# Comment utiliser la pression artérielle dans le monitorage des états de choc

**Olfa Hamzaoui**
Médecine Intensive-réanimation
Hôpital Robert Debré, Université de Reims
France

# Place de la pression artérielle

## Mes liens d'intérêt

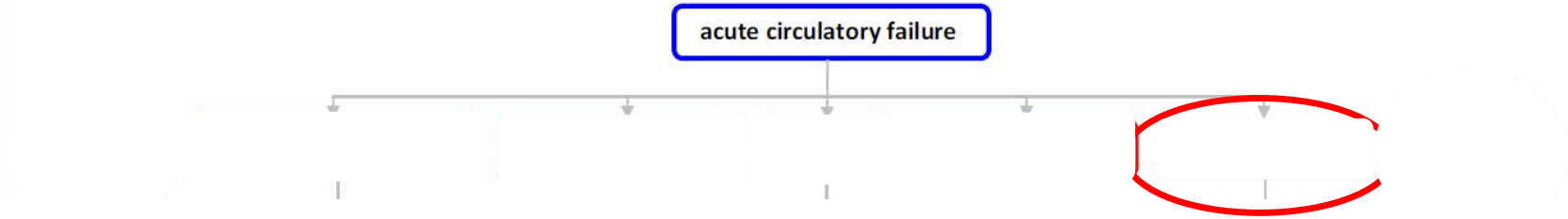
- Membre du board de AOP ORPHAN
- Honoraires pour des conférences invitées par Baxter

*Intensive Care Med (2016) 42:1350–1359*

CONFERENCE REPORTS AND EXPERT PANEL

# Less invasive hemodynamic monitoring in critically ill patients

Jean-Louis Teboul[1*], Bernd Saugel[2], Maurizio Cecconi[3], Daniel De Backer[4], Christoph K. Hofer[5], Xavier Monnet[1], Azriel Perel[6], Michael R. Pinsky[7], Daniel A. Reuter[2], Andrew Rhodes[3], Pierre Squara[8], Jean-Louis Vincent[9] and Thomas W. Scheeren[10]

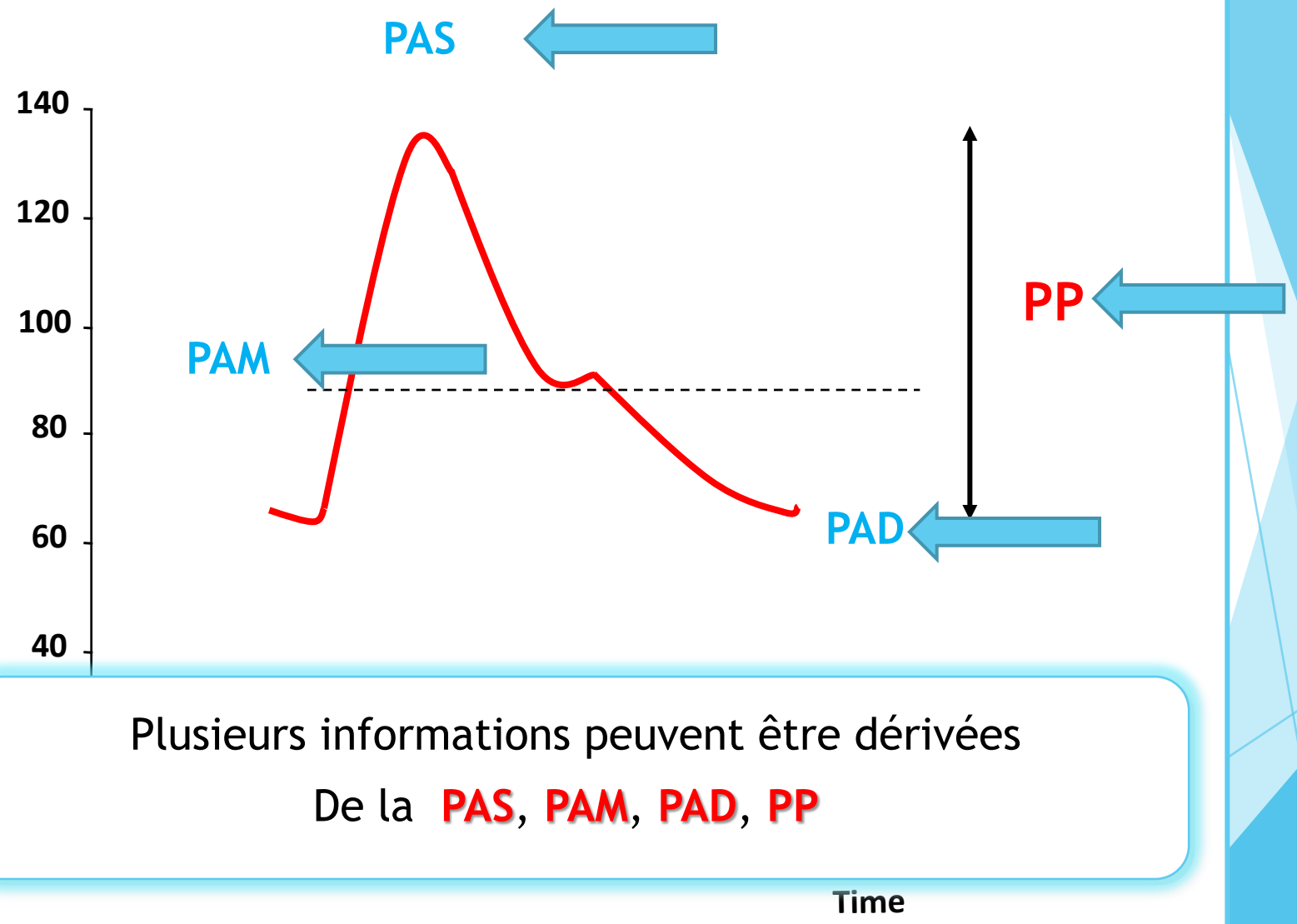



## Comment peut-on utiliser la pression artérielle?

- Analyse des valeurs de la pression artérielle statique
- Analyse de la variation dynamique de la pression artérielle
- Monitorage continue du débit cardiaque

- **Analyse des valeurs de la pression artérielle statique**
- Analyse de la variation dynamique de la pression artérielle
- Monitorage continue du débit cardiaque

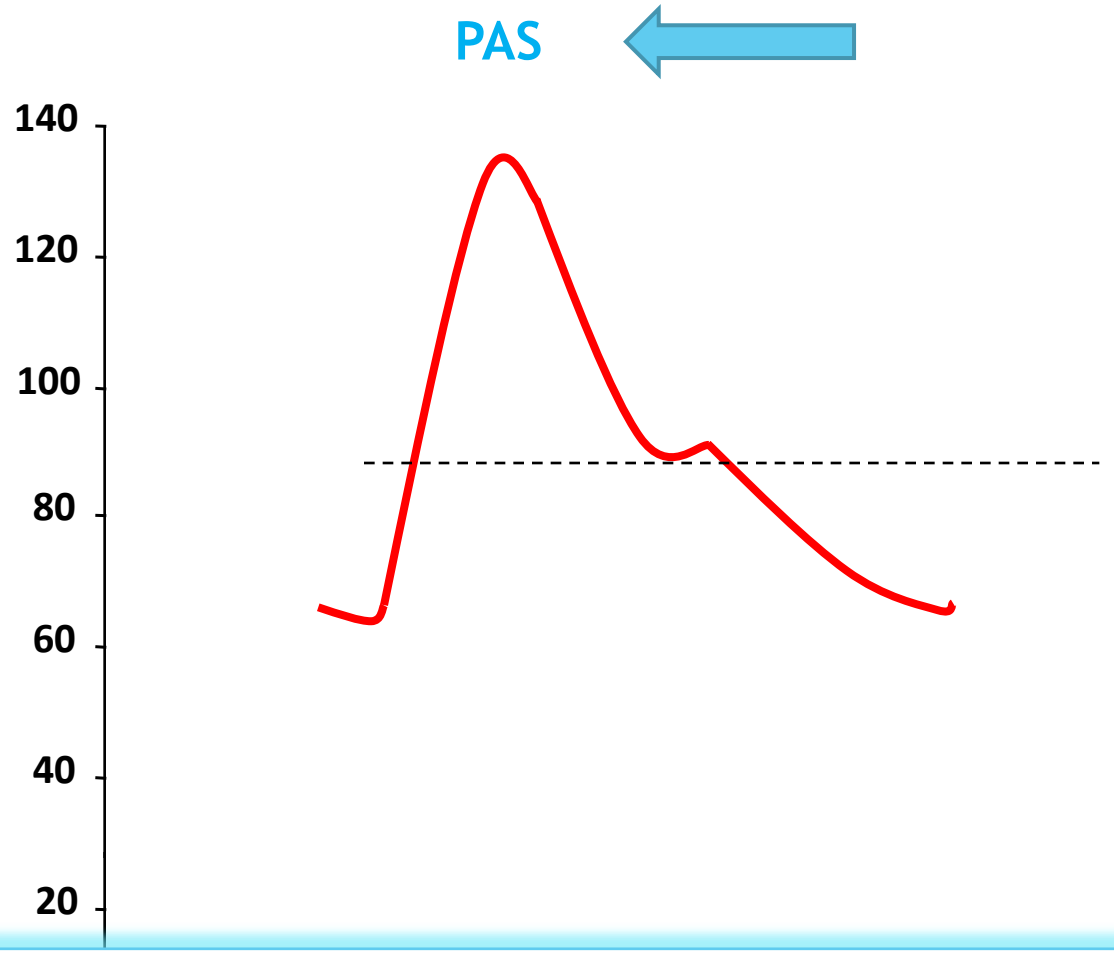
## Pression artérielle *(mmHg)*




Plusieurs informations peuvent être dérivées

De la **PAS**, **PAM**, **PAD**, **PP**

Pression artérielle *(mmHg)*



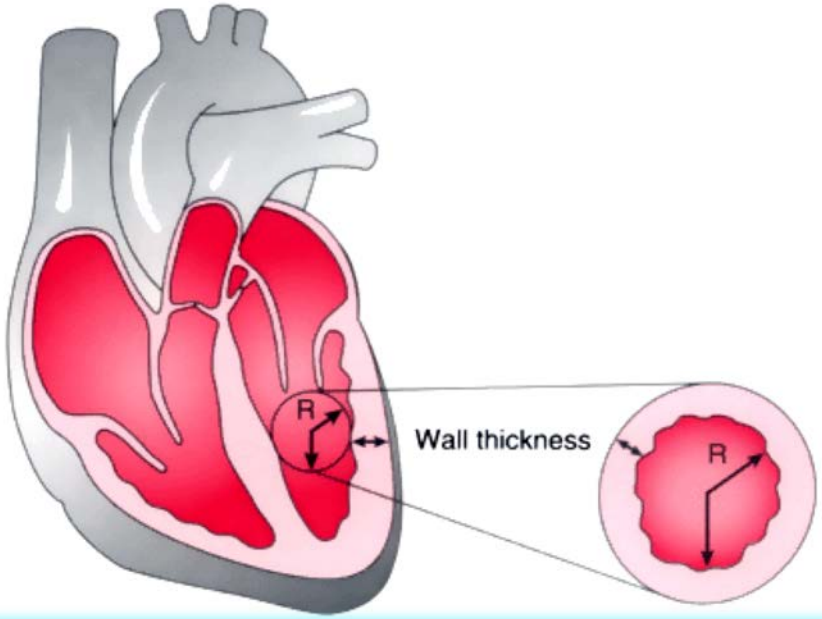

**PAS**: **Un determinant majeur** de **La post charge**

TOWARD CONSISTENT DEFINITIONS
FOR PRELOAD AND AFTERLOAD

James M. Norton

*Department of Physiology and Pharmacology; University of New England College of Osteopathic Medicine, Biddeford, Maine 04005*

