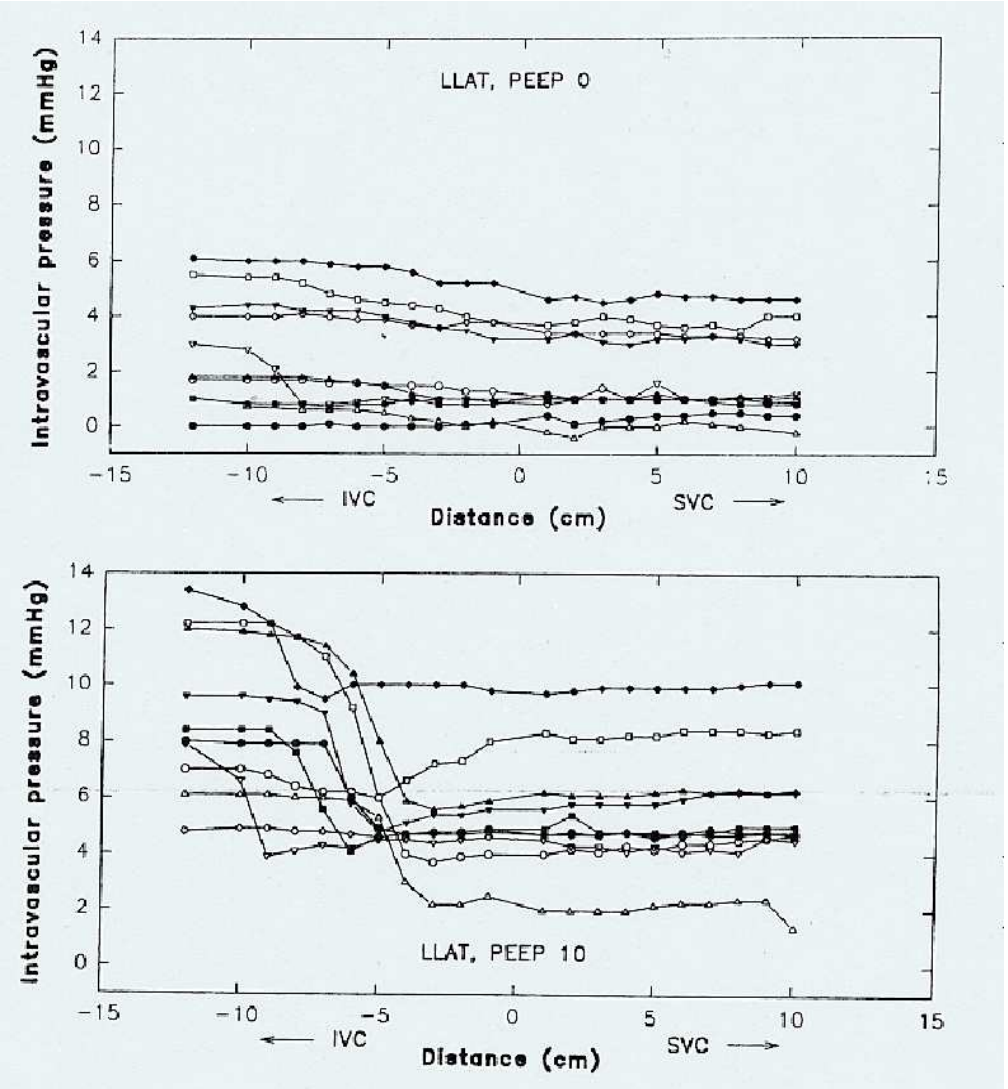
PEP 10 mmHg

1 : ↘ Retour veineux maximal
2 : ↗ Pra pour laquelle Qv = Qv max
3 : ↗ Pms
4 : ↗ Résistance au retour veineux

Fessler et al. ARRD 1992 ;146:4-10



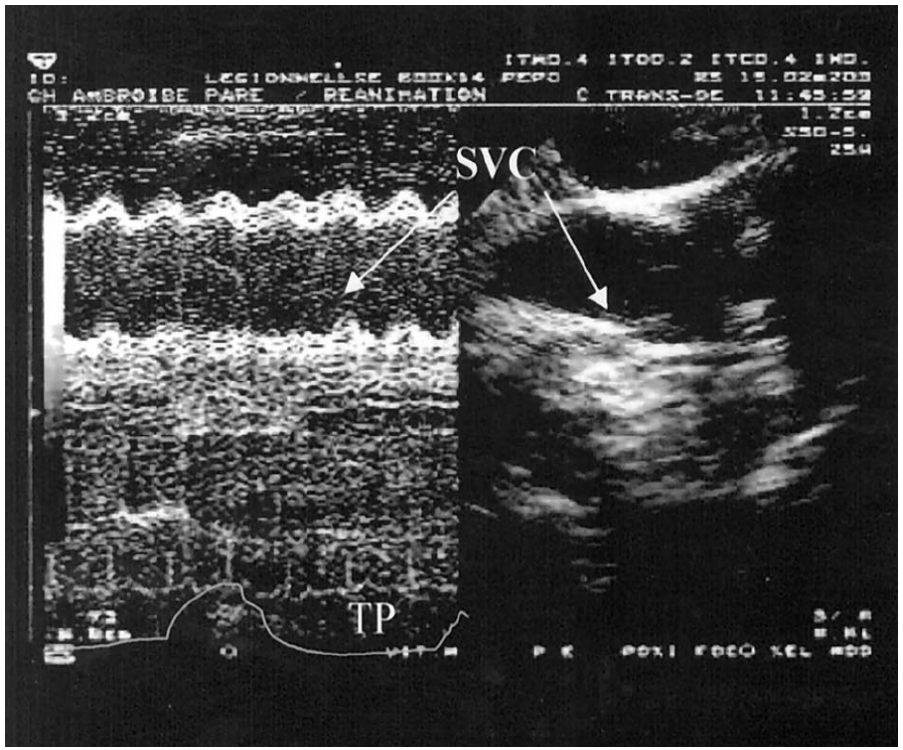
Effet de la PEP sur le Retour veineux

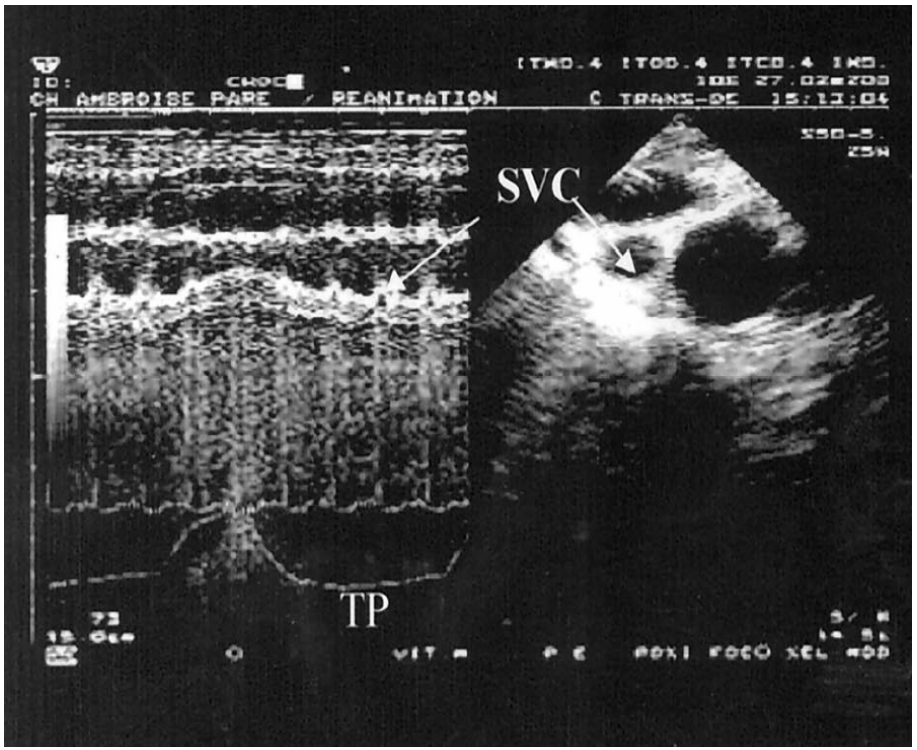


JRUR Avril 2007

Fessler et al. ARRD 1992 ;146:4-10

Phénomène de chute d'eau : « The vascular waterfall »
Compressibilité de la VCS en inspiration lors de la VM





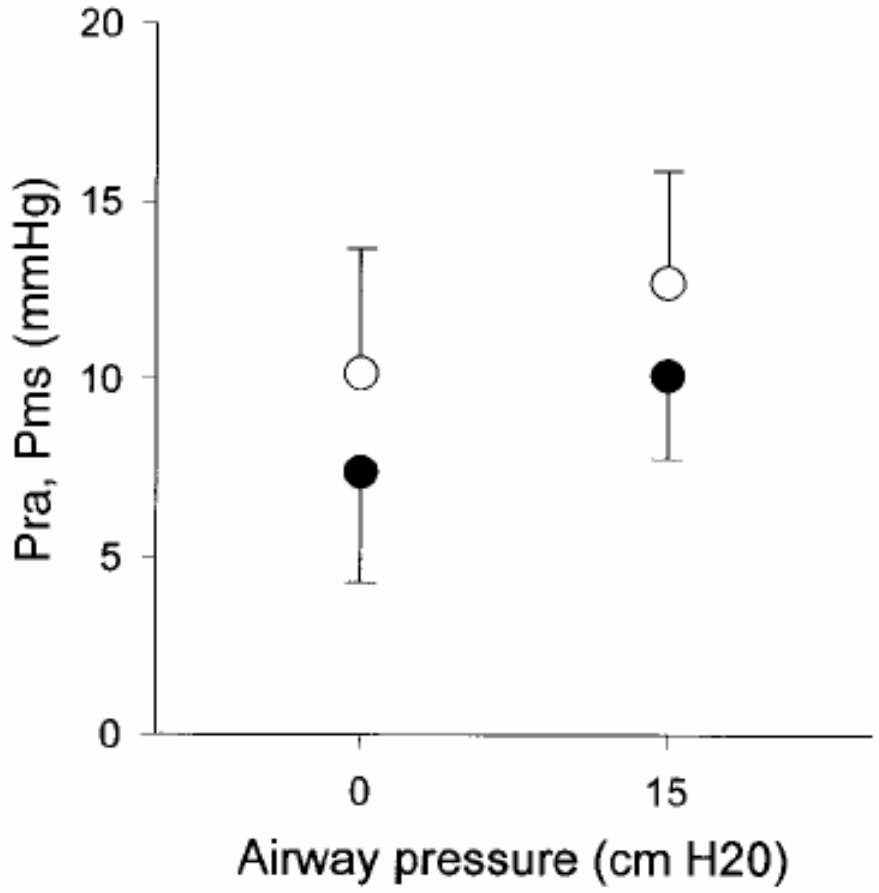
Groupe 1 (n = 15)

Groupe 2 (n = 7) Petm > Pim

Indice collapsus inspiratoire VCS = Diam exp max – Diam insp min/Diam exp max

Vieillard – Baron et al. Anesthesiology 2001; 95:1083-8

Influence of positive airway pressure on the pressure gradient for venous return in humans



Jellinek et al. JAP 2000 ; 86:926-932

Ventilation en pression positive
Pression abdominale et Hypovolémie

ECG

Qvci

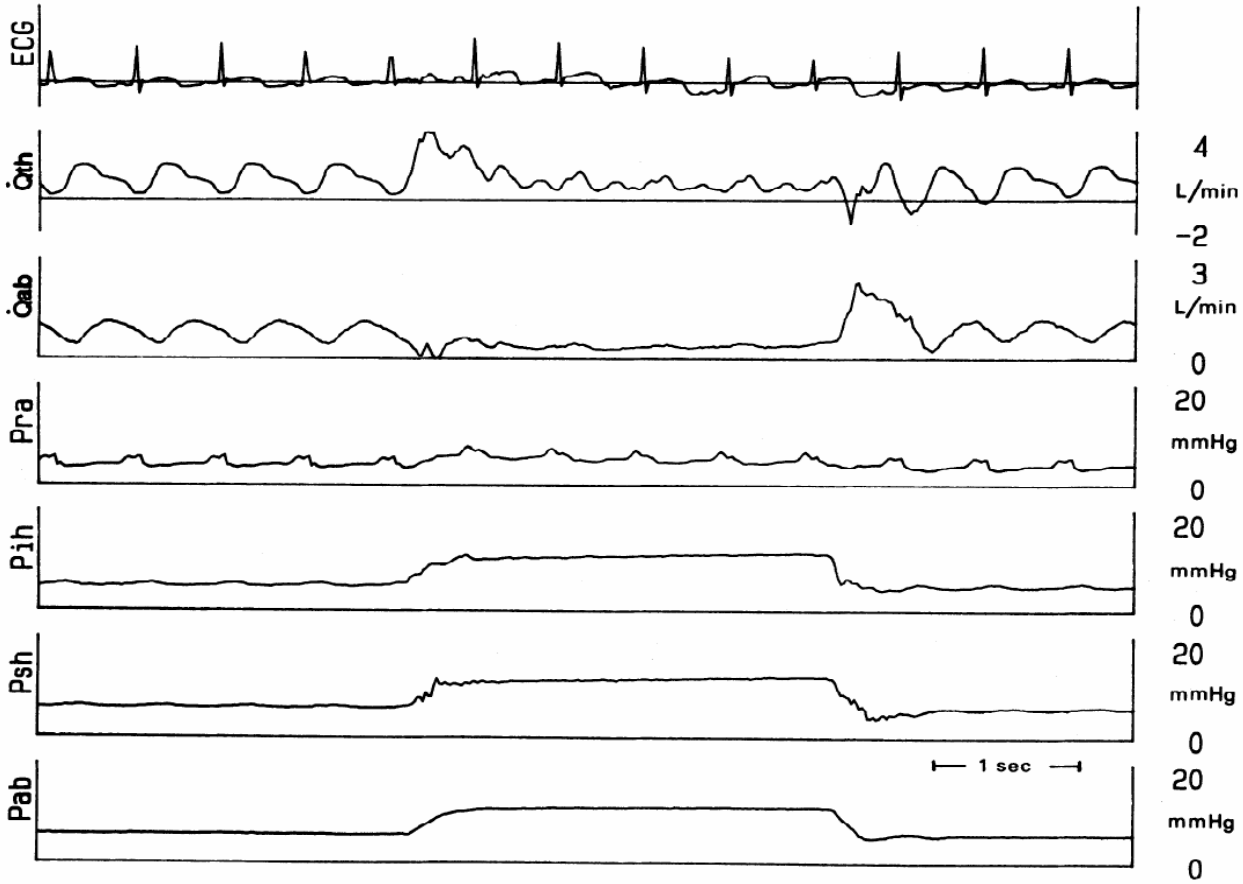
Qab (sous hep)