**La post charge peut-être définie comme la charge contre laquelle le VG doit éjecter du sang.**




**La loi de Laplace** → $\sigma = P \times r / h$

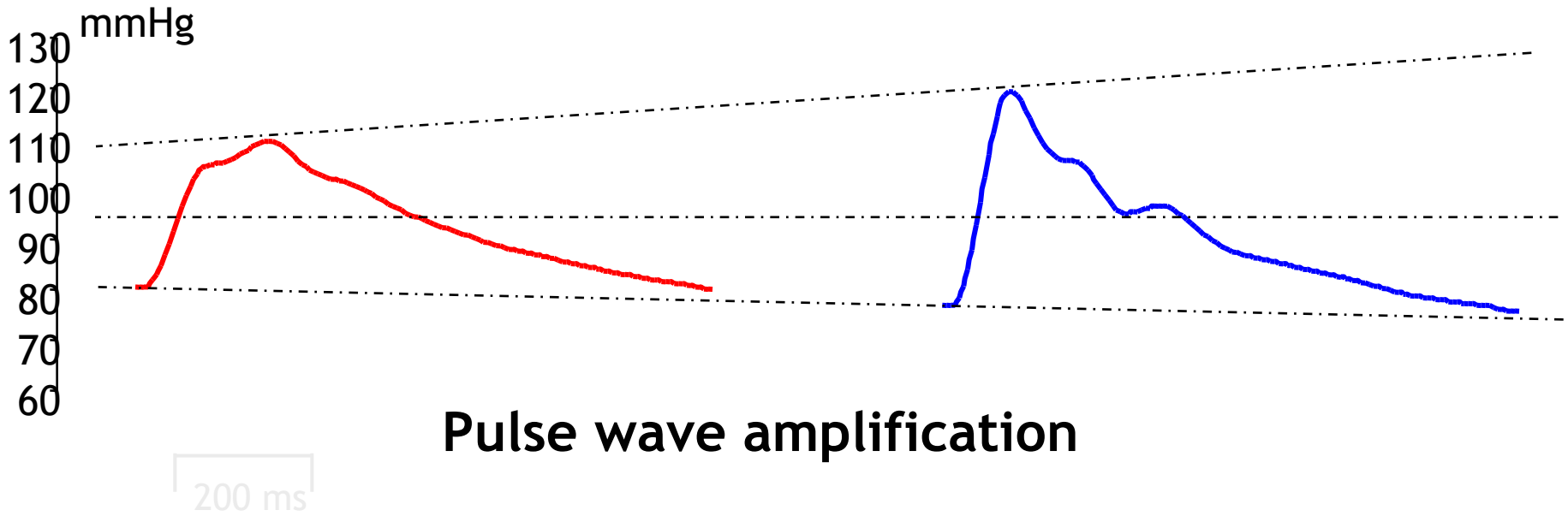
(σ: tension pariétale du VG, **P: Pression télésystolique du VG;** r: Rayon du VG; h: épaisseur de la paroi).

→ **Pression télésystolique du VG: Pression systolique aortique: 0.9 X PAS**

# La PAS périphérique reflète-elle PAS aortique?

**Central** pressure wave

**Peripheral** pressure wave



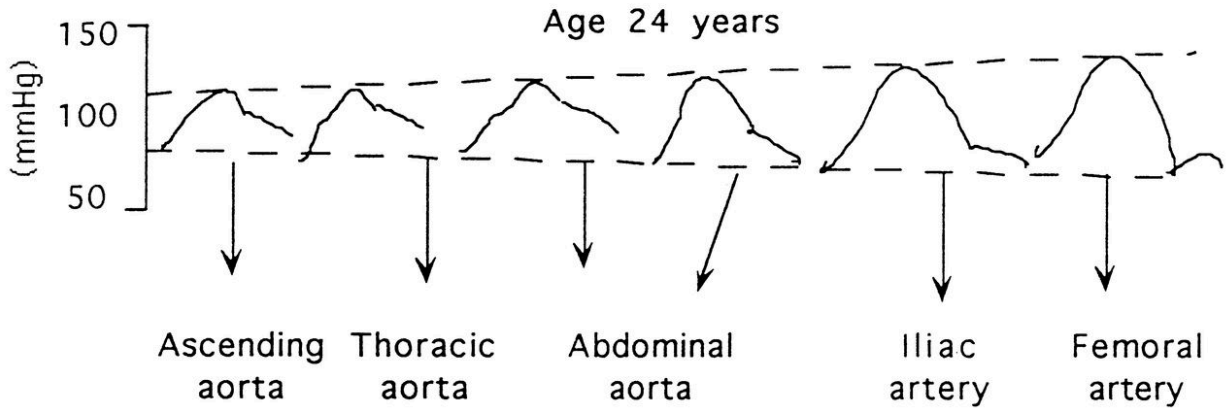

**Pulse wave amplification**

aortic SAP < femoral SAP

femoral SAP < radial SAP

Patients jeunes sans aucune rigidité de la paroi vasculaire**: PAS:130mmHg**

**Pression sytolique aortique est plus basse**

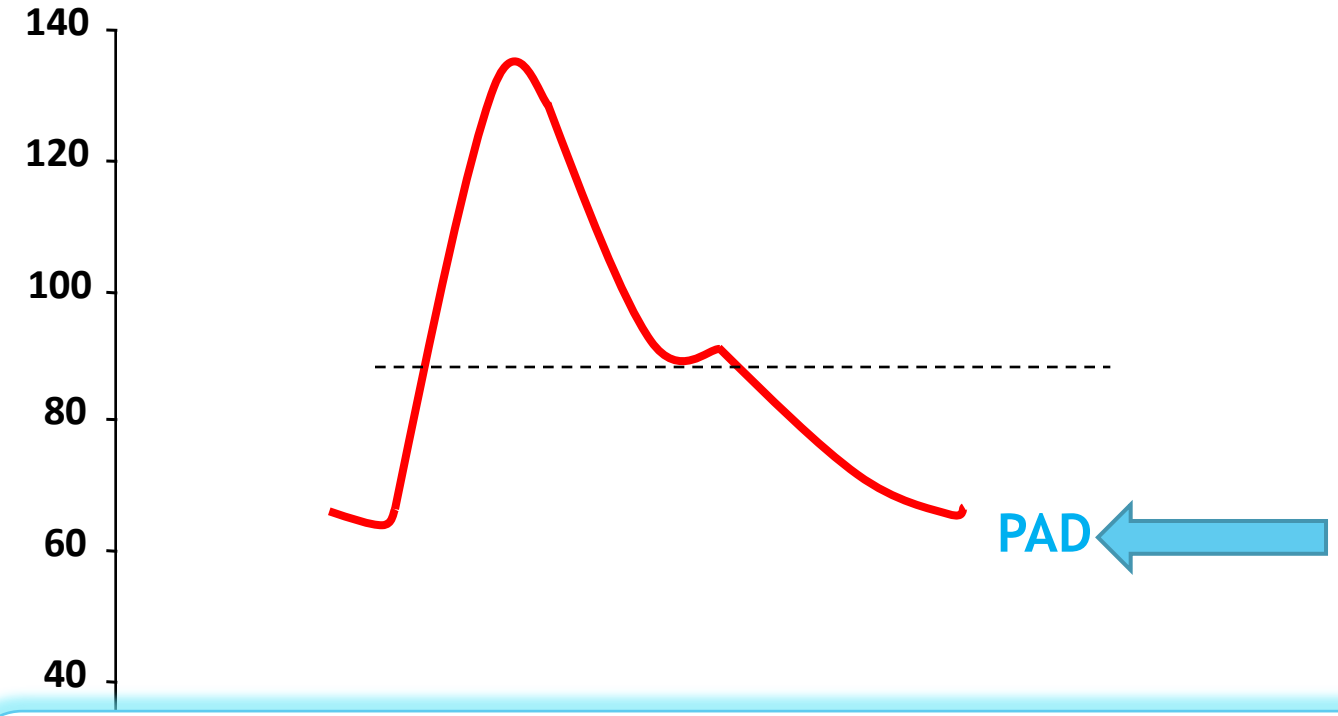



Patients agés et hypertendus
**PAS:150mmHg**

**Pression sytolique aortique est équivalente**

**Pression sytolique périphérique reflète la post charge**

## Pression artérielle*(mmHg)*




**PAD est déterminée** par :

- **Tonus vasomoteur: un reflet du tonus vasomoteur**

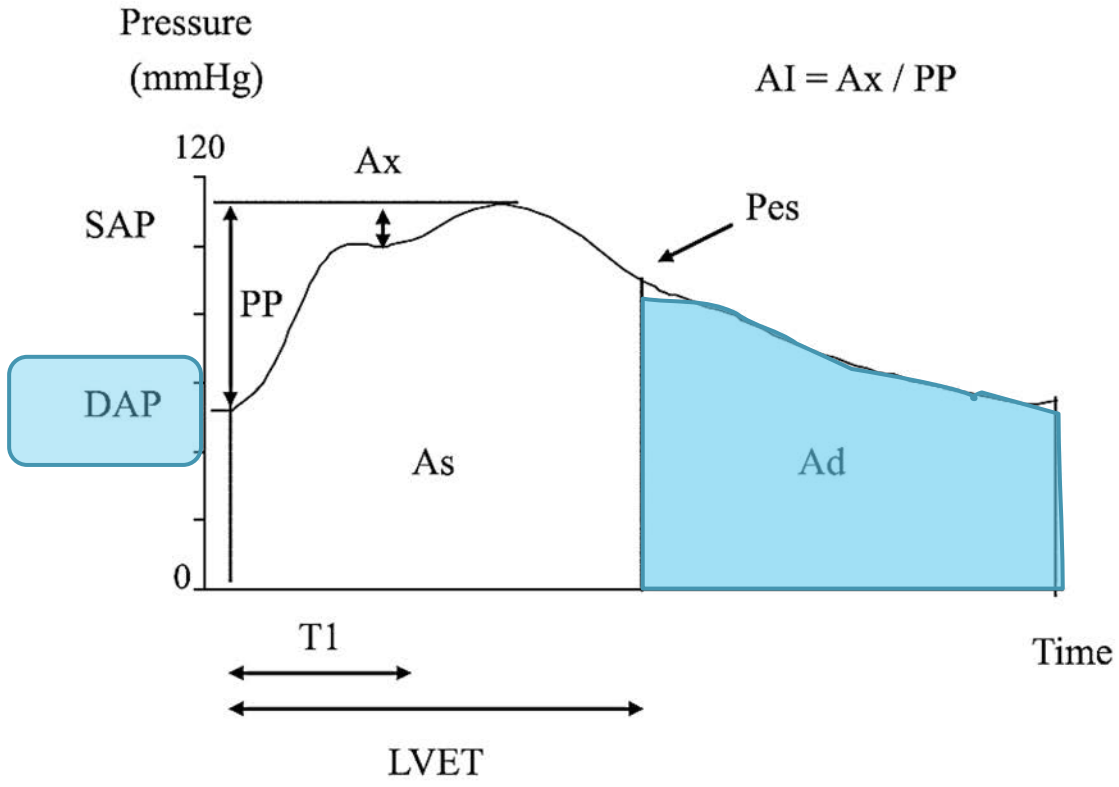
Intensive Care Med (2007) 33:1931–1937
DOI 10.1007/s00134-007-0738-4

ORIGINAL

Bouchra Lamia
Jean-Louis Teboul
Xavier Monnet
David Osman
Julien Maizel
Christian Richard
Denis Chemla

# Contribution of arterial stiffness and stroke volume to peripheral pulse pressure in ICU patients: an arterial tonometry study

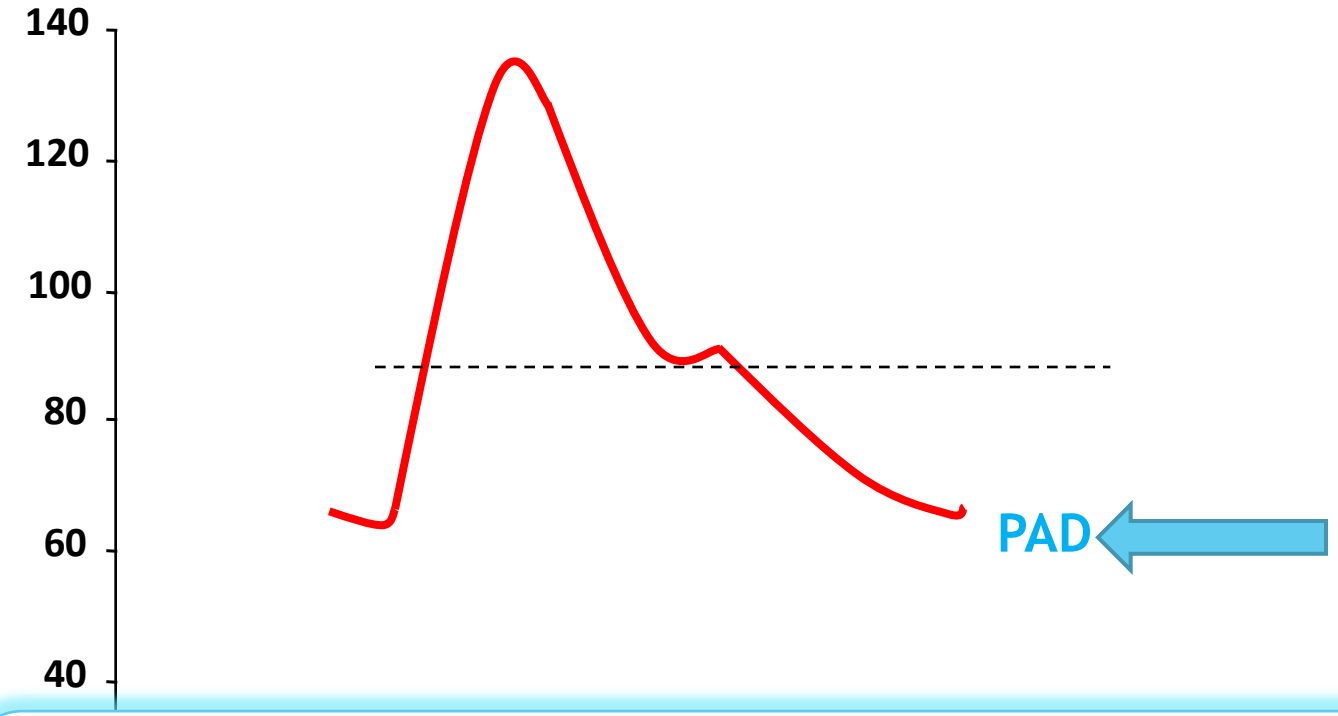
**67 ICU patients**




Peripheral **resistance**

- **related** to peripheral **DAP** (**r = 0.71**) ($p<0.001$)
- but **not related** to peripheral **SAP** ($r^2 = 0.04$) and **PP** ($r^2 = 0.02$)