Pra

Pintrahep

Psuprahépa

Pabd



Hypovolémie

JRUR Avril 2007

Takata et al. JAP 1992; 72:597-607

Ventilation en pression positive
Pression abdominale et Hypervolémie

ECG

Qvci

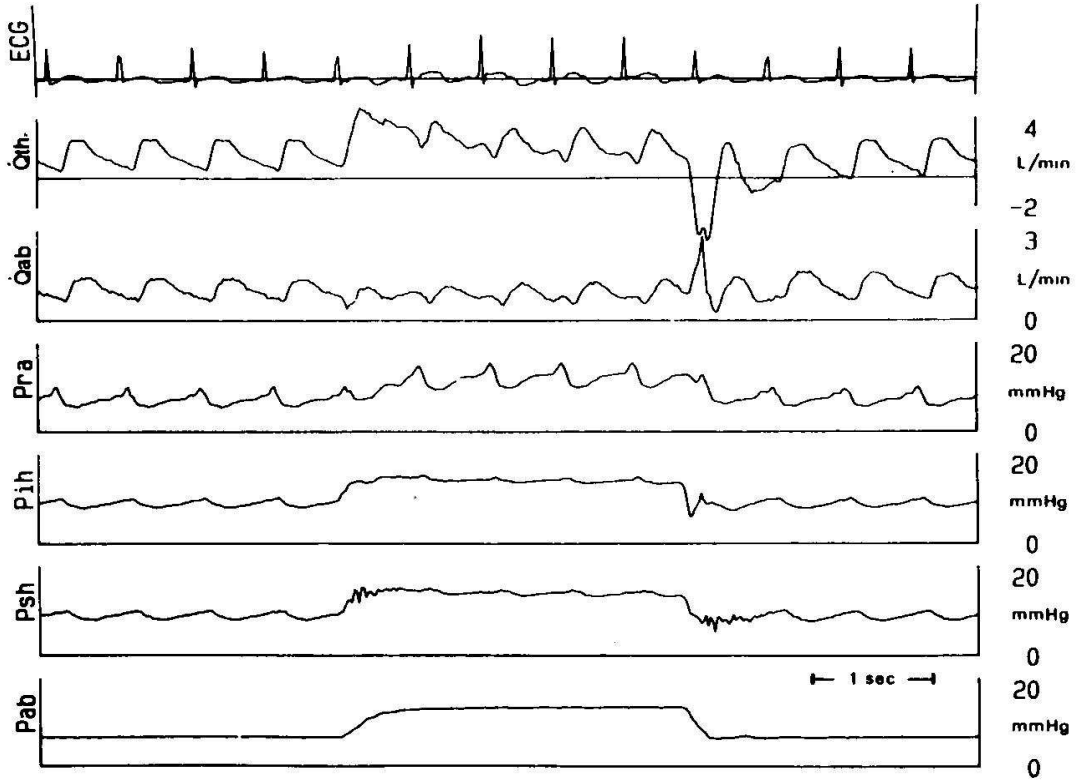
Qab (sous hep)

Pra

Pintrahep

Psuprahépa

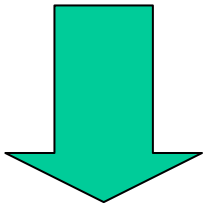
Pabd



Hypervolémie

Takata et al. JAP 1992; 72:597-607

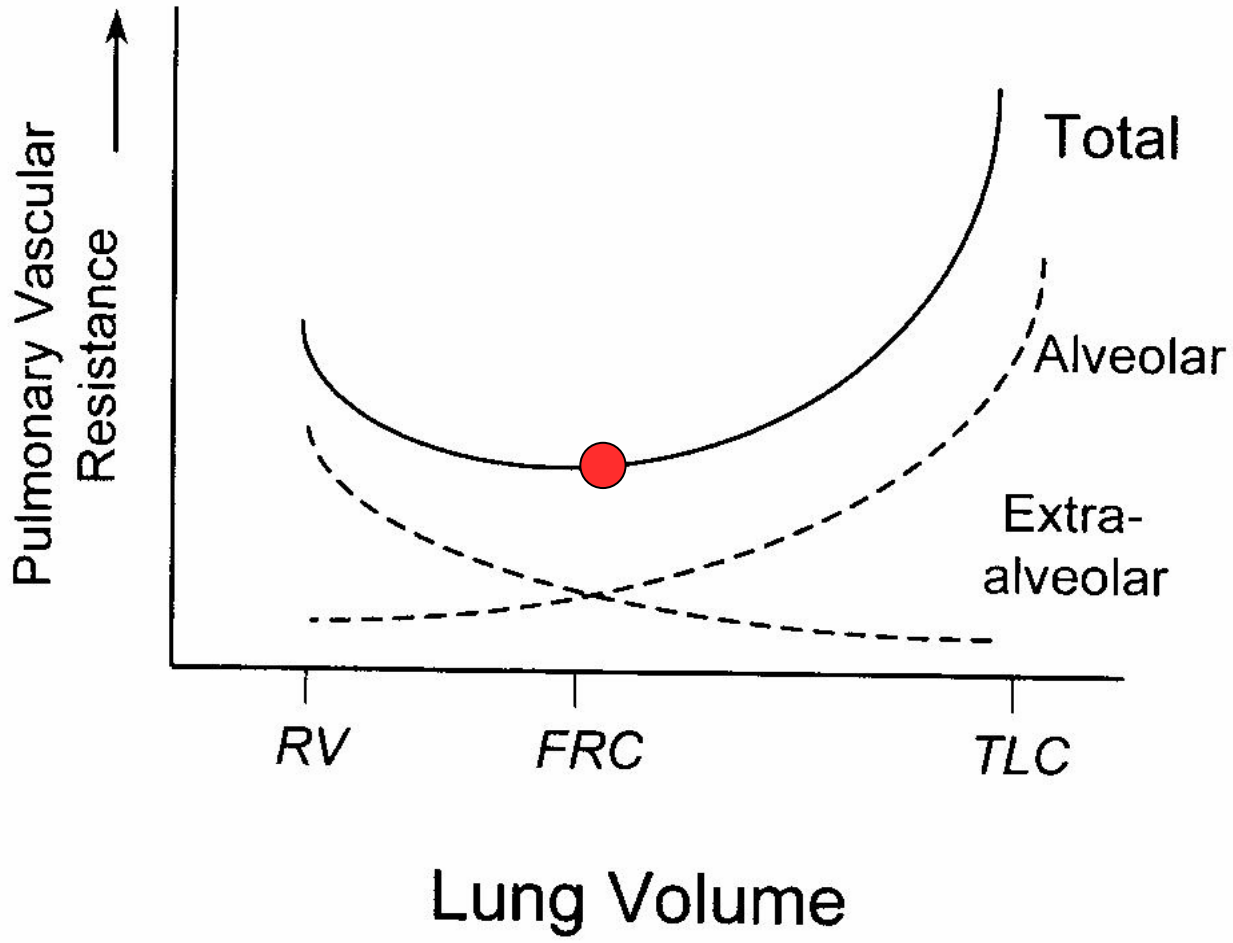
Effets de la VM en pression positive et PEP sur la précharge VD



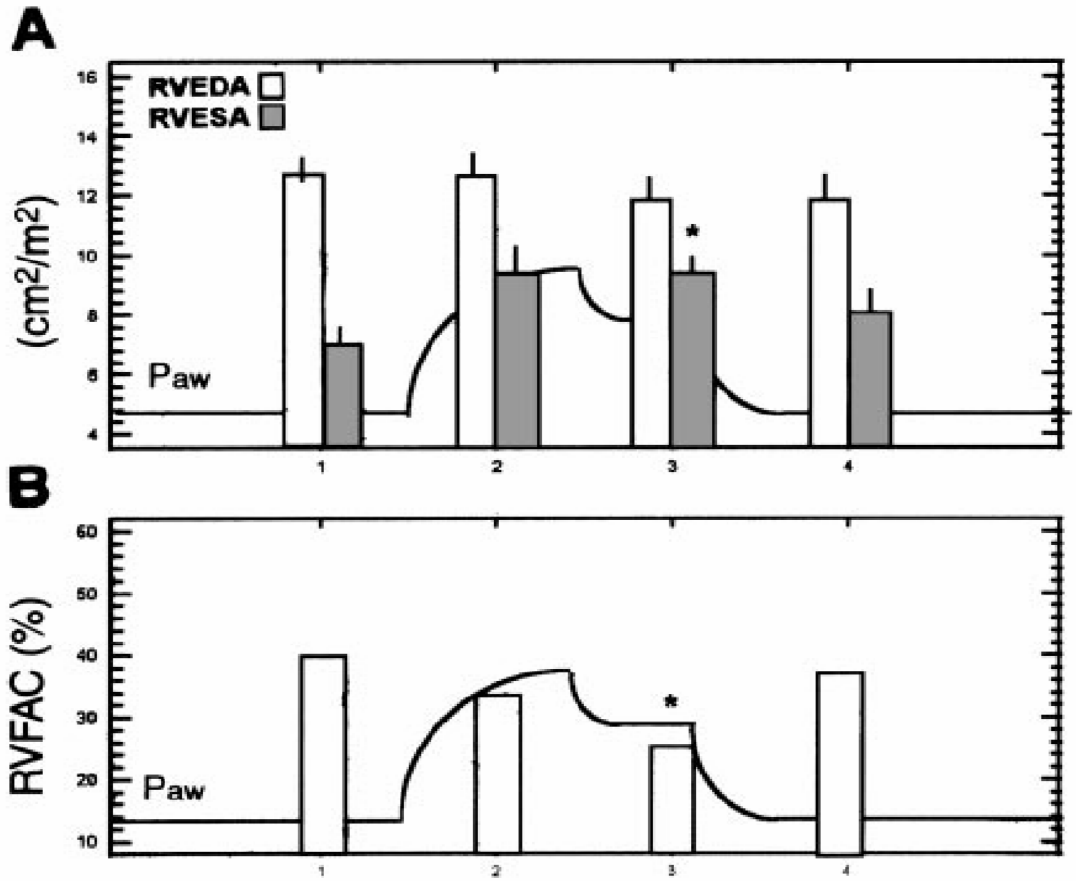
Baisse de la précharge VD

Effets de la VM en PP + PEP sur la post-charge VD

Volume pulmonaire et RVP



Défaillance VD lors de la VP



Vieillard Baron et al. JAP 1999; 87:1644-1650

Effets de la VM en PP sur le VG

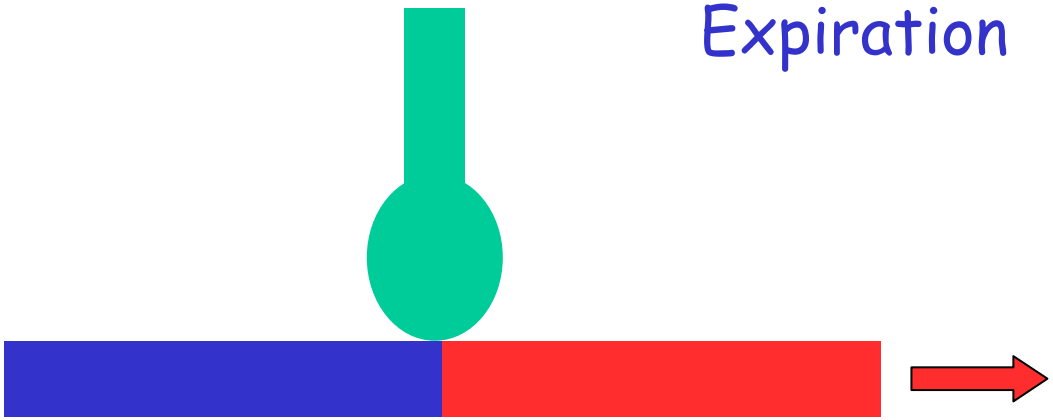
JRUR Avril 2007

Effets de la VM en PP sur le VG

Pré-charge VG

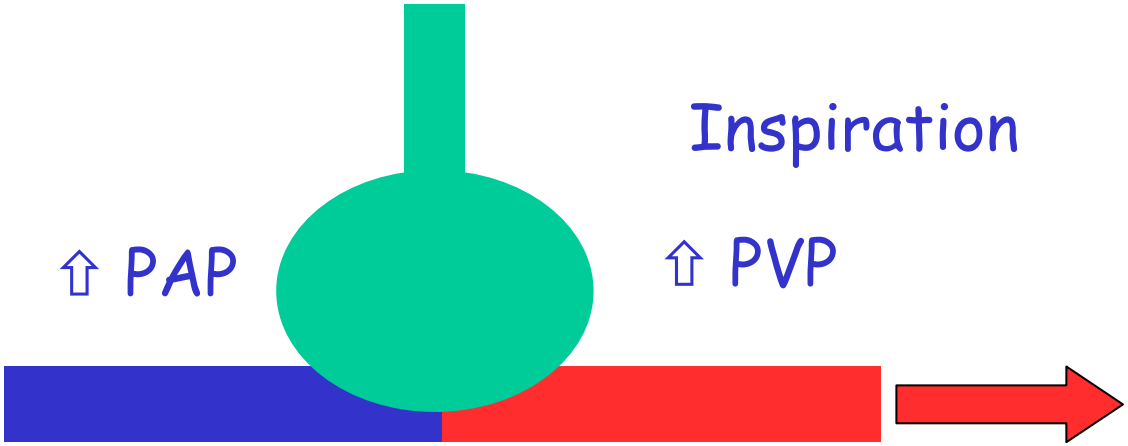
JRUR Avril 2007

Expiration



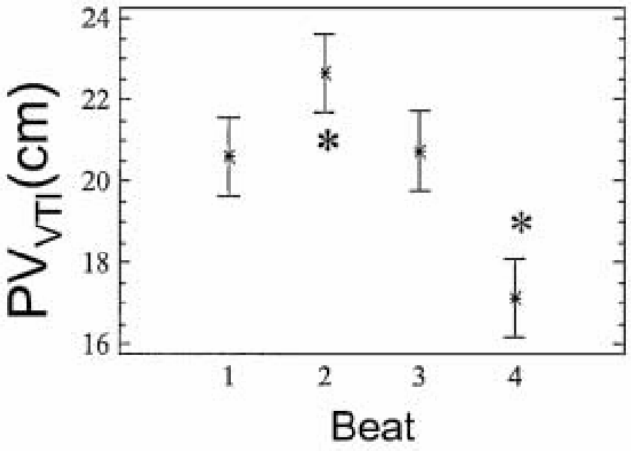
PAP > PVP > Palv

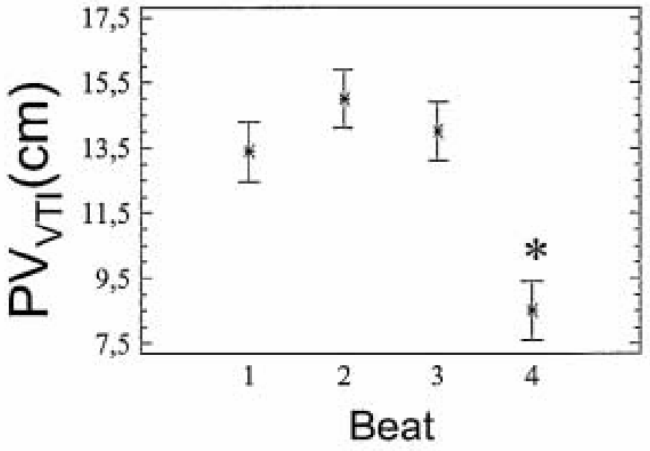
Inspiration

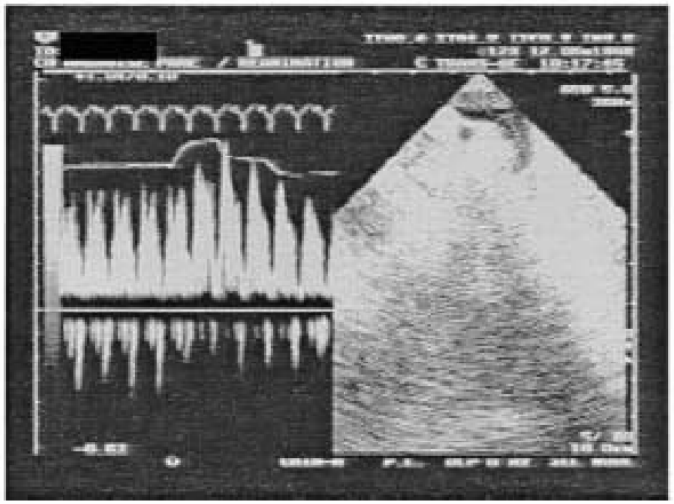


PAP > Palv > PVP

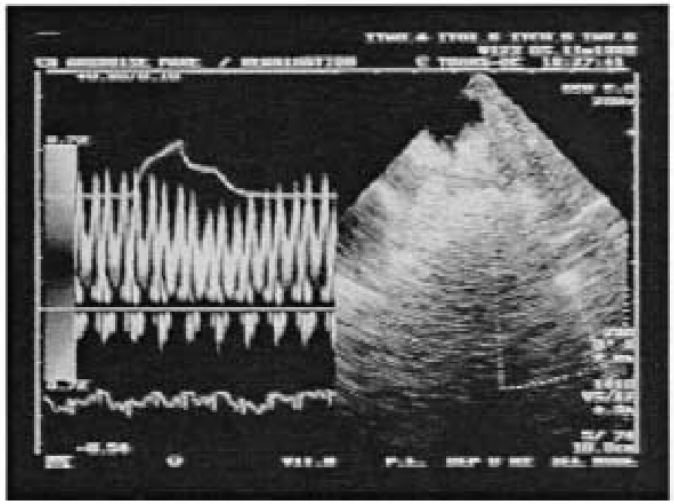
Δup et augmentation du flux veineux pulmonaire à l'inspiration







Δup prédominant



Δdown prédominant

JRUR Avril 2007

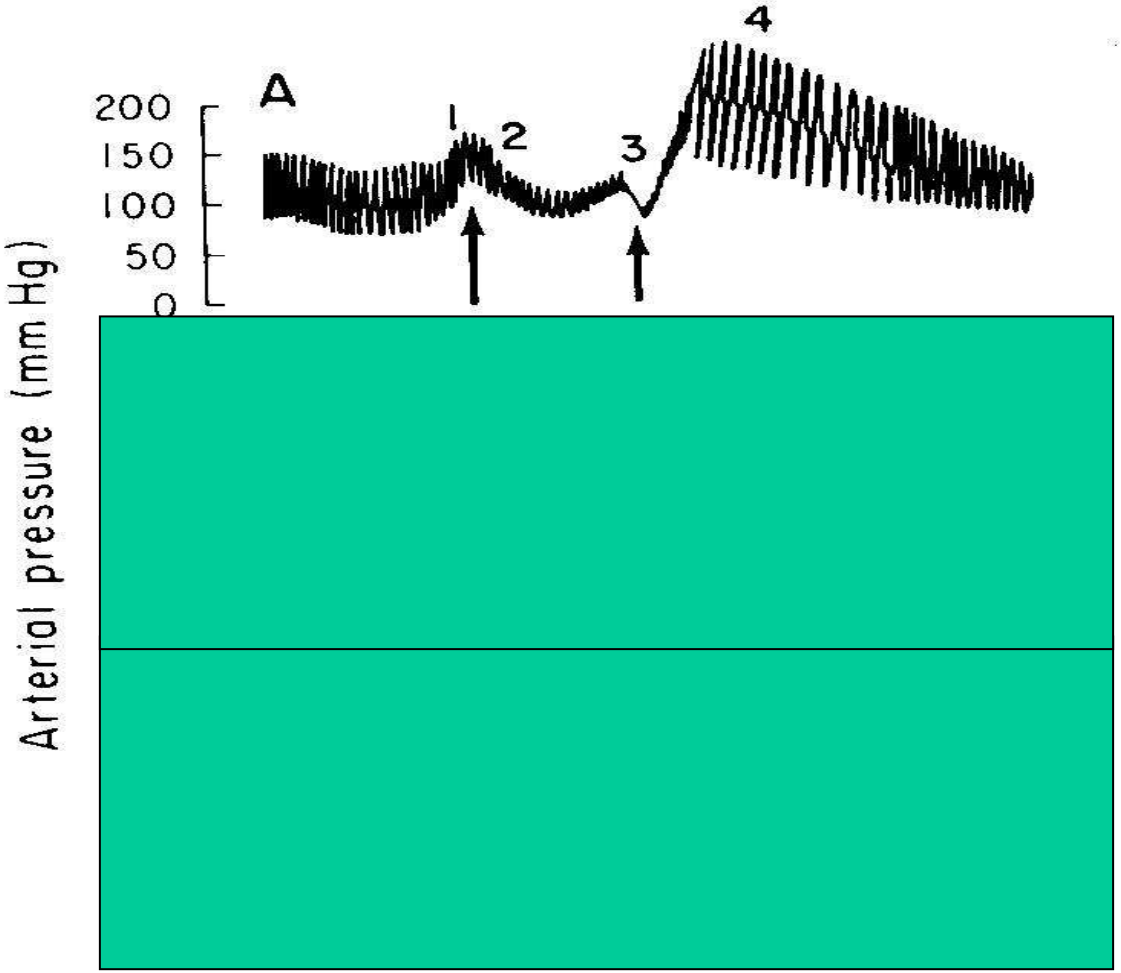
Vieillard Baron et al. AJRCCM 2003 ; 168: 671-676

Effets de la VM en PP sur le VG

Post-charge VG

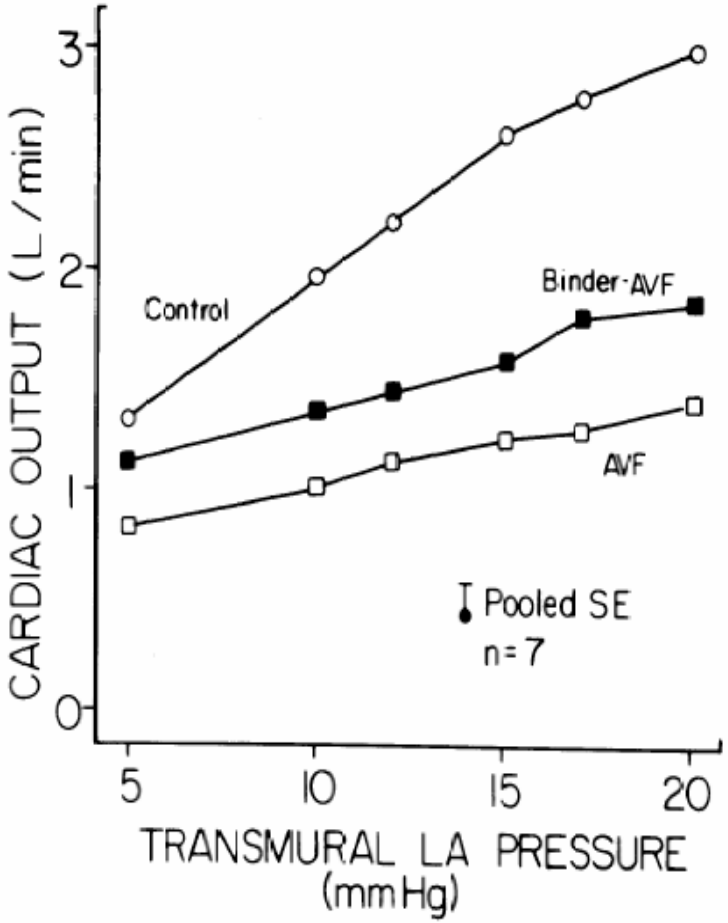
JRUR Avril 2007

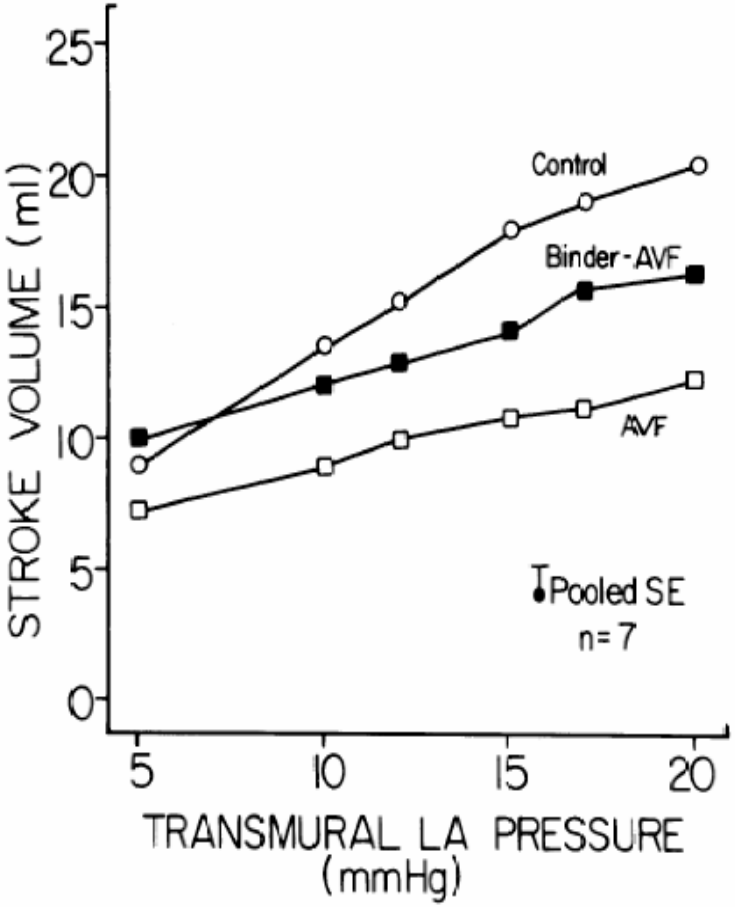
Valsalva et Insuffisance cardiaque Gauche