## Pression artérielle*(mmHg)*



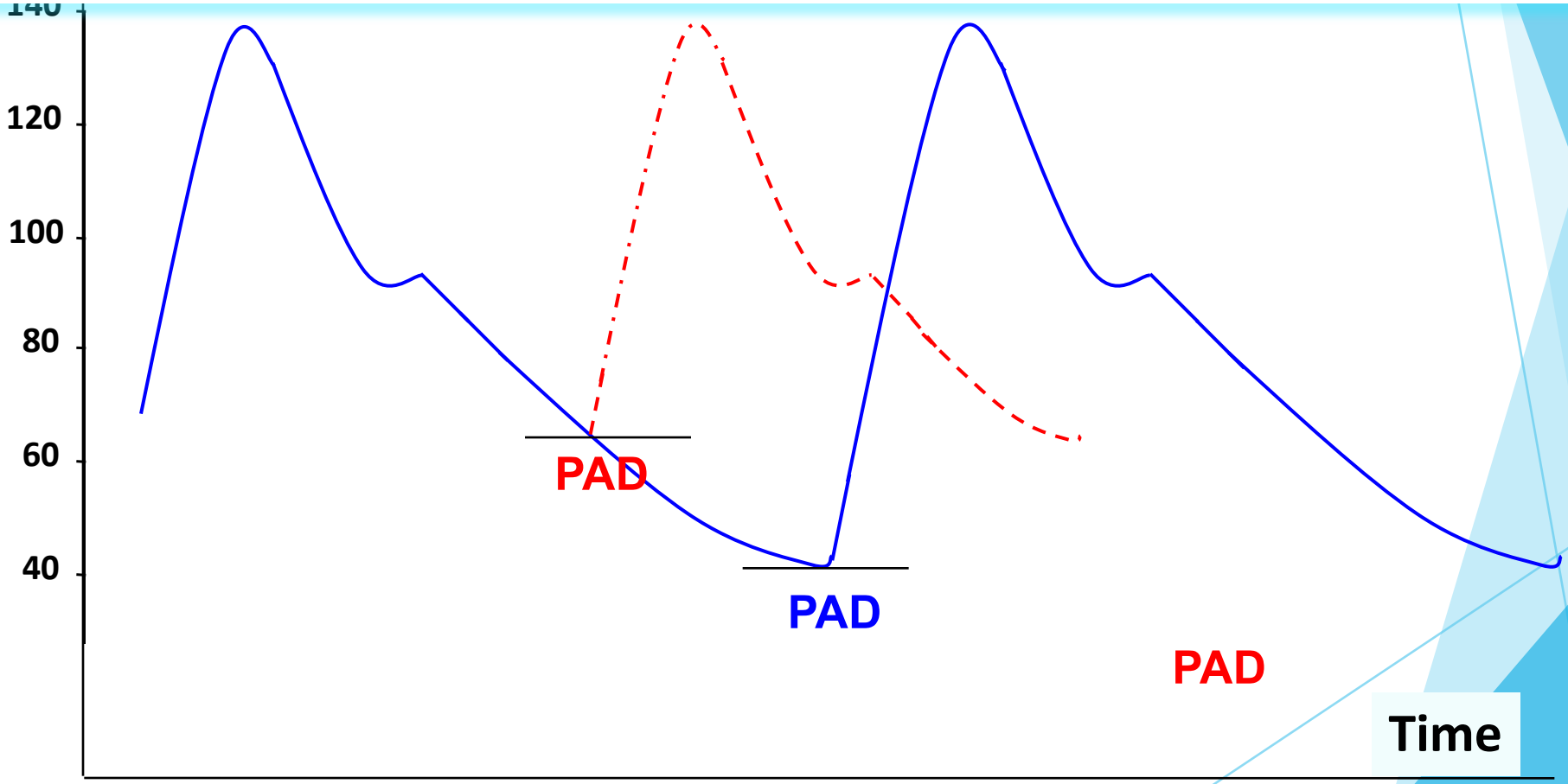

**PAD est déterminée** par :

- Tonus vasomoteur: un reflet du tonus vasomoteur
- **Fréquence cardiaque**

Toujours prendre en consideration la FC

**Pression artérielle***(mmHg)*

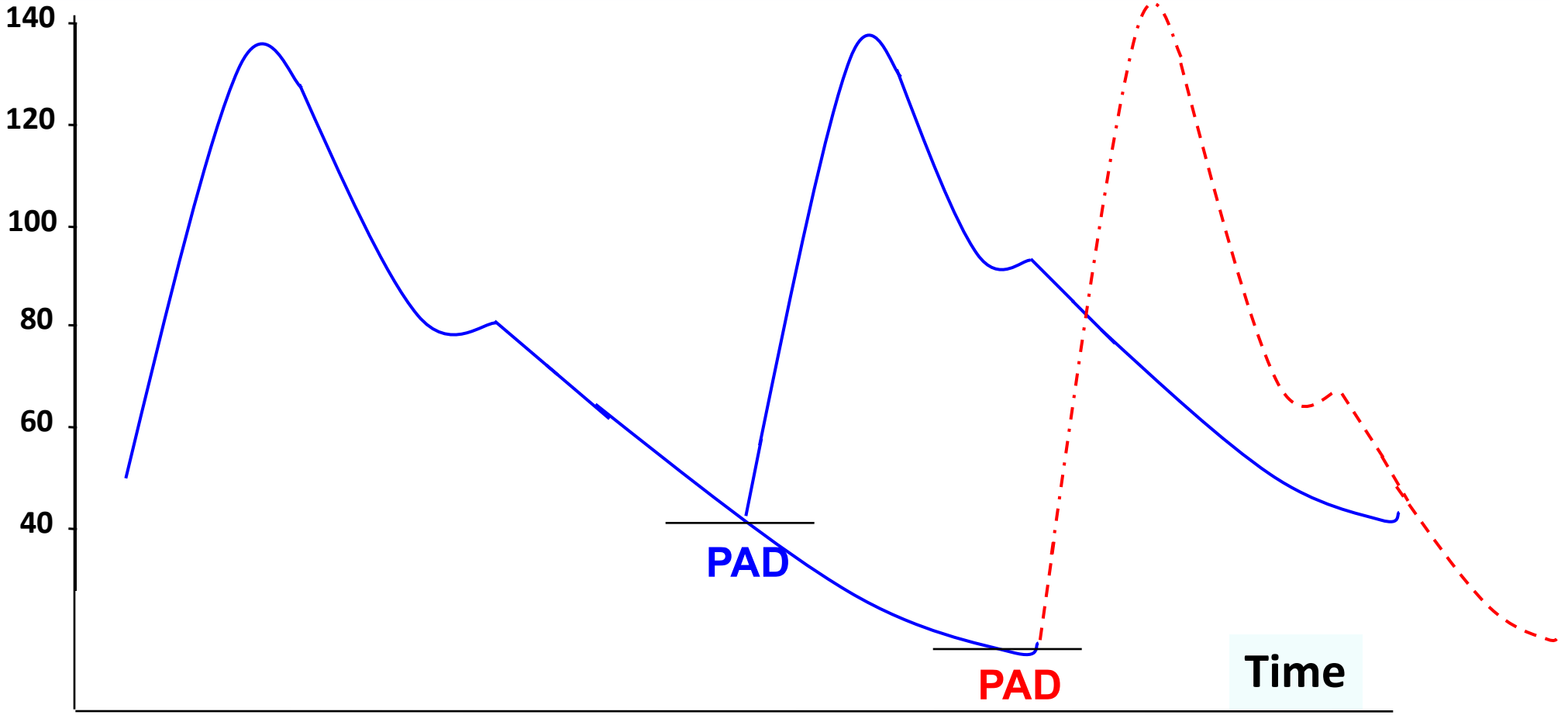
**La tachycardie** résulte théoriquement **à des valeurs plus élevées de PAD,**en raison d'une durée plus courte de la diastole ce qui empêche la décroissance diastolique de la pression artérielle de se terminer.



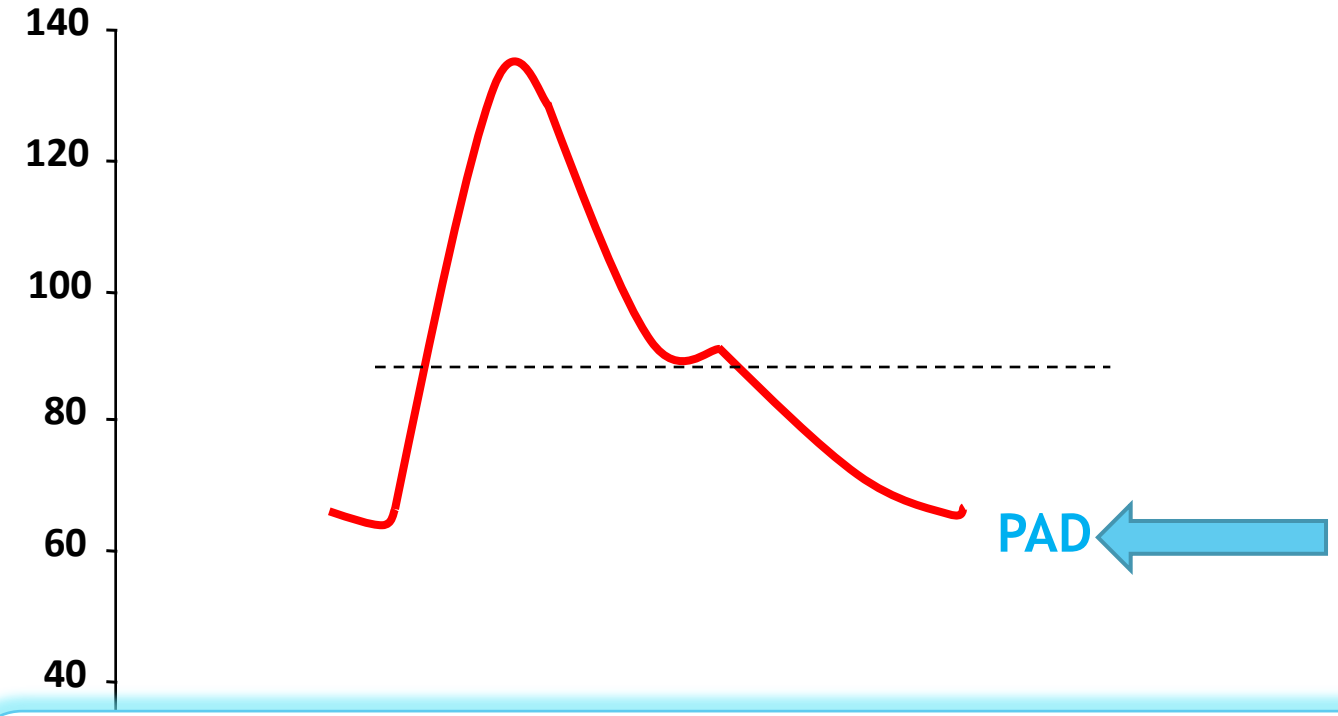
Toujours prendre en consideration la FC

**Pression artérielle*(mmHg)***

A l'inverse, **la bradycardie** résulte en une **Valeur plus basse de la PAD**



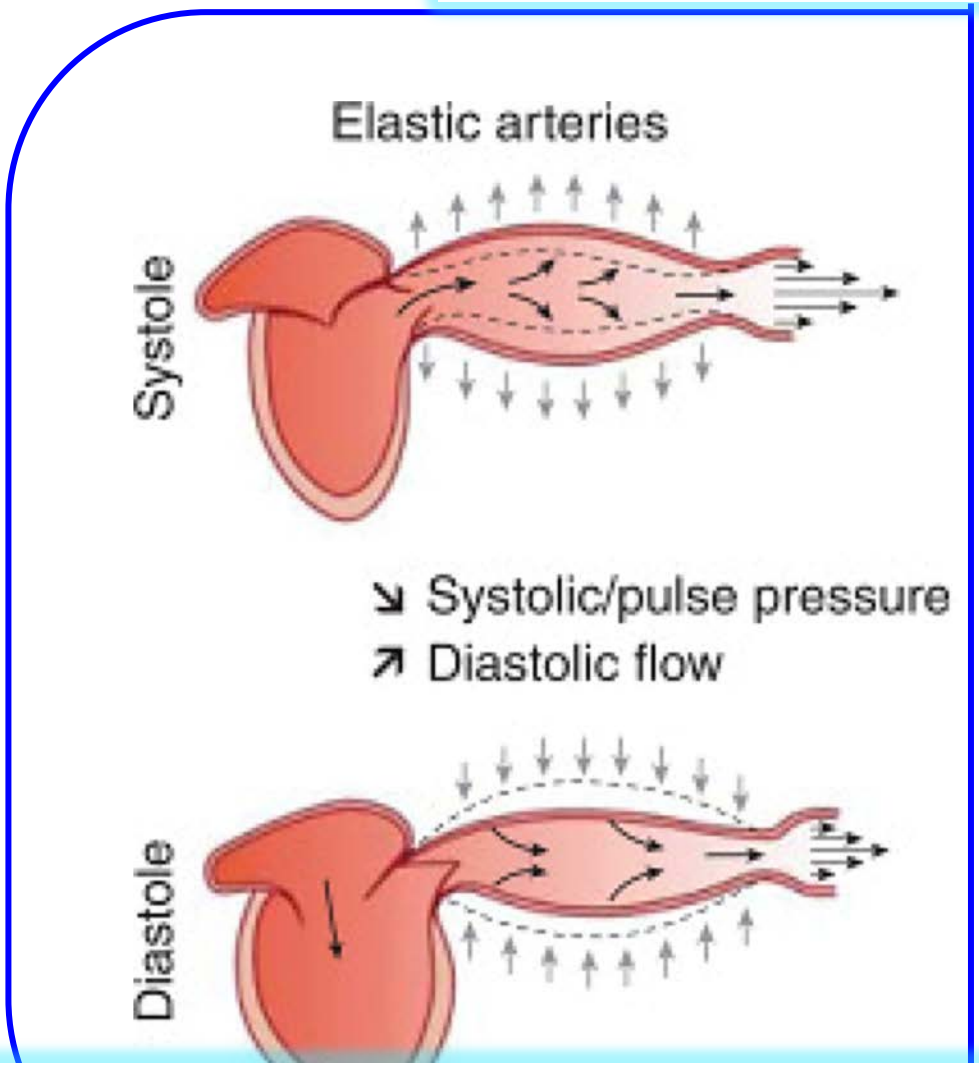
## Pression artérielle*(mmHg)*




**PAD est déterminée** par :

- Tonus vasomoteur: un reflet du tonus vasomoteur
- Fréquence cardiaque
- **Degré de rigidité artérielle**