Zema, B Heart J, 1980

Augmentation of cardiac function by elevation of intrathoracic pressure

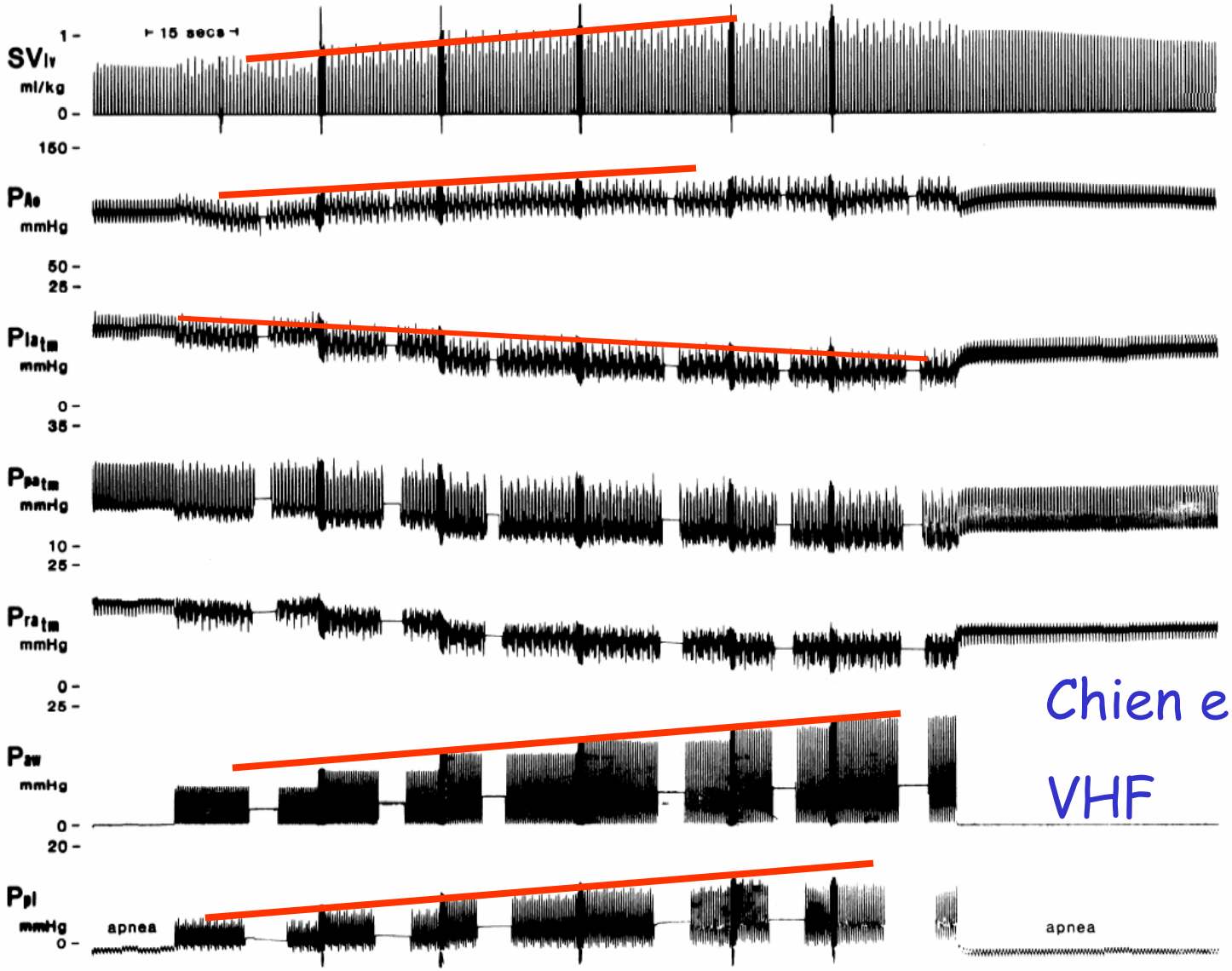




JRUR Avril 2007

Pinsky et al JAP 1983 ; 54: 950-955

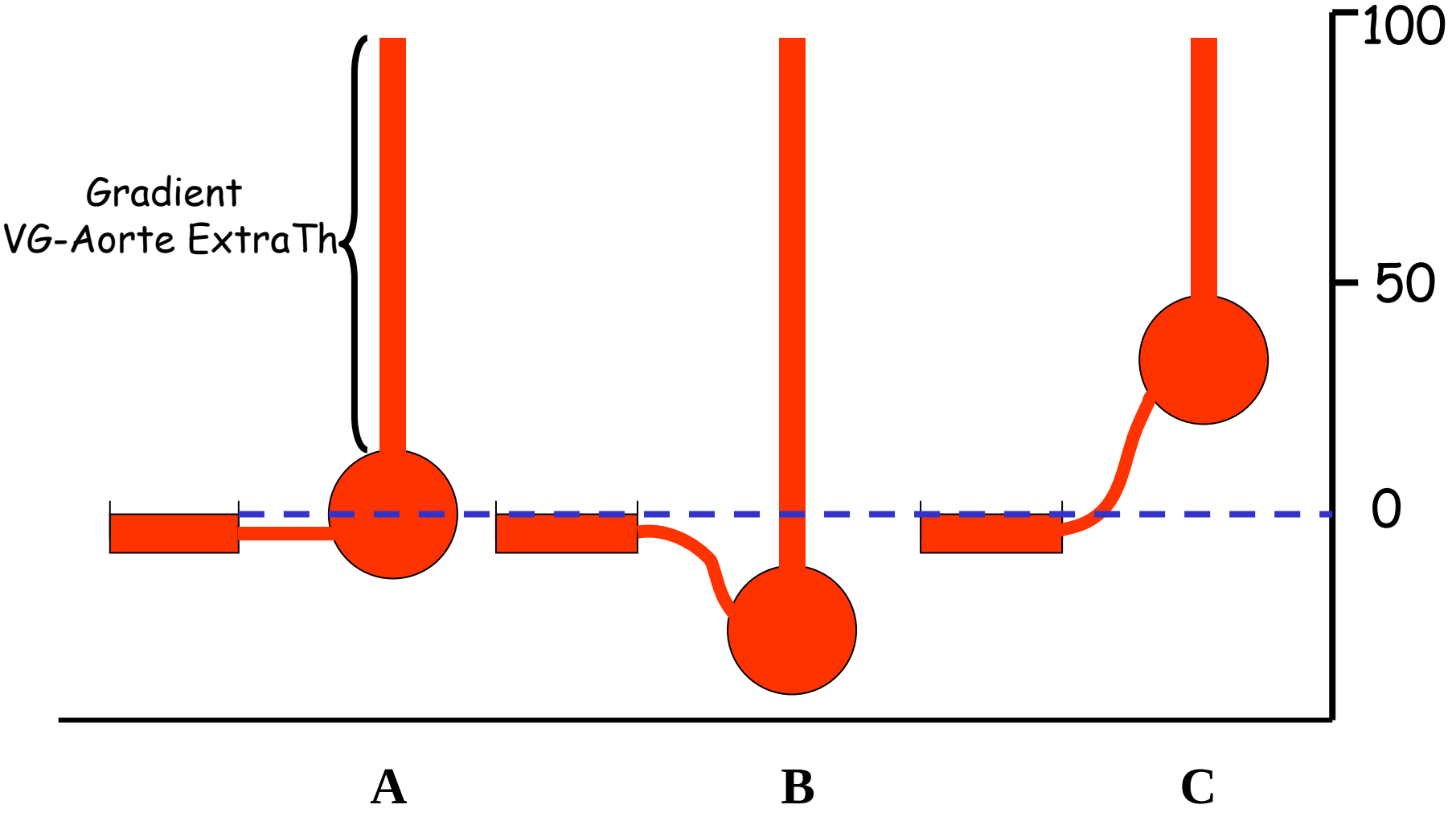
Determinants of cardiac augmentation by elevations in intrathoracic pressure.



Chien en IVG

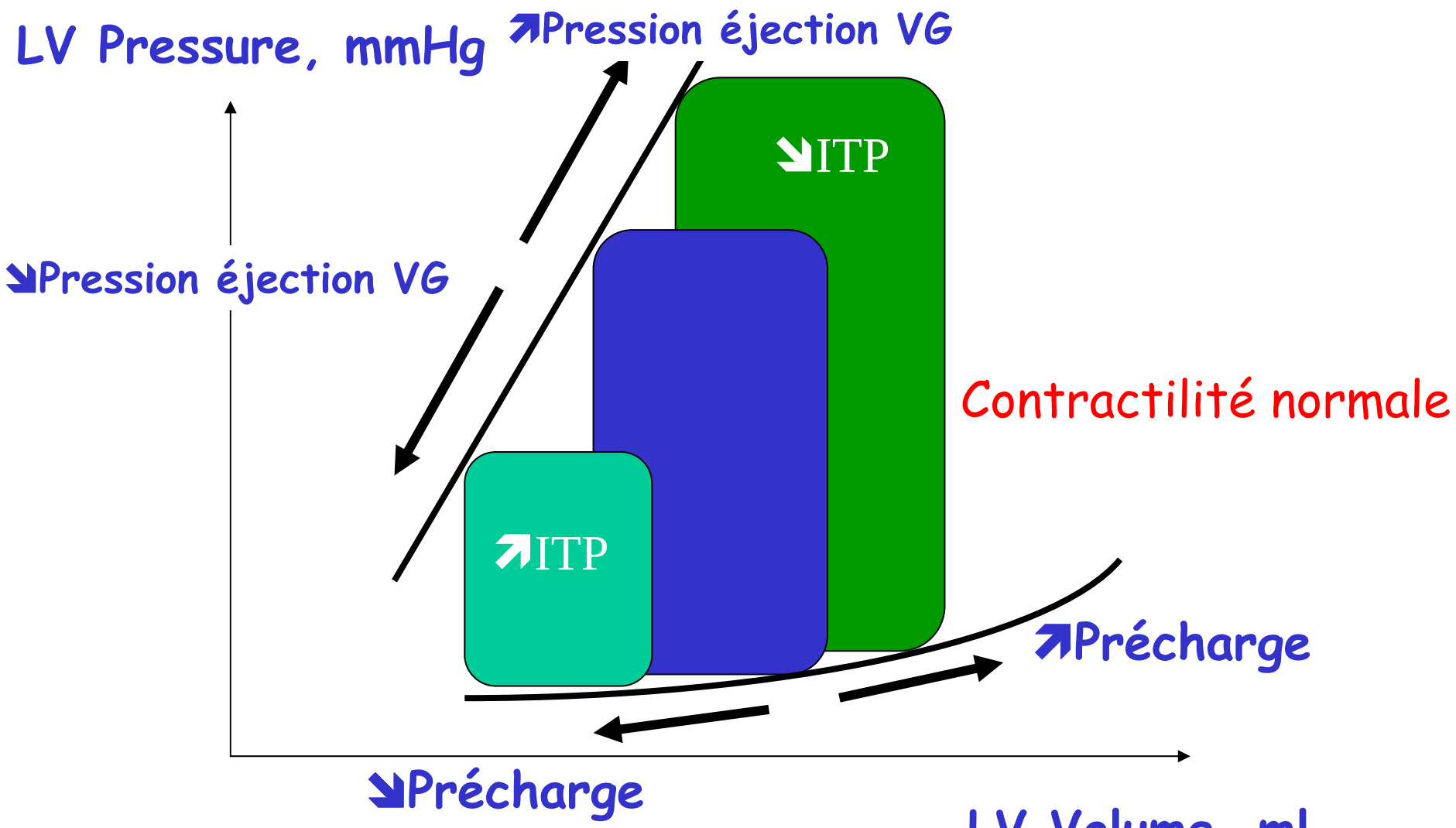
VHF

Pinsky et al JAP 1985 ; 58:1189-1198

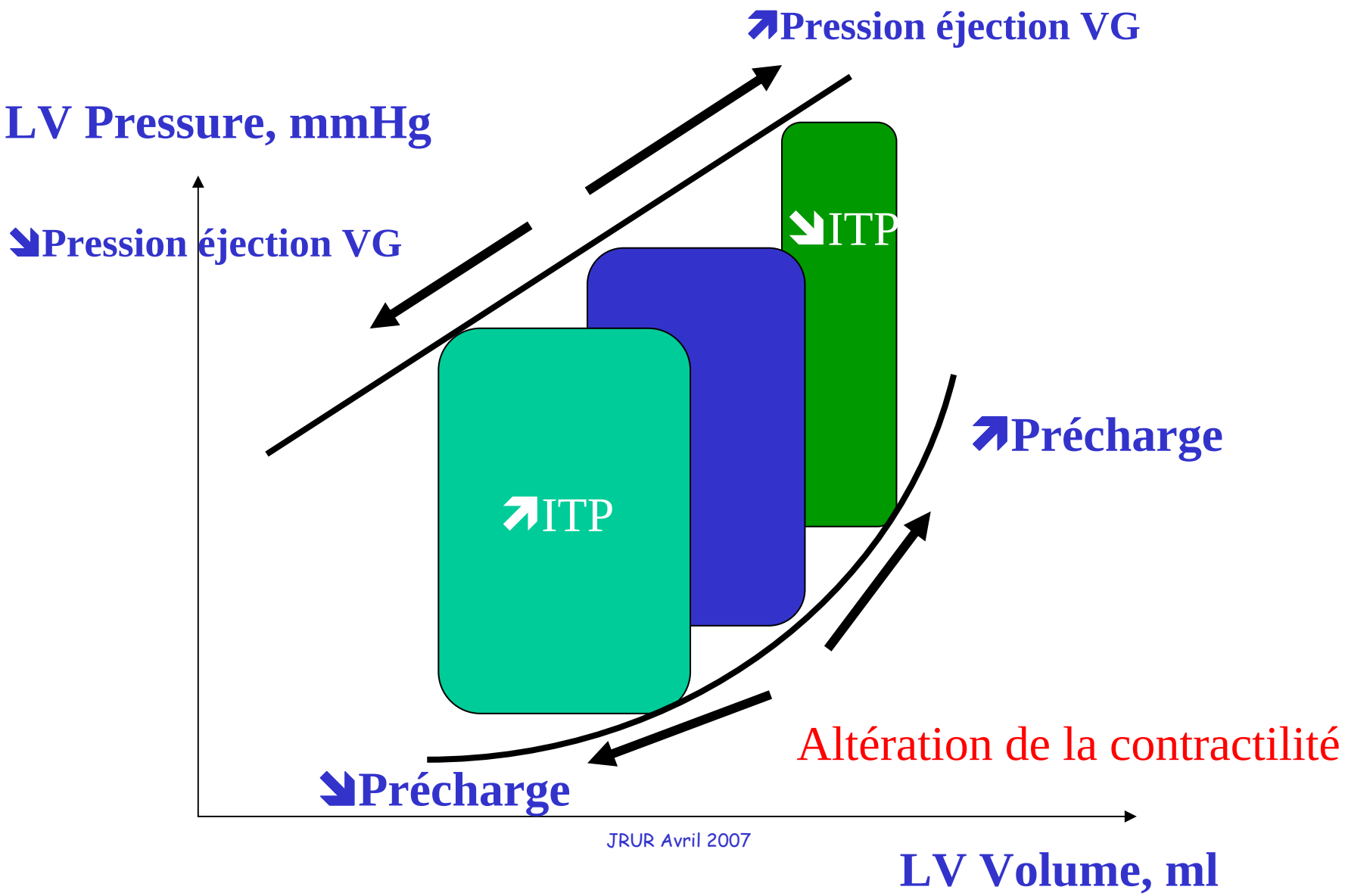


McGregor. N Engl J Med. 1979 ;301(9):480-2.

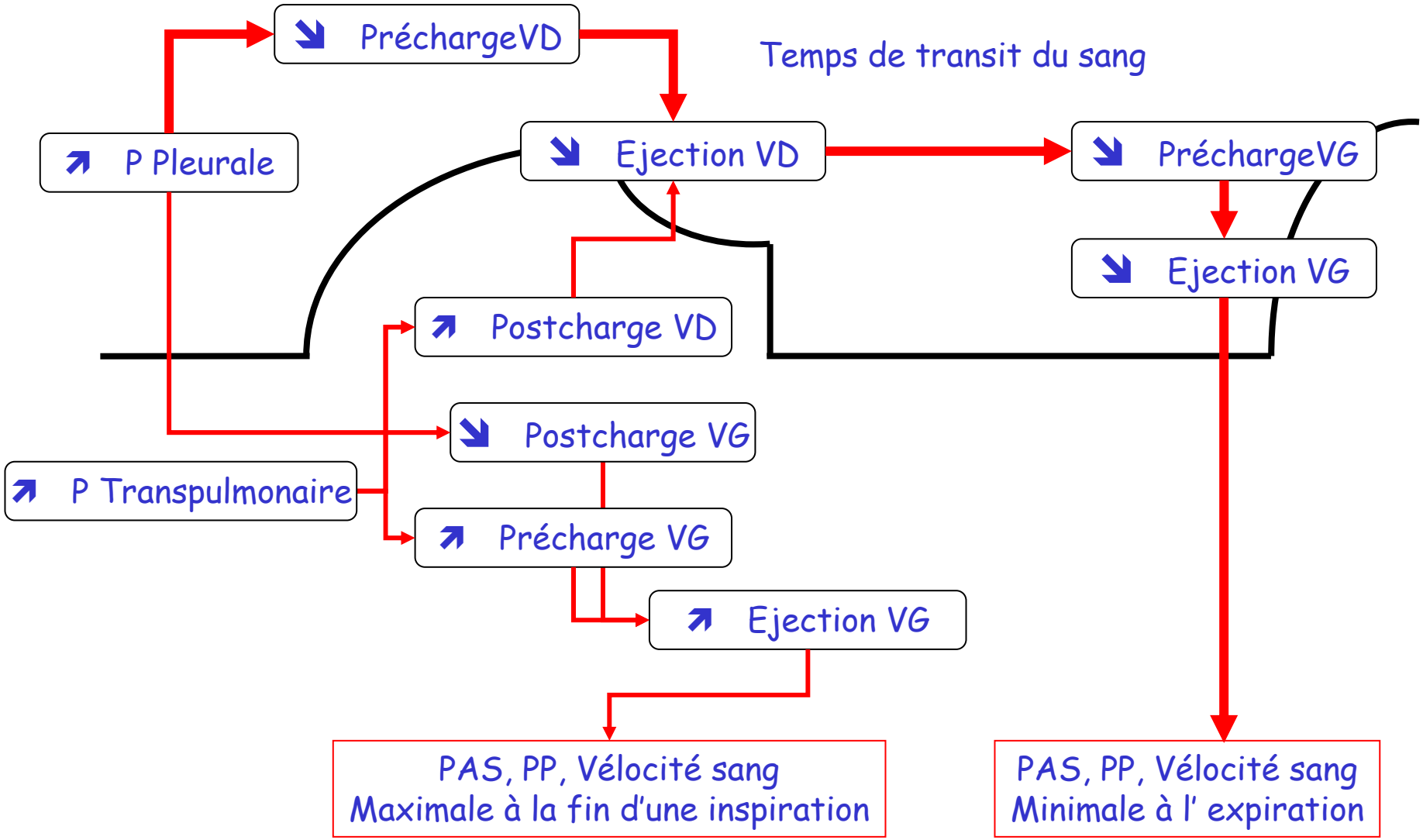
Effets des variations des Pressions Intrathoraciques sur la relation PV du VG

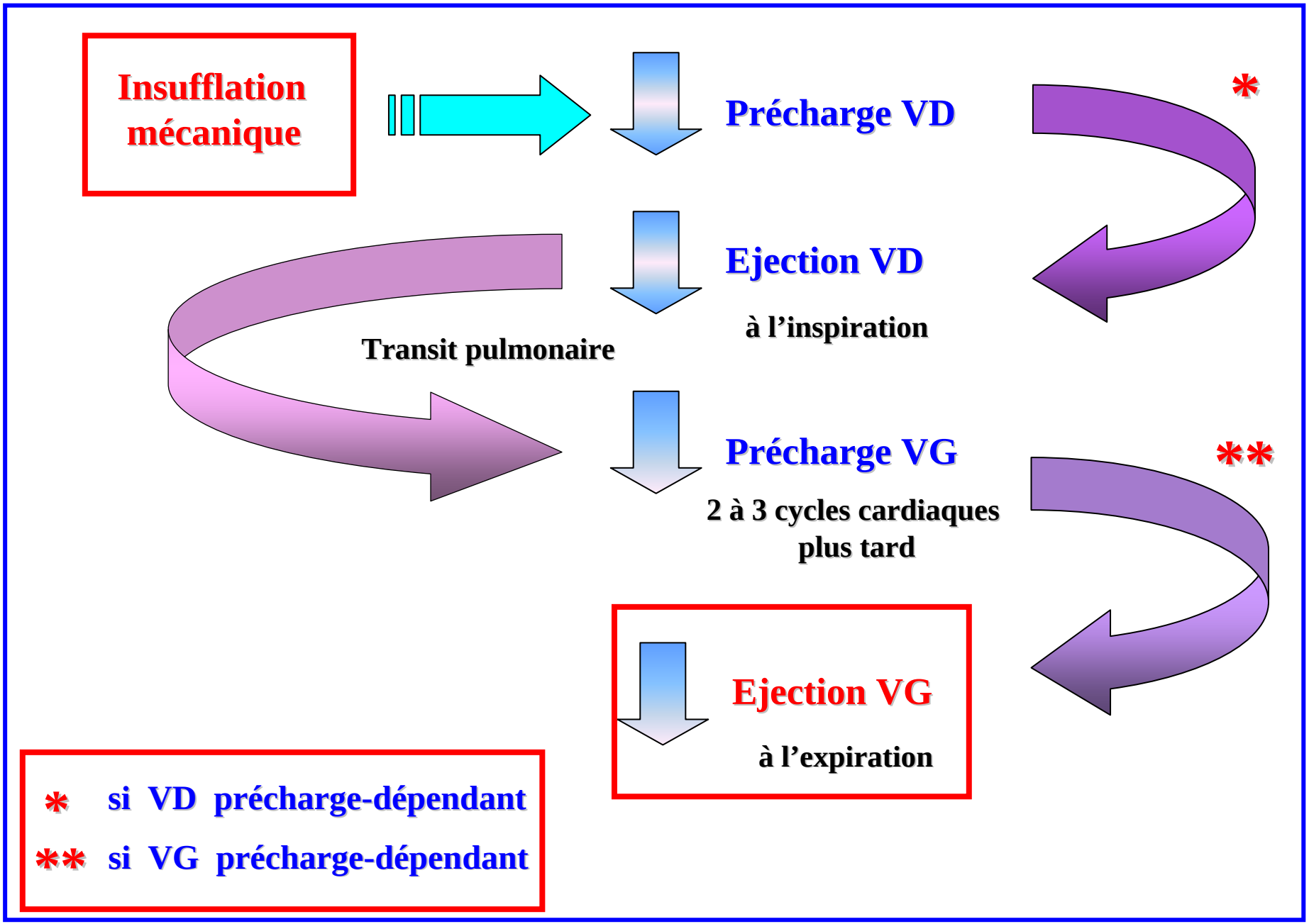


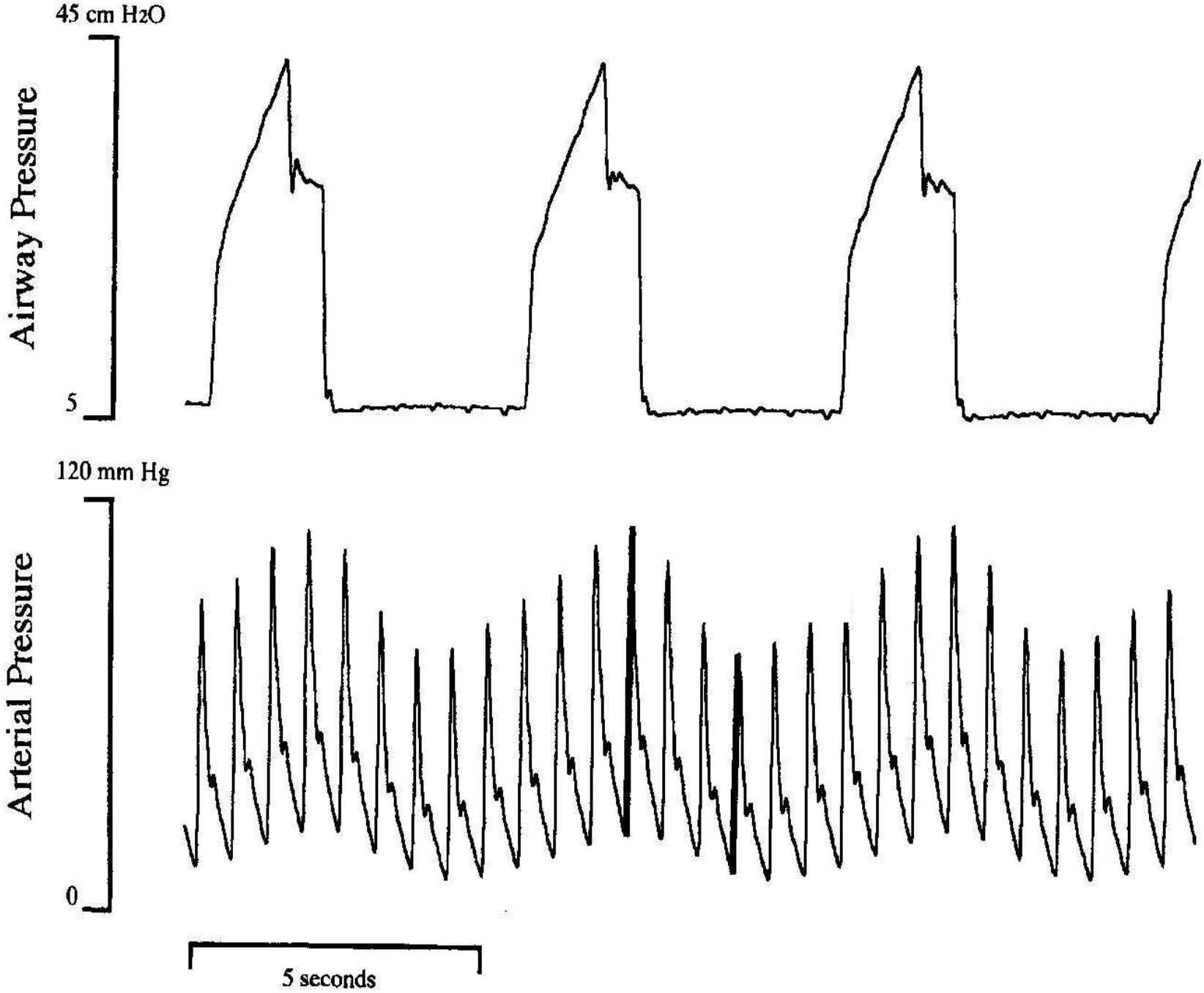
Effet des variations des Pressions Intrathoraciques sur la relation PV du VG