The **cardiac pump** generates a **pulsatile flow**

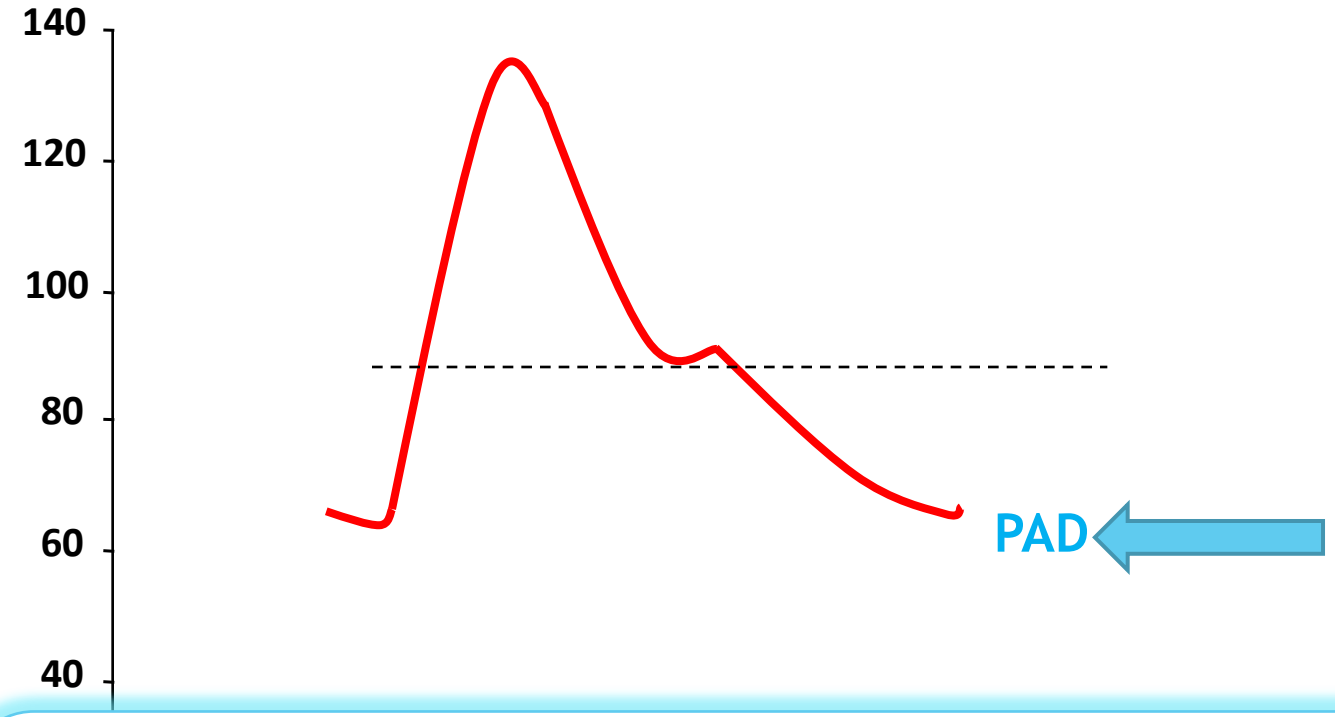



The **arteries** a

In patients **with stiff arteries the diastolic part** of aortic pressure **is reduced**

part of the **stroke volume** during the **systole** and by **restituting** it during the **diastole**

## Pression artérielle*(mmHg)*




**PAD est déterminée** par :

- **Tonus vasomoteur: un reflet du tonus vasomoteur :basse PAD** indique un **bas tonus vasomoteur**
- Fréquence cardiaque
- Degré de rigidité artérielle

# Diastolic arterial pressure is important in septic shock: PRO

Olfa Hamzaoui
Jean-Louis Teboul

Journal of Critical Care 51 (2019) 238–240




- ✓ **La PAD est un marqueur du Tonus vasomoteur**
- ✓ **Témoigne de la composante vasoplégique**




La pression mortice de perfusion **des coronaires du VG**

Journal of Critical Care 51 (2019) 238–240

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# Diastolic arterial pressure is important in septic shock: PRO

Olfa Hamzaoui Jean-Louis Teboul

## La PAD un Trigger pour les thérapeutiques

*Diastolic arterial pressure is important in septic shock: PRO*

Patient of **70** years old and history of **CAD**

with **tachycardia** (heart rate: 100 beats/min)

and clinical signs of **septic shock** in spite of initial fluid resuscitation

CLINICAL INVESTIGATION

# Norepinephrine exerts an inotropic effect during the early phase of human septic shock

O. Hamzaoui[1,*], M. Jozwiak[2], T. Geffriaud[2], B. Sztrymf[1], D. Prat[1], F. Jacobs[1], X. Monnet[2], P. Trouiller[1], C. Richard[2] and J.L. Teboul[2]

*British Journal of Anaesthesia*, 120 (3): 517–524 (2018)

- 38 septic shock pts
- resuscitated < 3 hrs and with MAP< 65mmHg
- Repeated TTE

**Table 2** Haemodynamic variables before ($T_0$) and after ($T_1$) initiation of norepinephrine (or increase in its dose) for the whole population ($n$=38). DAP, diastolic arterial pressure; HR, heart rate; MAP, mean arterial pressure; NE, norepinephrine; SAP, systolic arterial pressure

| Variable | $T_0$ | $T_1$ | P-value |
|---|---|---|---|
| NE dose (μg kg $^{-1}$ min$^{-1}$; median [25%–75% interquartile range]) | 0.23 [0.20–0.40] | 0.40 [0.20–0.80] | <0.05 |
| HR [beats min$^{-1}$; mean (SD)] | 99 (20) | 99 (23) | 0.9 |
| SAP [mm Hg; mean (SD)] | 85 (12) | 124 (15) | <0.05 |
| DAP [mm Hg; mean (SD)] | 45 (6) | 60 (10) | <0.05 |
| MAP [mm Hg; mean (SD)] | 56 (7) | 80 (9) | <0.05 |
| Lactate [mmol litre$^{-1}$; mean (SD)] | 3.2 (2.0) | 2.5 (1.3) | <0.05 |

CLINICAL INVESTIGATION

# Norepinephrine exerts an inotropic effect during the early phase of human septic shock

O. Hamzaoui[1,*], M. Jozwiak[2], T. Geffriaud[2], B. Sztrymf[1], D. Prat[1], F. Jacobs[1], X. Monnet[2], P. Trouiller[1], C. Richard[2] and J.L. Teboul[2]

*British Journal of Anaesthesia*, 120 (3): 517–524 (2018)

- 38 septic shock pts
- resuscitated < 3 hrs and with MAP< 65mmHg
- Repeated TTE

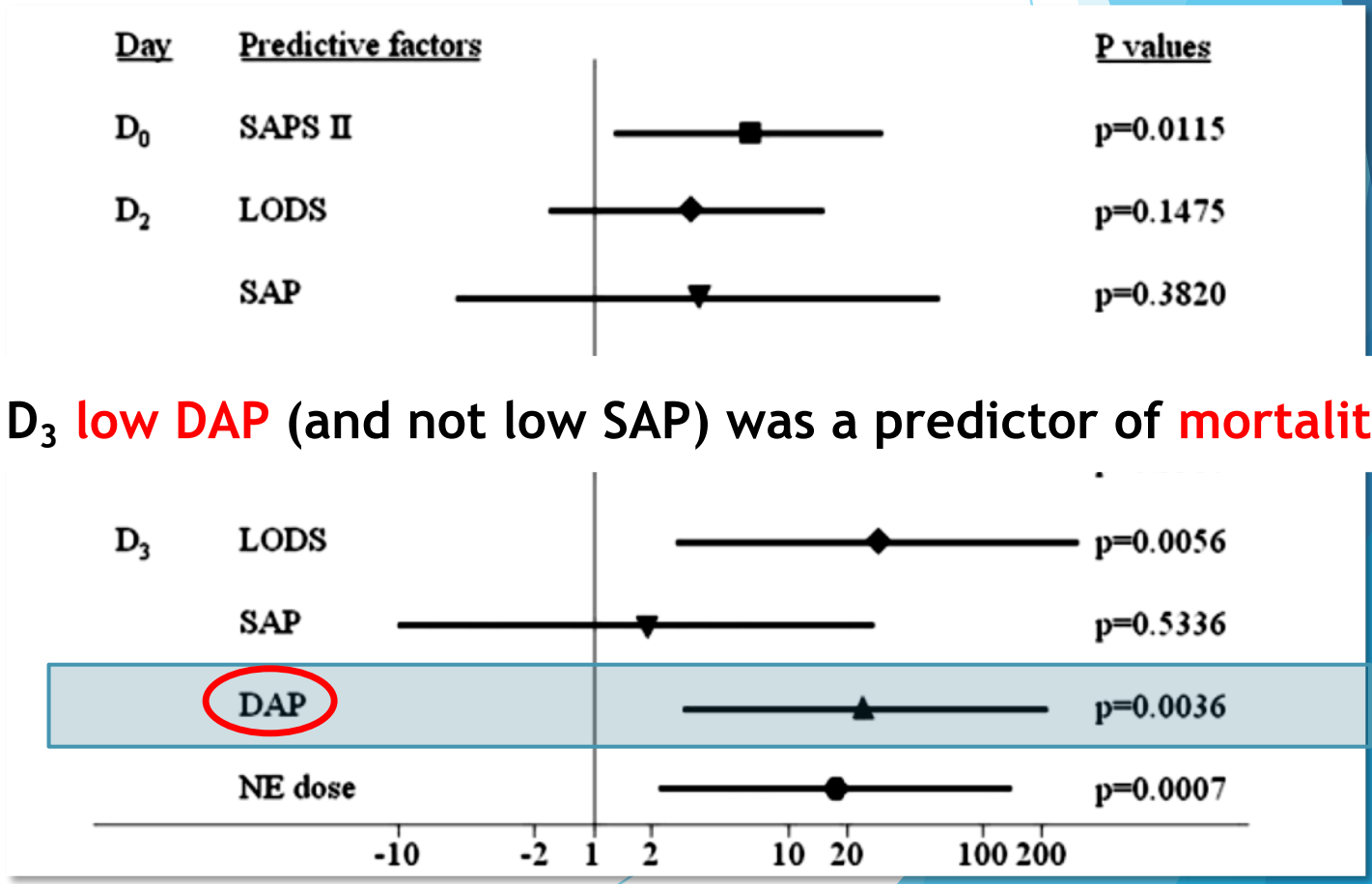
In spite of the **increase** in **LV afterload**, all the indices of **systolic function improved** with early **NE** suggesting an **improved cardiac contractility**

# Diastolic Arterial Blood Pressure: A Reliable Early Predictor of Survival in Human Septic Shock

*Samir Benchekroune, MD, Peter C. J. Karpati, MD, Christine Berton, MD†, Cédric Nathan, MD, Joaquim Mateo, MD, Mansour Chaara, MD, Florence Riché, MD, Marie-Josèphe Laisné, MD, Didier Payen, MD, PhD, and Alexandre Mebazaa, MD, PhD*

*J Trauma.* 2008;64:1188–1195

- **68 septic shock patients**
- **Receiving NE** for at least 72 hrs
- **Observational** study