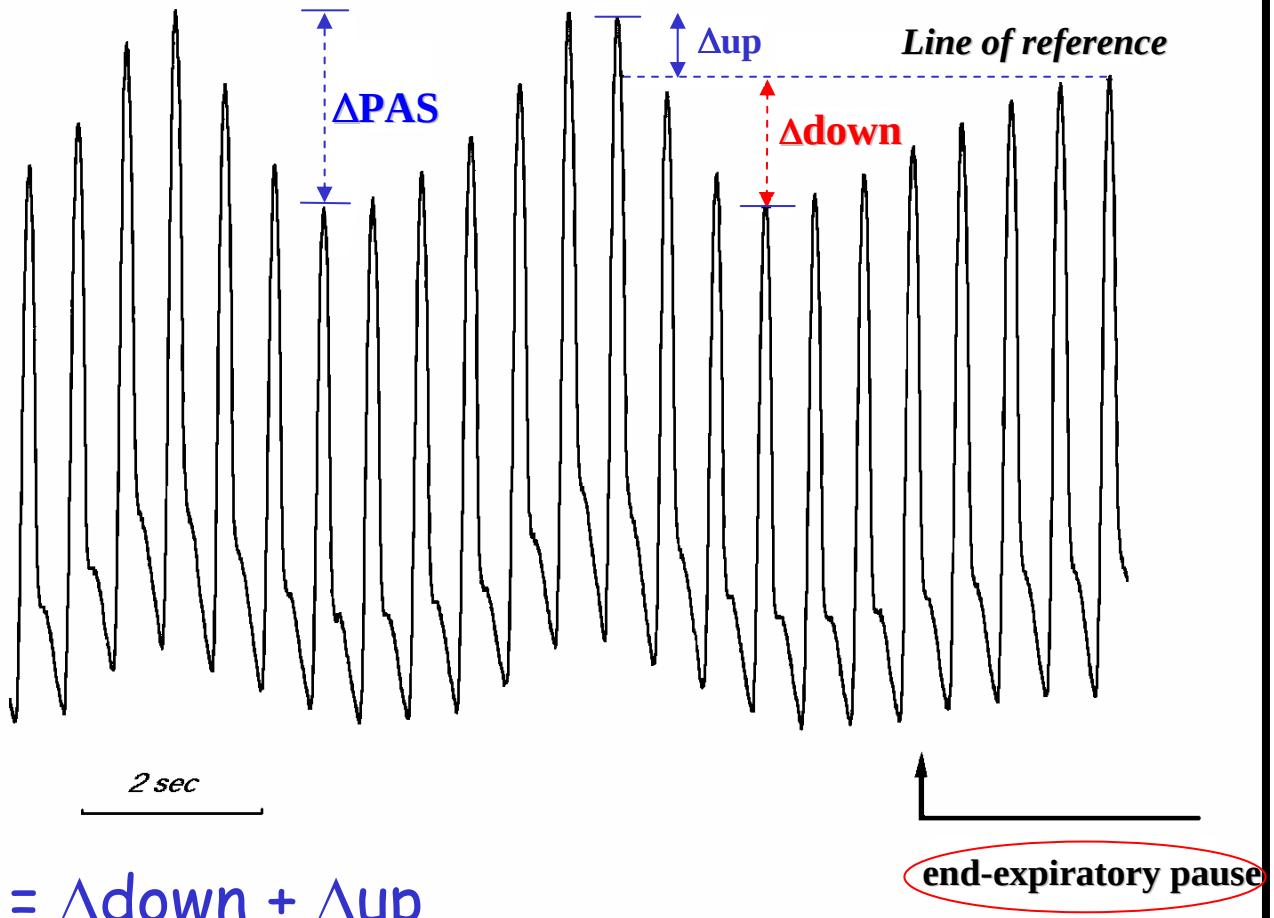
Effet de la VM en PP sur le VD et VG




Insufflation mécanique
Précharge VD
*
Ejection VD
à l'inspiration
Transit pulmonaire
Précharge VG
**
2 à 3 cycles cardiaques plus tard
Ejection VG
à l'expiration
* si VD précharge-dépendant
** si VG précharge-dépendant


45 cm H2O
Airway Pressure
5
120 mm Hg
Arterial Pressure
0
5 seconds

VPS (7-16 mmHg) = Δdown (2-11 mmHg) + Δup



VPS = Δdown + Δup

Perel et al. Anesthesiology 1987;67:498-502

critical care review

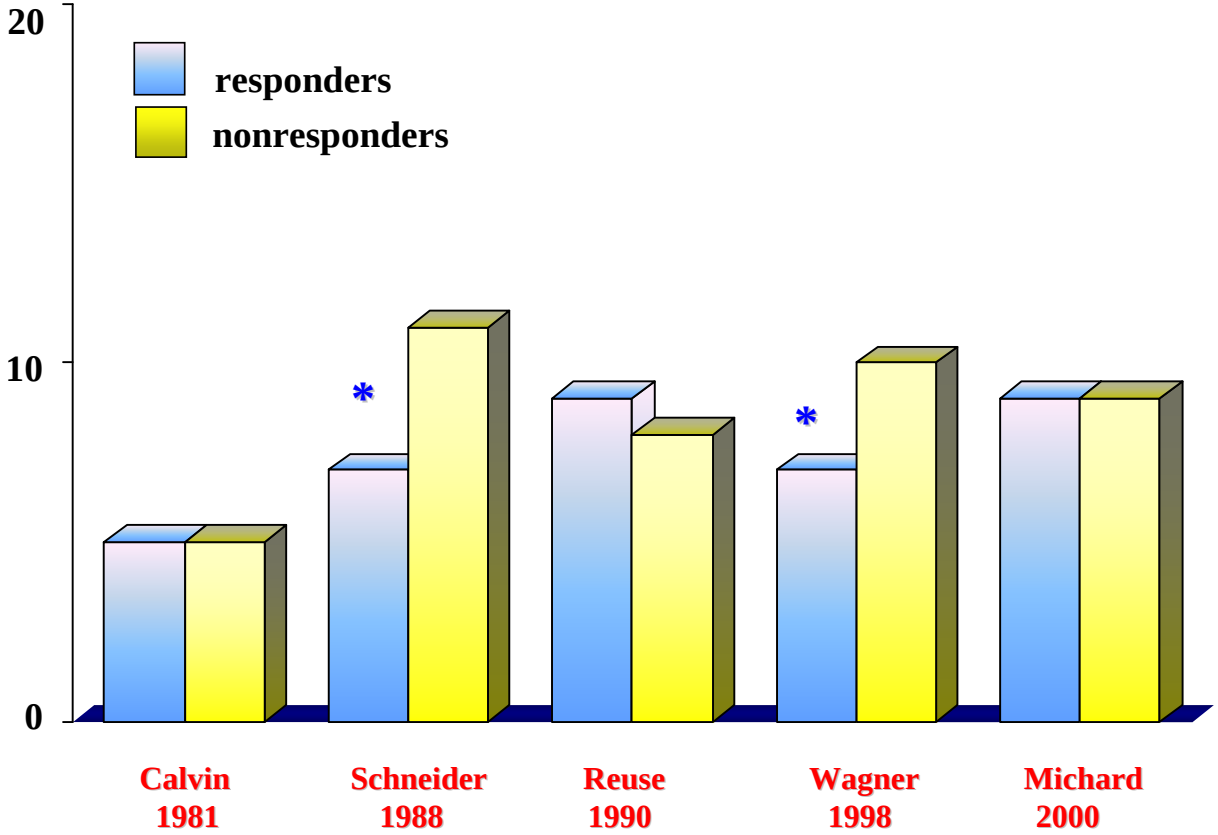
Predicting Fluid Responsiveness in ICU Patients*

A Critical Analysis of the Evidence

Frédéric Michard, MD, PhD; and Jean-Louis Teboul, MD, PhD

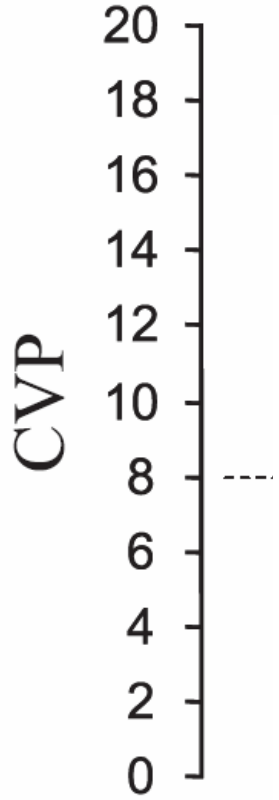
Chest 2002, 121:2000-8

RAP *(mmHg)* before volume expansion



Cardiac filling pressures are not appropriate to predict hemodynamic response to volume challenge.

Osman et al. CCM 2007; 35: 64-68



R = ΔIC >= 15 %

150 épreuves de remplissage chez 96 patients *en choc septique*
Nombre répondeurs = 65 (43%)-VM 100 % - PEP 7 ± 3 cmH2O

Les indices dynamiques sont proposés
pour détecter directement
la précharge-dépendance
(ou réserve de précharge)

Effets cycliques de la ventilation mécanique

Variables Hémodynamiques dynamiques

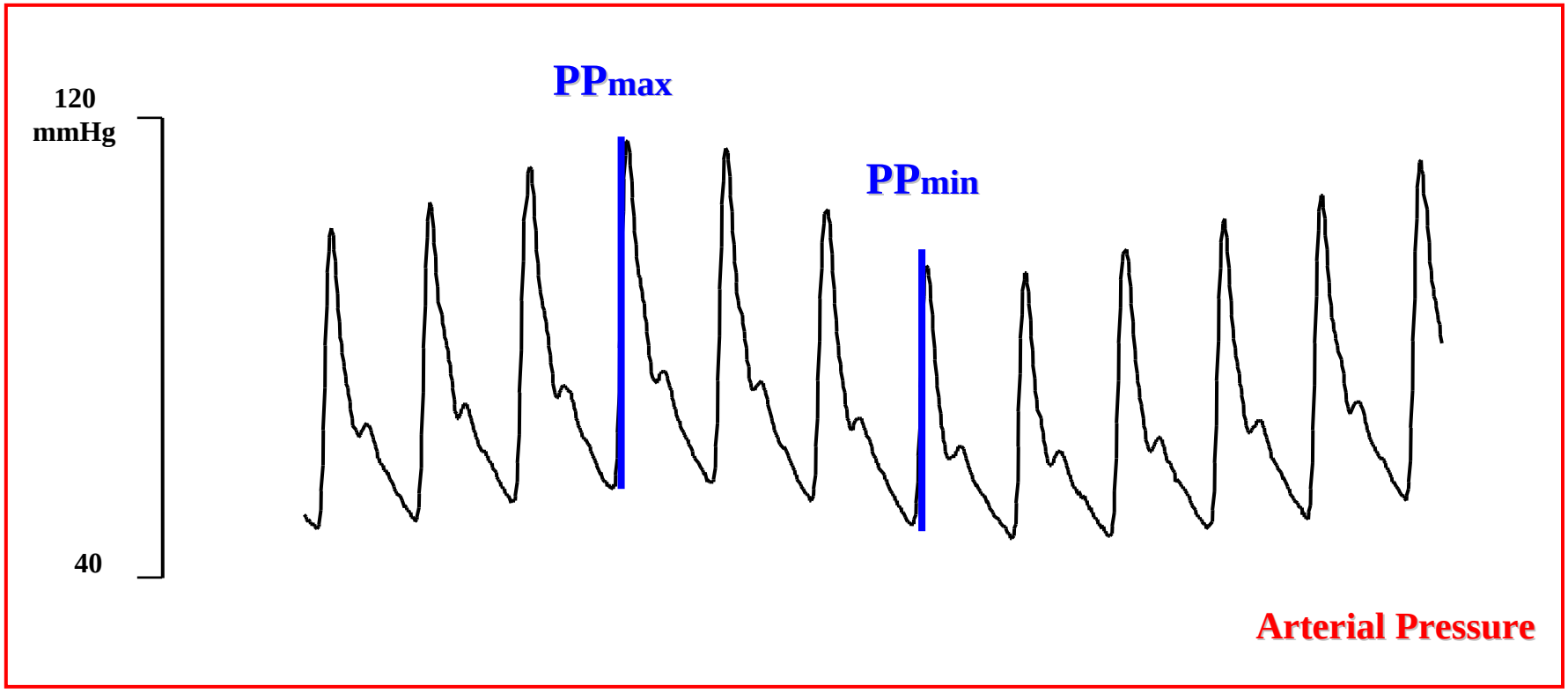
- SPV : variations de pression systolique (systolic pressure variation)
- PPV : variations de pression pulsée (pulse pressure variation)
- SSV : variations du volume systolique (stroke volume variation) – Pulse Contour
- Indice de Collapsibilité respiratoire de la VCS (SVC)
- Index de distension de la VCI (IVC)
- Variations respiratoire du signal pléthysmographique (SpO2)
- Test de variation respiratoire systolique (RSVT)

Relation between Respiratory Changes in Arterial Pulse Pressure and Fluid Responsiveness in Septic Patients with Acute Circulatory Failure

FRÉDÉRIC MICHARD, SANDRINE BOUSSAT, DENIS CHEMLA, NADIA ANGUEL, ALAIN MERCAT, YVES LECARPENTIER, CHRISTIAN RICHARD, MICHAEL R. PINSKY, and JEAN-LOUIS TEBOUL