**At $D_3$ low DAP (and not low SAP) was a predictor of mortality**

Ospina-Tascón et al. Ann. Intensive Care (2020) 10:41
https://doi.org/10.1186/s13613-020-00658-8

Annals of Intensive Care

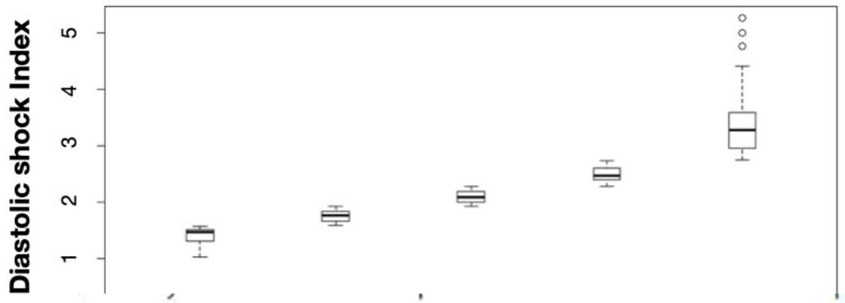
RESEARCH Open Access

# Diastolic shock index and clinical outcomes in patients with septic shock

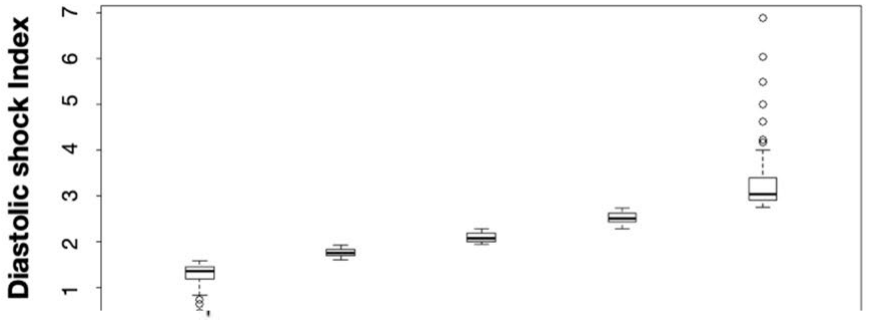
Gustavo A. Ospina-Tascón[1,2*], Jean-Louis Teboul[1,3,4], Glenn Hernandez[1,5], Ingrid Alvarez[1], Alvaro I. Sánchez-Ortiz[1], Luis E. Calderón-Tapia[1], Ramiro Manzano-Nunez[1], Edgardo Quiñones[1], Humberto J. Madriñan-Navia[1], Juan E. Ruiz[1], José L. Aldana[1] and Jan Bakker[1,5,6,7,8]

**Aim:** Relationships between very early HR:DAP ratios: the **diastolic shock index** (DSI), before or at the start of vasopressor and **clinical outcomes**

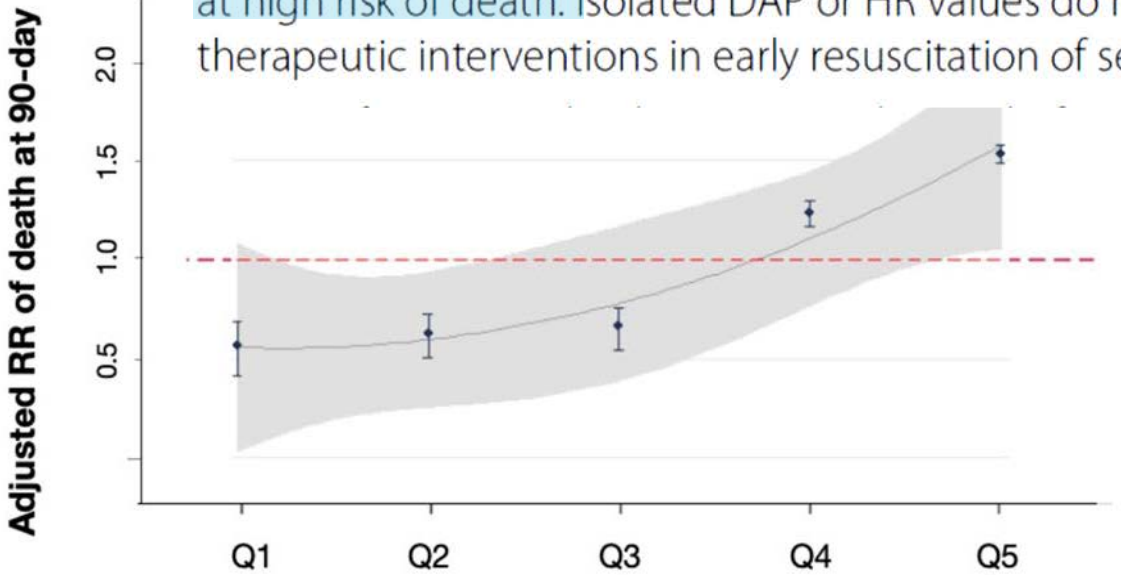
**337 preliminary cohort**

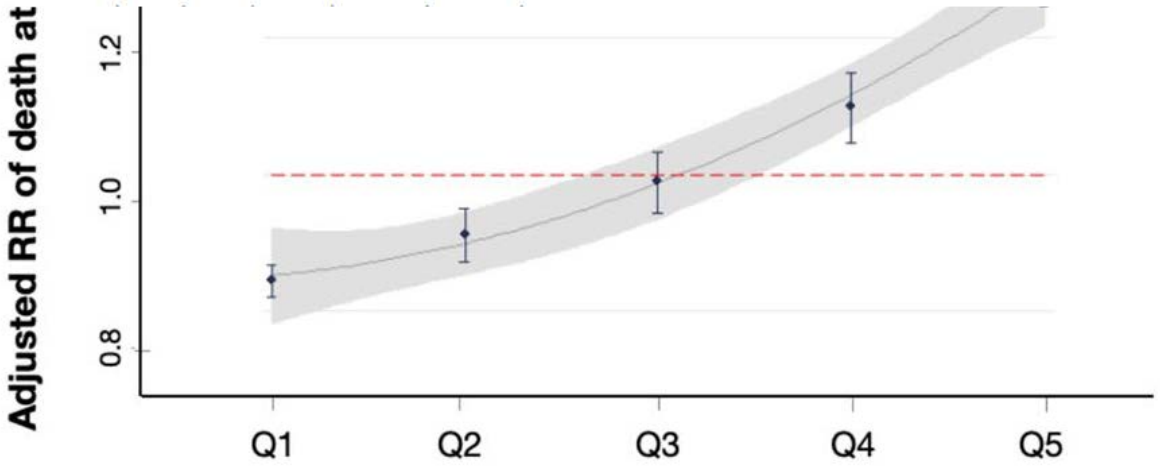



**424 Andromeda cohort**

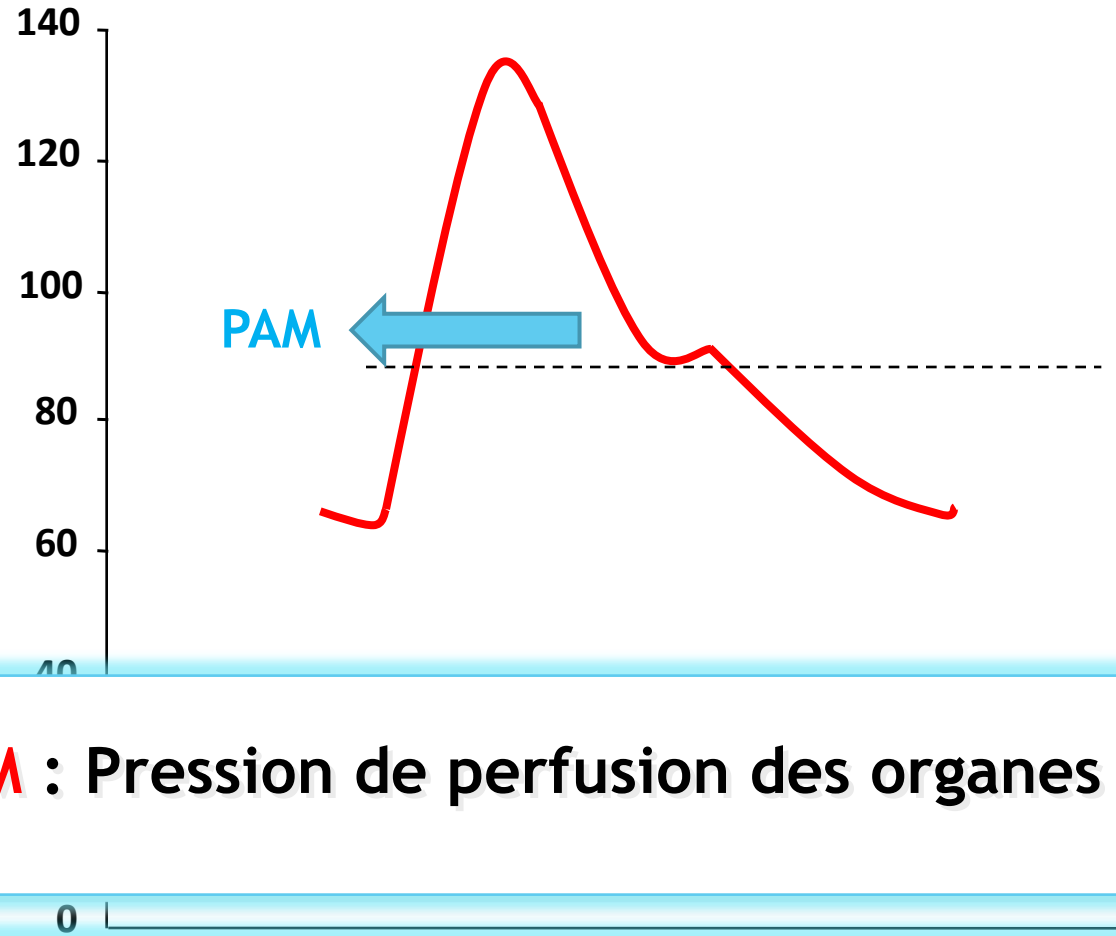



**Conclusions:** DSI at pre-vasopressor and vasopressor start points might represent a very early identifier of patients at high risk of death. Isolated DAP or HR values do not clearly identify such risk. Usefulness of DSI to trigger or to direct therapeutic interventions in early resuscitation of septic shock need to be addressed in future studies.



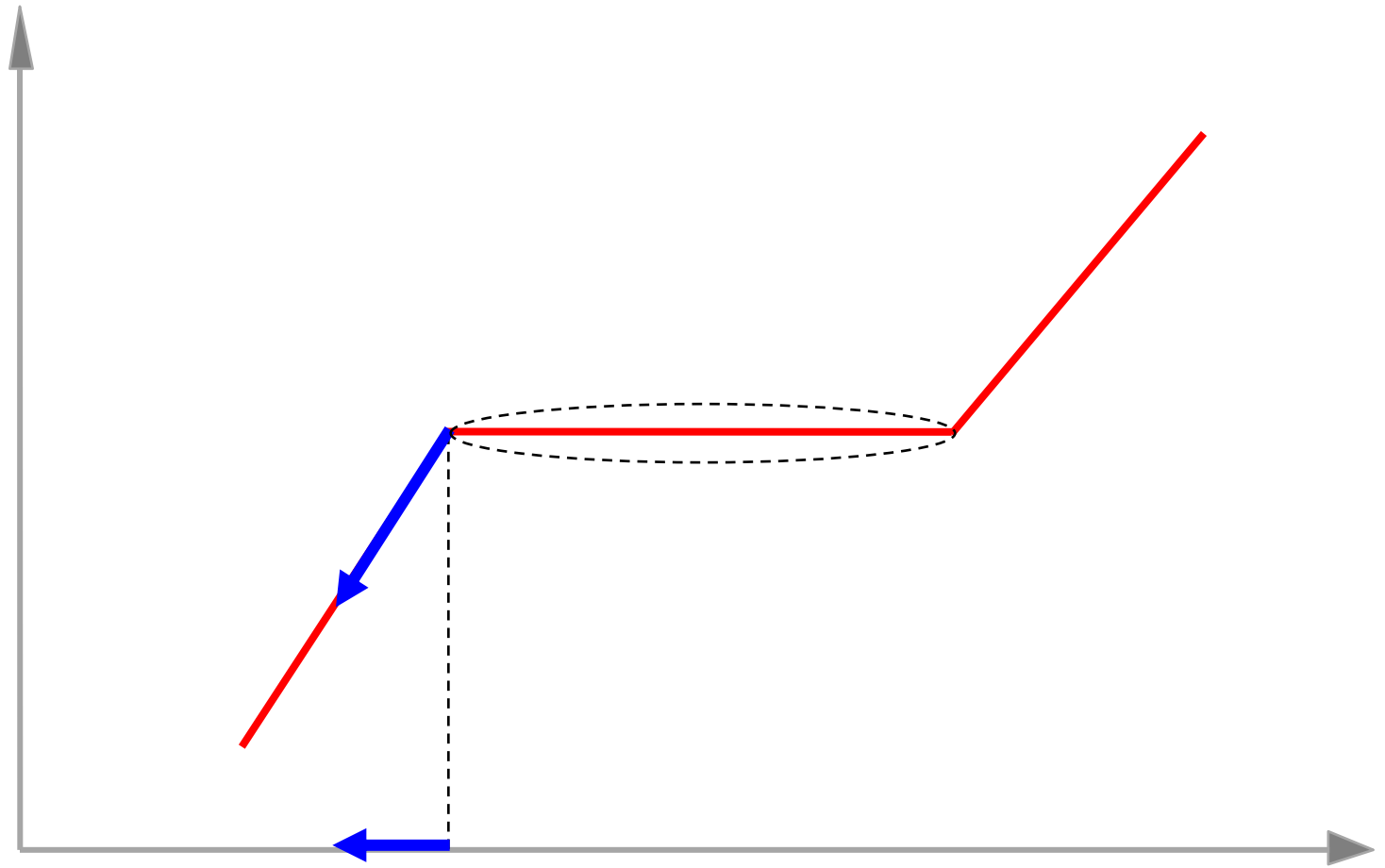
Pression artérielle*(mmHg)*




**PAM** : Pression de perfusion des organes

**PAM** : Cible thérapeutique

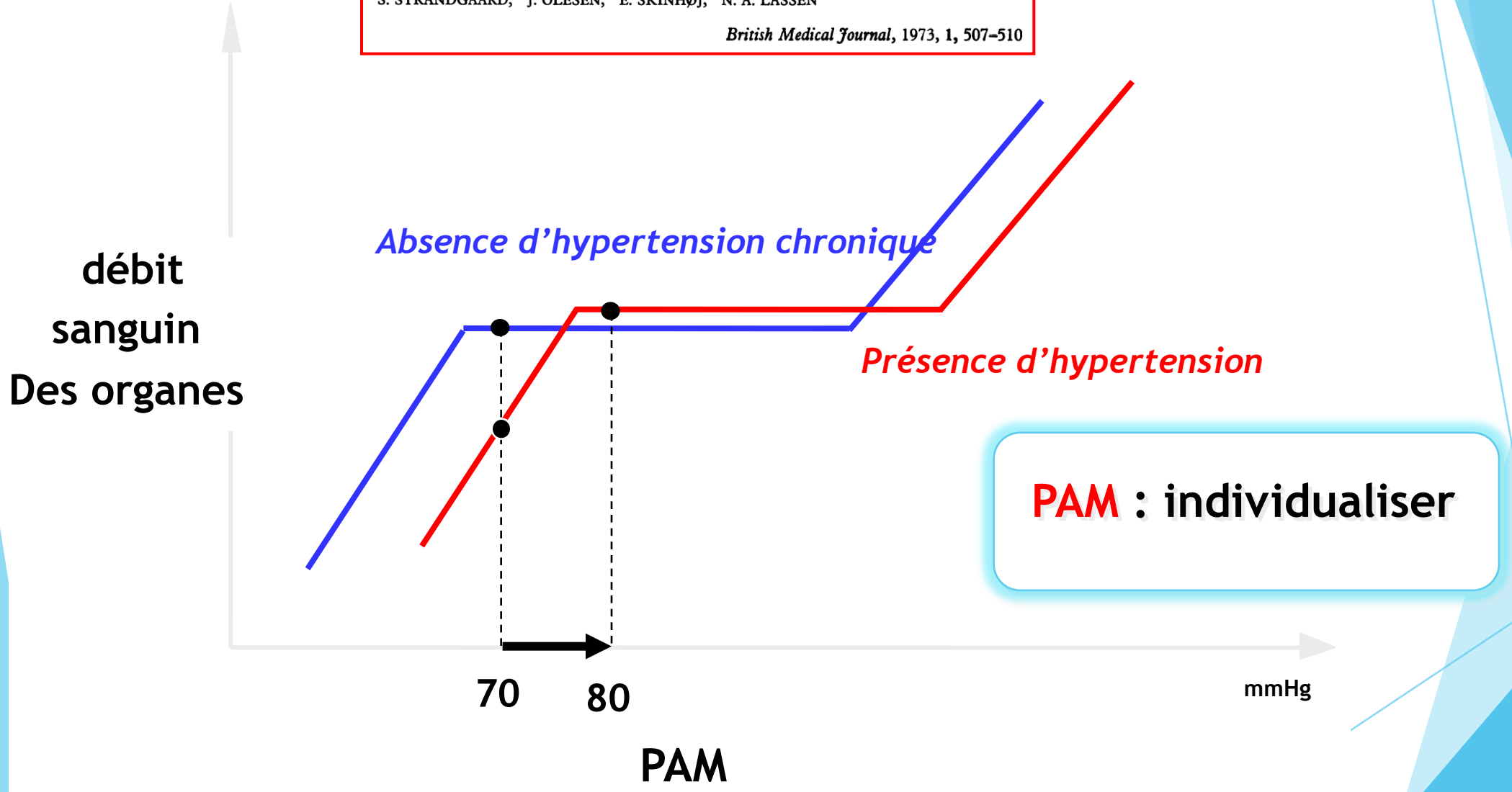
# Autoregulation du débit sanguin



**Autoregulation of Brain Circulation in Severe Arterial Hypertension**

S. STRANDGAARD, J. OLESEN, E. SKINHØJ, N. A. LASSEN

*British Medical Journal*, 1973, **1**, 507–510




**PAM : individualiser**

*Intensive Care Med (2022) 48:1498–1500*

**SPECIAL ISSUE INSIGHT**

# Central venous pressure (CVP)

Olfa Hamzaoui[1*] and Jean-Louis Teboul[2,3]

## CVP as the downstream pressure for organ perfusion

The CVP also reflects the downstream pressure for perfusion of most vital organs (e.g., brain and kidney). The mean perfusion pressure (MPP) of such organs is the difference between mean arterial pressure (MAP) and CVP.

**Pression de perfusion moyenne (PPM = PAM - PVC)** → si PVC basse : **PPM ~ PAM**

Ostermann et al. BMC Nephrology (2017) 18:151
DOI 10.1186/s12882-017-0568-8

BMC Nephrology

RESEARCH ARTICLE Open Access

# Low mean perfusion pressure is a risk factor for progression of acute kidney injury in critically ill patients – A retrospective analysis