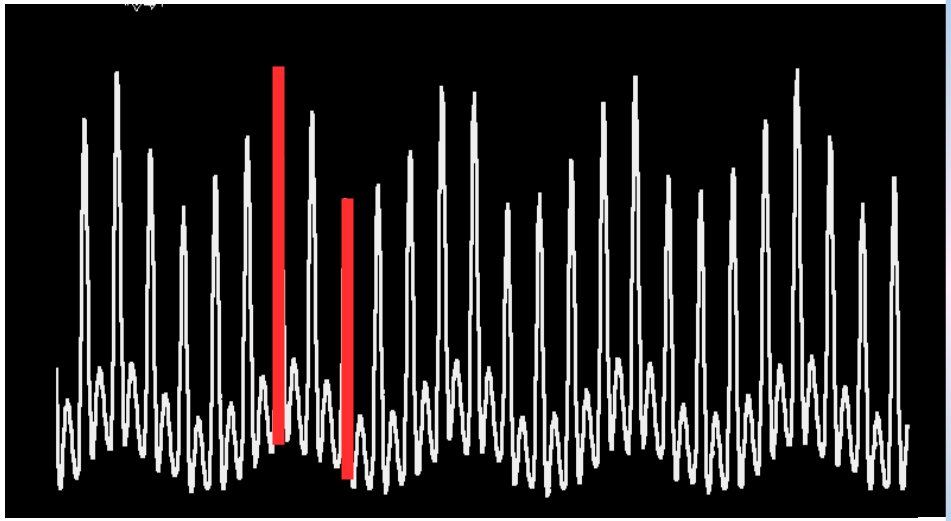
Am J Respir Crit Care Med 2000; 162:134-8

$$\Delta PP = \frac{PP_{max} - PP_{min}}{(PP_{max} + PP_{min}) / 2}$$



Patient répondeur

ΔPP = 32 %

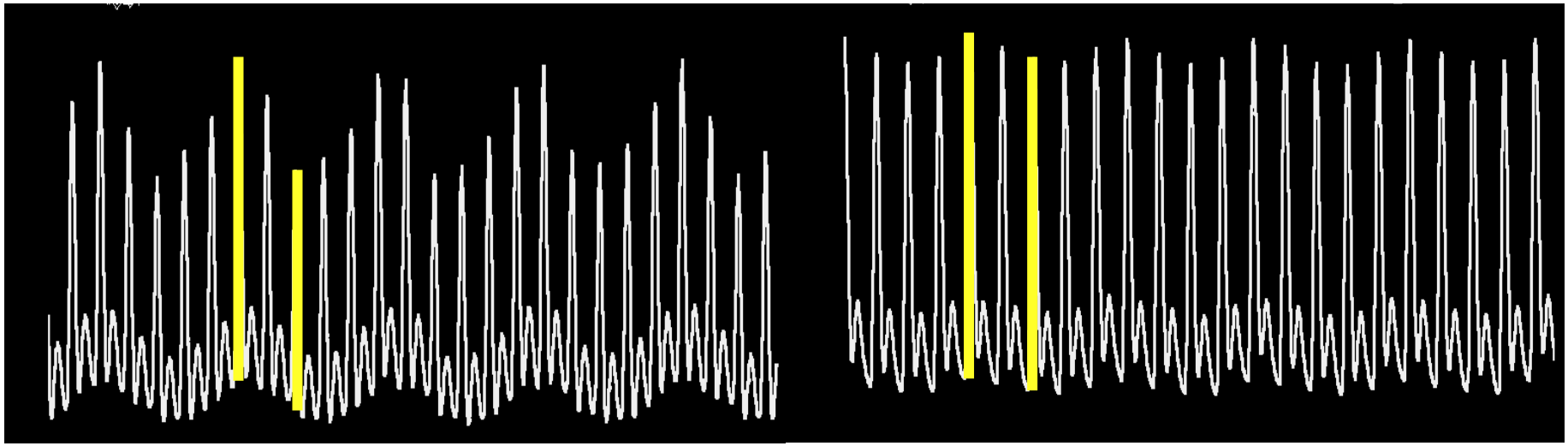


Avant remplissage

Patient répondeur

ΔPP = 32 %

ΔPP = 5 %



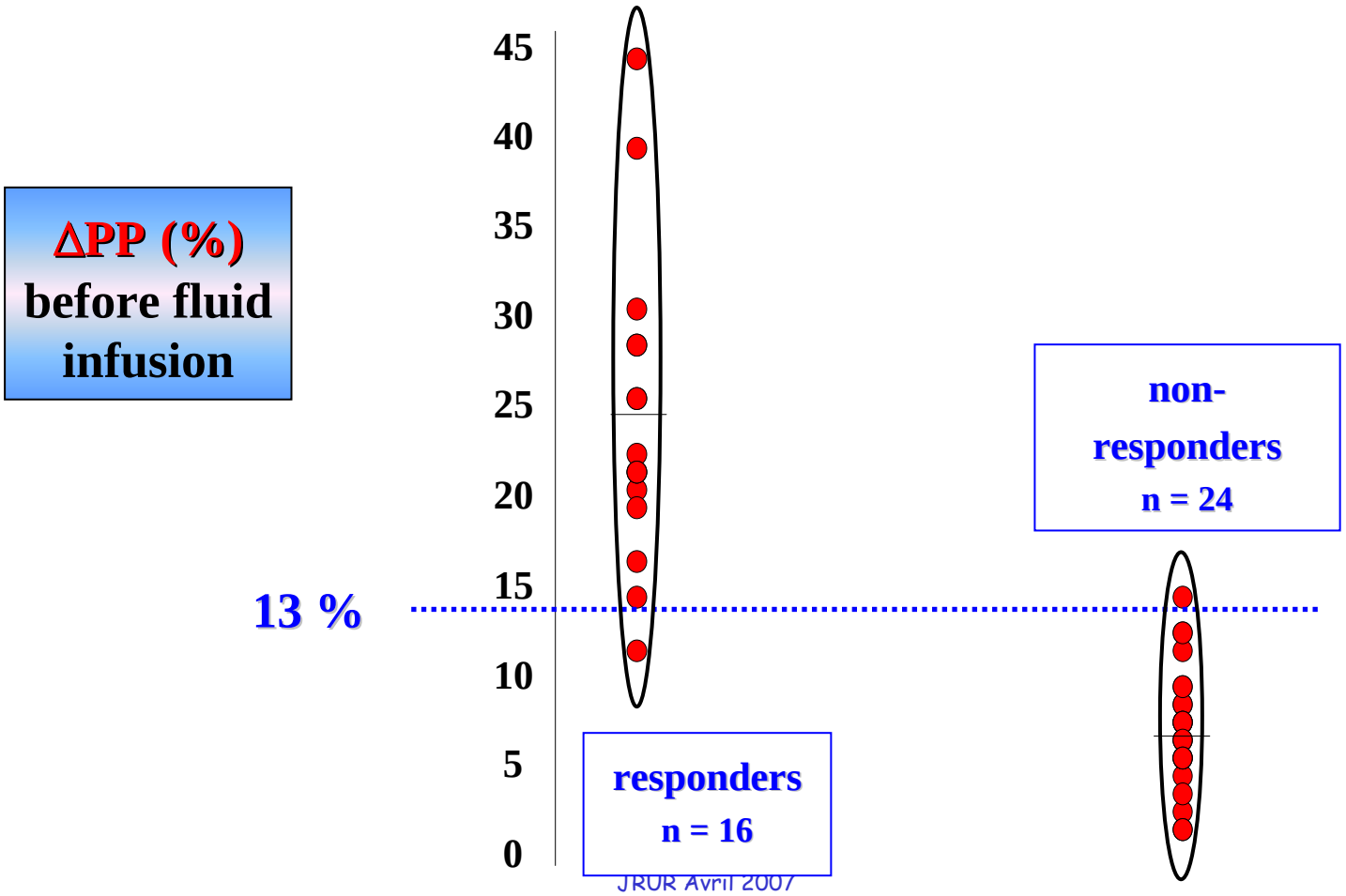
Avant remplissage

Après remplissage

Relation between Respiratory Changes in Arterial Pulse Pressure and Fluid Responsiveness in Septic Patients with Acute Circulatory Failure

FRÉDÉRIC MICHARD, SANDRINE BOUSSAT, DENIS CHEMLA, NADIA ANGUEL, ALAIN MERCAT, YVES LECARPENTIER, CHRISTIAN RICHARD, MICHAEL R. PINSKY, and JEAN-LOUIS TEBOUL

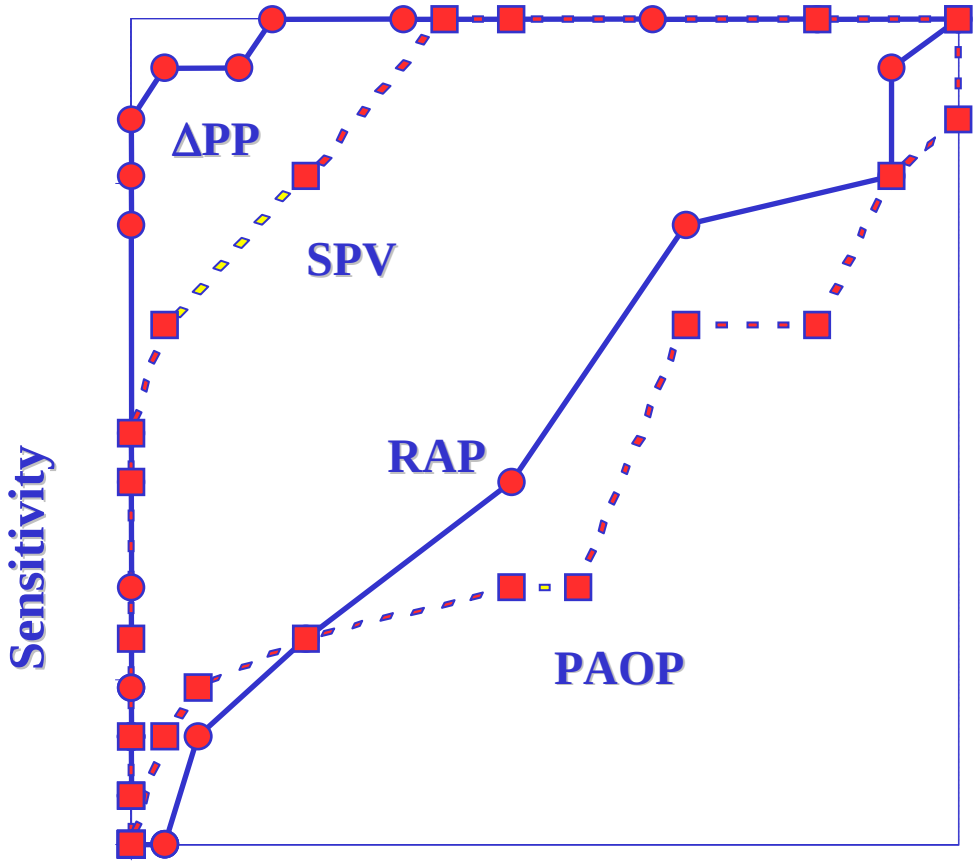
Am J Respir Crit Care Med 2000; 162:134-8



Relation between Respiratory Changes in Arterial Pulse Pressure and Fluid Responsiveness in Septic Patients with Acute Circulatory Failure

FRÉDÉRIC MICHARD, SANDRINE BOUSSAT, DENIS CHEMLA, NADIA ANGUEL, ALAIN MERCAT, YVES LECARPENTIER, CHRISTIAN RICHARD, MICHAEL R. PINSKY, and JEAN-LOUIS TEBOUL

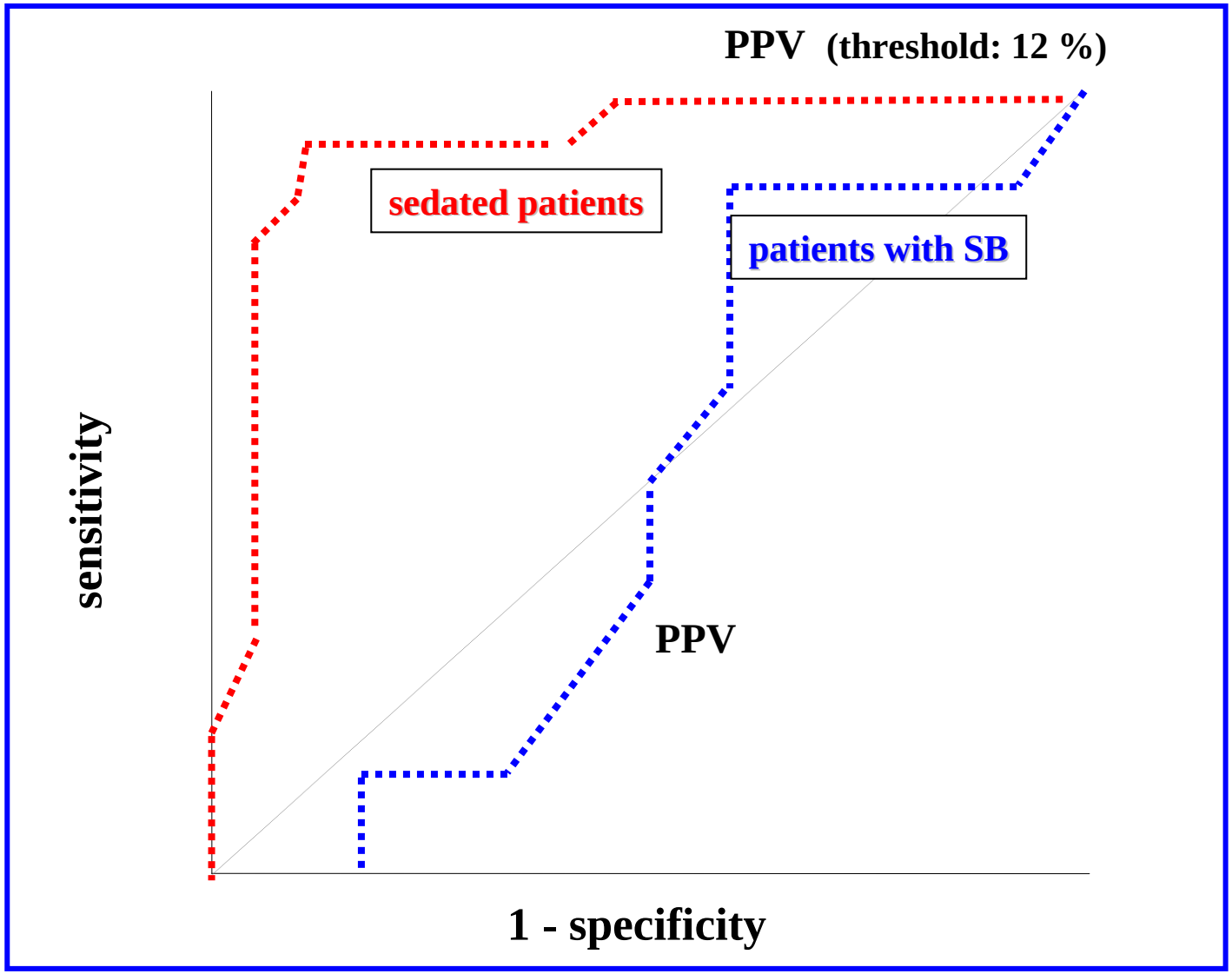
Am J Respir Crit Care Med 2000; 162:134-8



Passive leg raising predicts fluid responsiveness in the critically ill*

Xavier Monnet, MD, PhD; Mario Rienzo, MD; David Osman, MD; Nadia Anguel, MD; Christian Richard, MD;

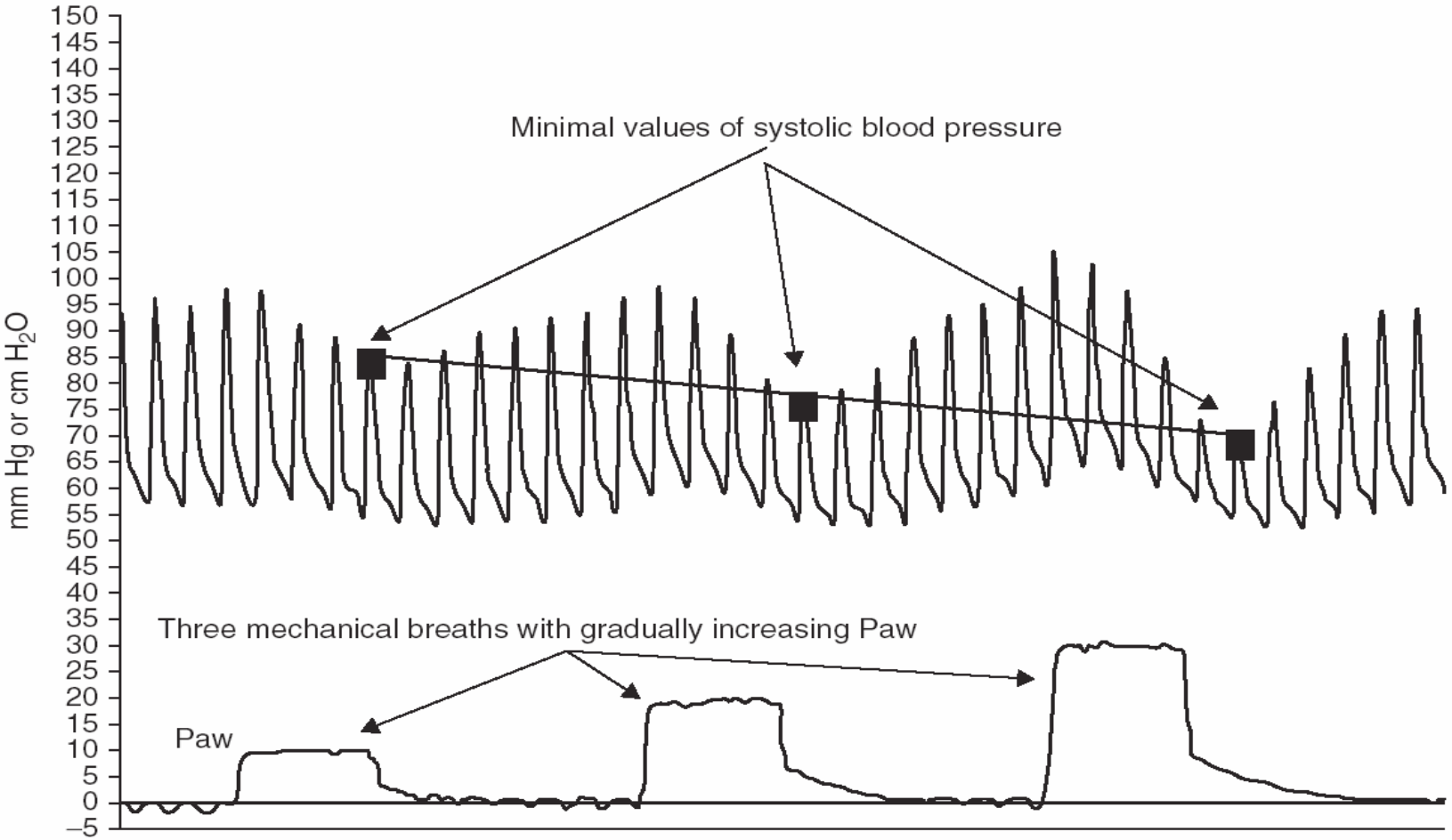
Crit Care Med 2006; 34:1402–1407



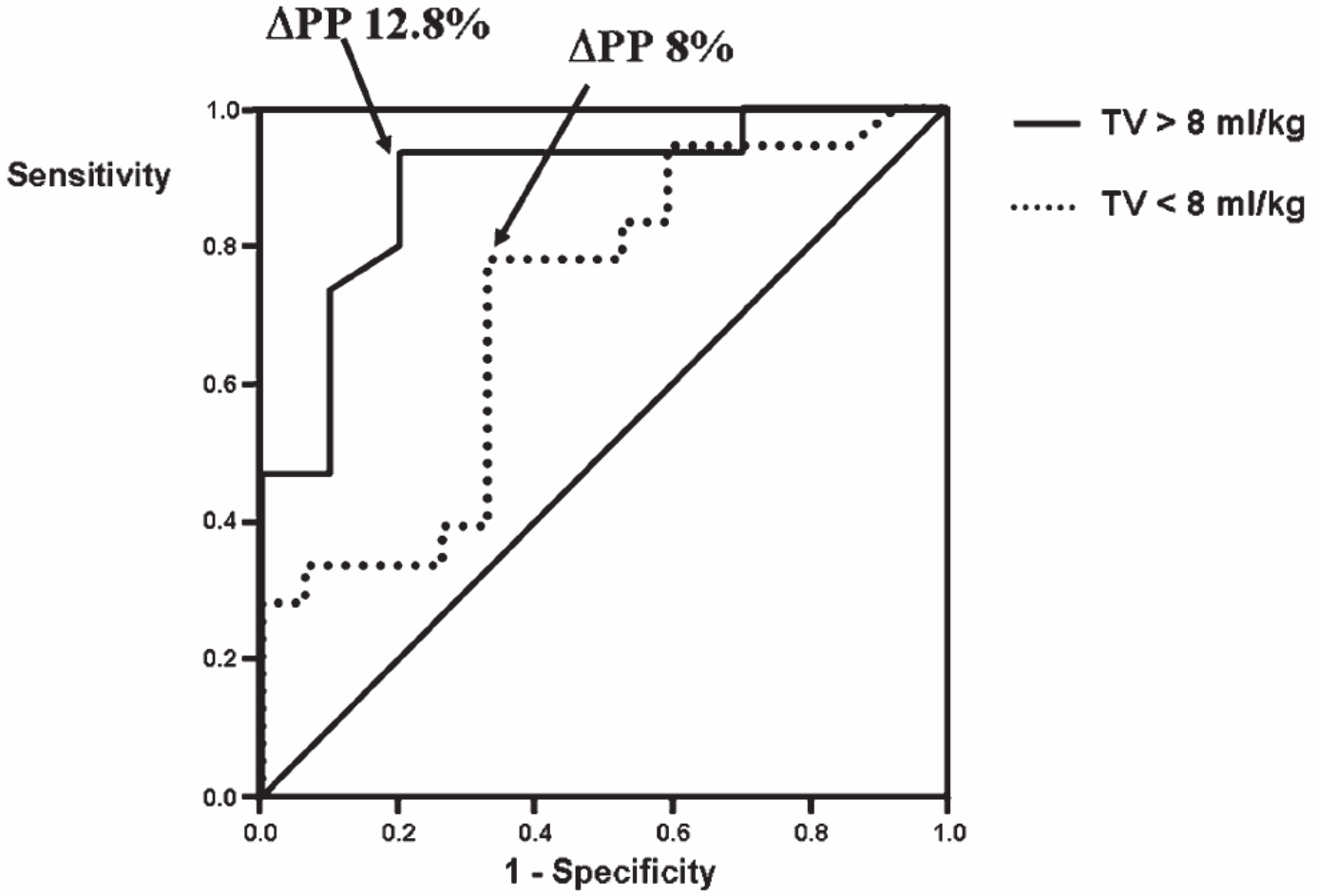
Assessing Fluid-Responsiveness by a Standardized Ventilatory Maneuver: The Respiratory Systolic Variation Test

Azriel Perel, MD*, Leonid Minkovich, MD*, Sergey Preisman, MD*, Michel Abiad, MD†, Eran Segal, MD*, and Pierre Coriat, MD†

(Anesth Analg 2005;100:942–5)



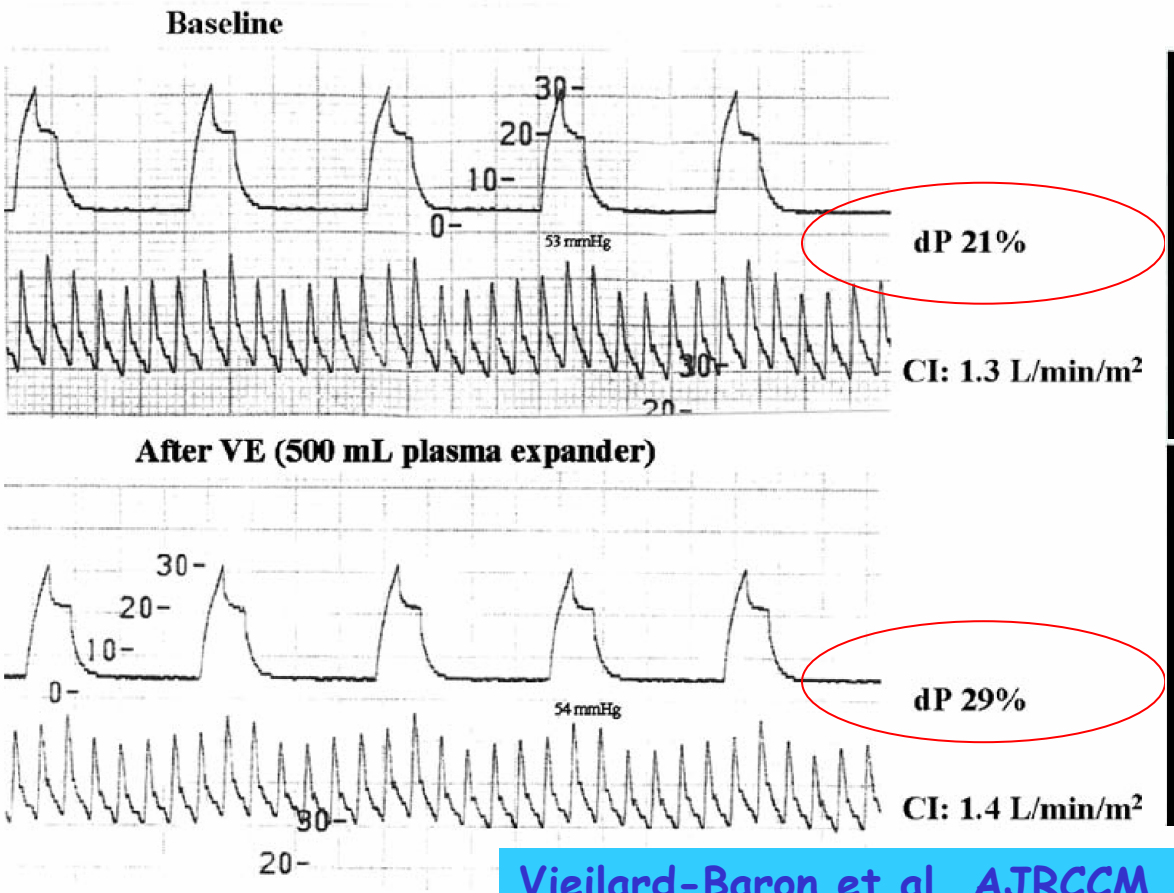
Pulse pressure variations to predict fluid responsiveness: influence of tidal volume

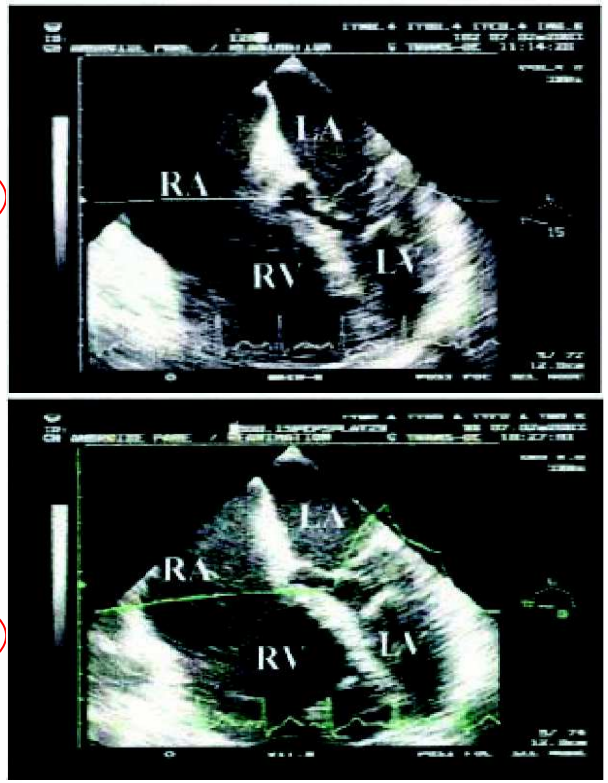


JRUR Avril 2007

De Backer at al ICM 2005; 31:517-523

Défaillance VD
et variations de pression artérielle





Vieilard-Baron et al. AJRCCM 2003; 168 :1270–1276

Jardin ICM 2004; 30:1047-1050

Limitations des variables dynamiques

- Patient ventilés en VC
- Influencés par le volume courant
- Valides en rythme sinusal
- Absence de défaillance ventriculaire droite
- Influence de la mécanique pulmonaire
- Aucune réponse à l'indication de remplissage