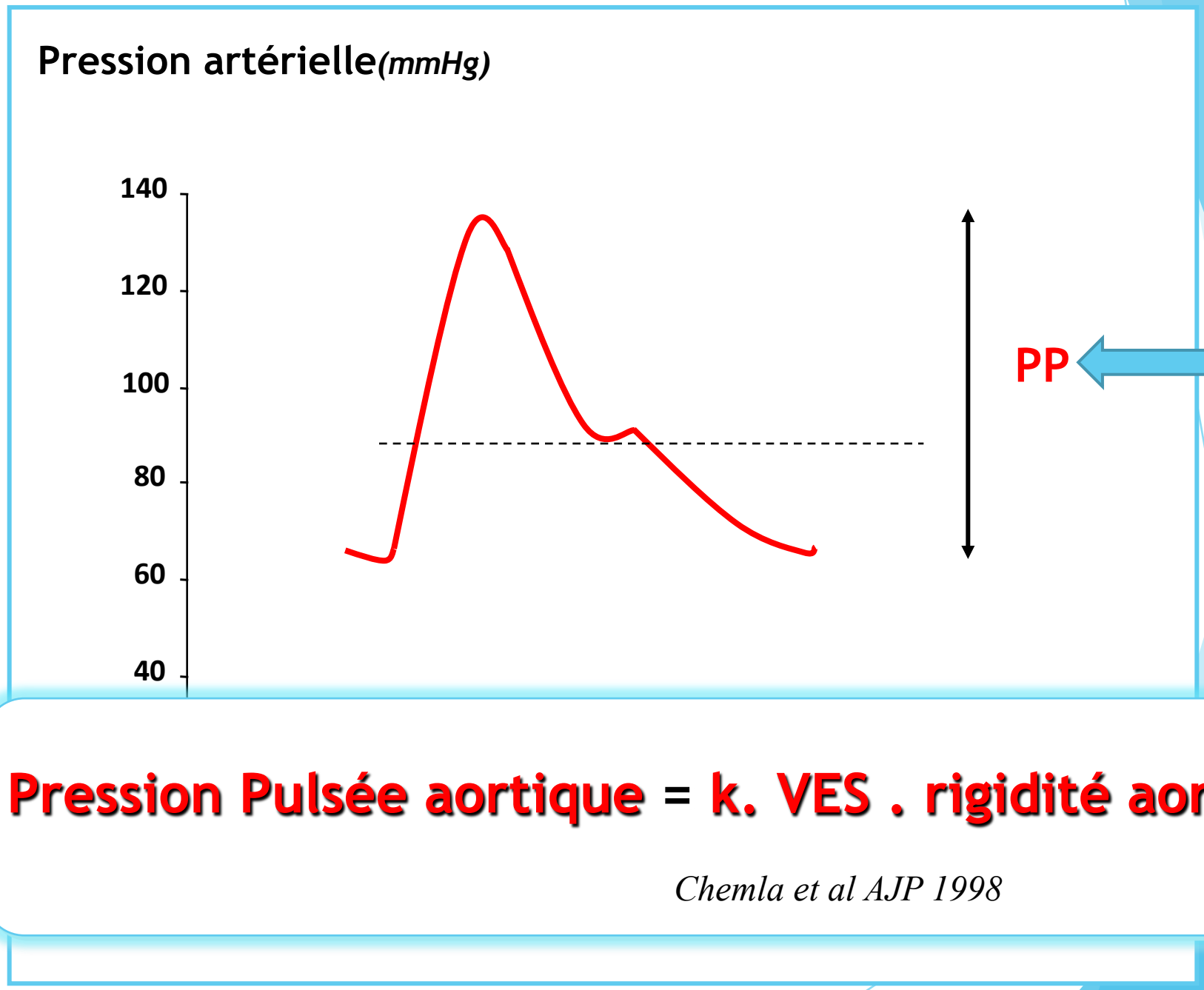
Marlies Ostermann[1*], Anna Hall[2] and Siobhan Crichton[3]

- Analyse **rétrospective** des patients admis en réanimation
- **2118 patients: 790 patients** (37%) ont développé une **IRA**
- **205 équippés** monitorage hémodynamique avancé dans les 12 h IRA stade I.

**Mean perfusion pressure** (MPP = MAP-CVP) but **not MAP** was an independent factor associated with **AKI progression.**

A value of **MPP** of **60 mmHg** was found as a cutoff.

| | | |
|---|---|---|
| Cumulative fluid balance on day of AKI I [ml] | 1.00 (0.99–1.00) | 0.98 |
| MAP <65 mmHg for >1 h in first 12 h after diagnosis of AKI I | 0.97 (0.48–1.96) | 0.93 |




**Pression Pulsée aortique = k. VES . rigidité aortique**

*Chemla et al AJP 1998*

**Pression Pulsée aortique = k. VES . rigidité aortique**

Pour une **rigidité aortique** donnée → **Variation** de **PP aortique** devrait refléter **la variation** du **VES**

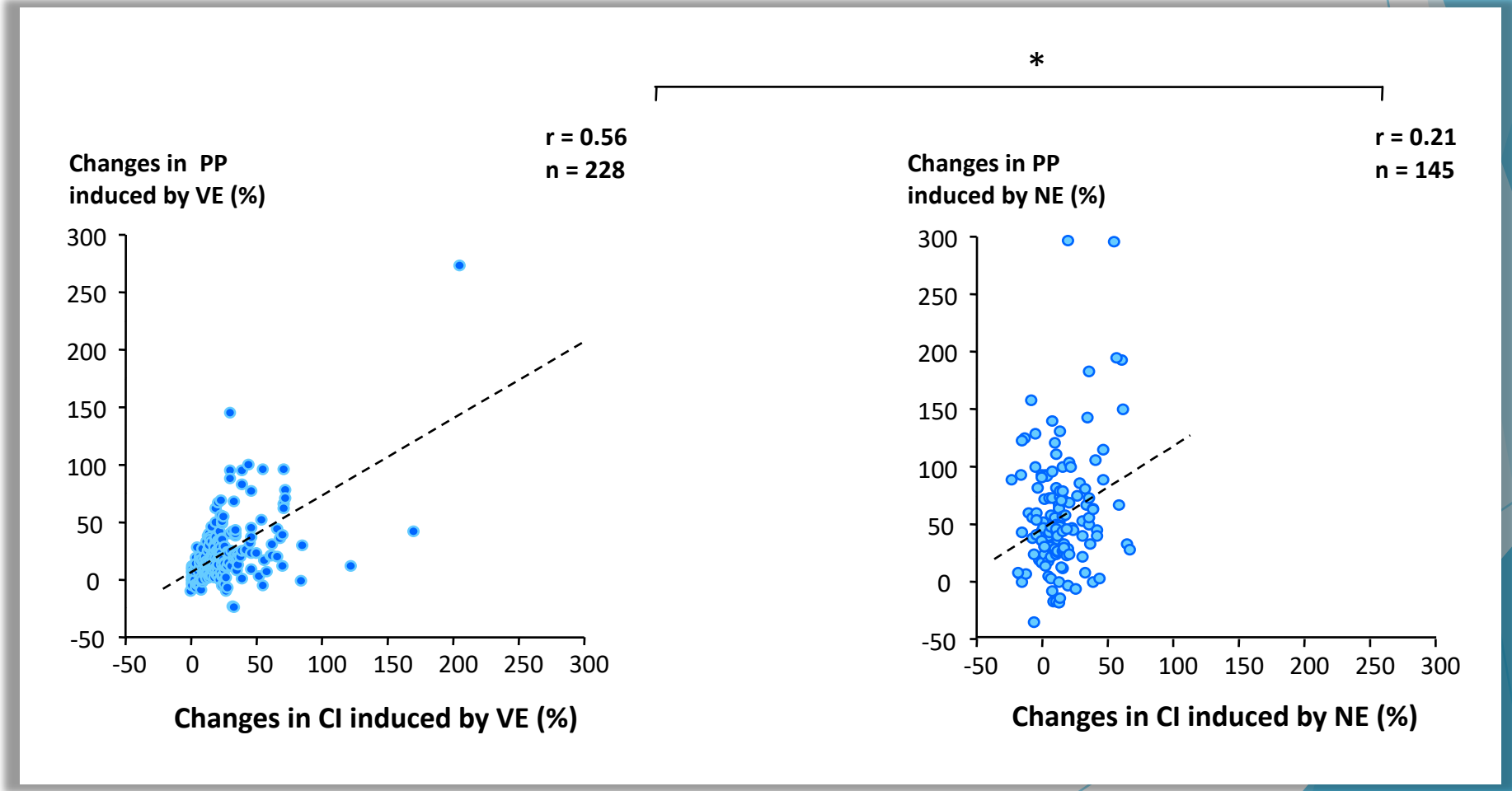
Utile pour suivre la **la variation du VES** sous un traitement

→ **Est-ce que la variation PP périphérique reflète la variation du VES?**

# Arterial pressure allows monitoring the changes in cardiac output induced by volume expansion but not by norepinephrine*

Xavier Monnet, MD, PhD; Alexia Letierce, PhD; Olfa Hamzaoui, MD; Denis Chemla, MD, PhD; Nadia Anguel, MD; David Osman, MD; Christian Richard, MD; Jean-Louis Teboul, MD, PhD

Crit Care Med 2011; 39:1394–1399



Intensive Care Med (2011) 37:942–949

ORIGINAL

Nicolas Dufour
Denis Chemla
Jean-Louis Teboul
Xavier Monnet
Christian Richard
David Osman

# Changes in pulse pressure following fluid loading: a comparison between aortic root (non-invasive tonometry) and femoral artery (invasive recordings)

**Table 5** Relationship between changes in PP and SV after volume expansion in young and elderly patients

| PP versus SV relationship | Age <60 years | | Age ≥60 years | |
|---|---|---|---|---|
| | *r* | *p* | *r* | *p* |
| Femoral | 0.46 | 0.03 | 0.75 | <0.01 |

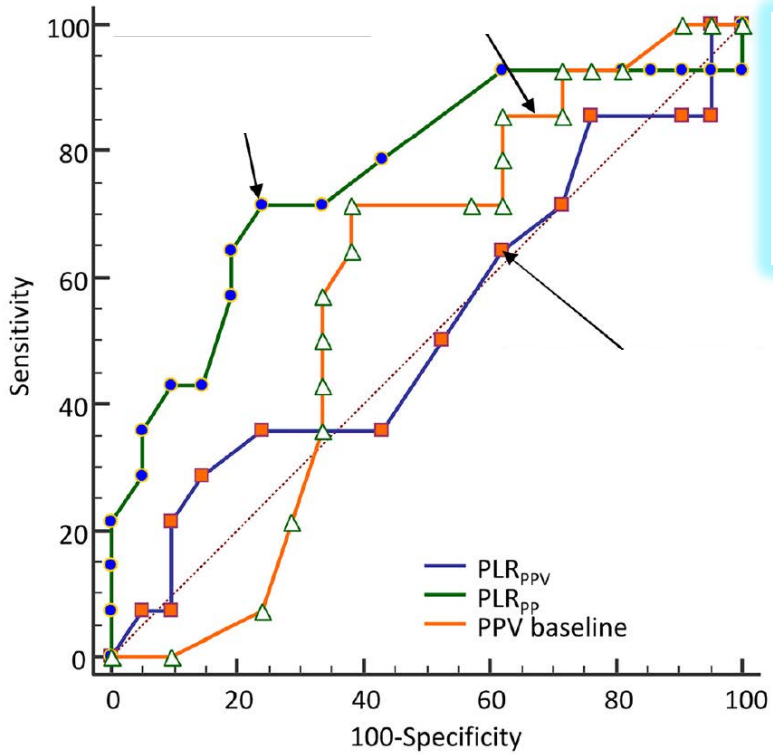
# Dynamic changes of pulse pressure but not of pulse pressure variation during passive leg raising predict preload responsiveness in critically ill patients with spontaneous breathing activity

Rui Shi, MD, PhD [a,b], Francesca Moretto, MD [a], Dominique Prat, MD [c], Frederic Jacobs, MD [c], Jean-Louis Teboul, MD, PhD [a,b], Olfa Hamzaoui, MD [c,*]

Journal of Critical Care 72 (2022) 154141

33 Patients ventilated with pressure support mode or totally spontaneously breathing

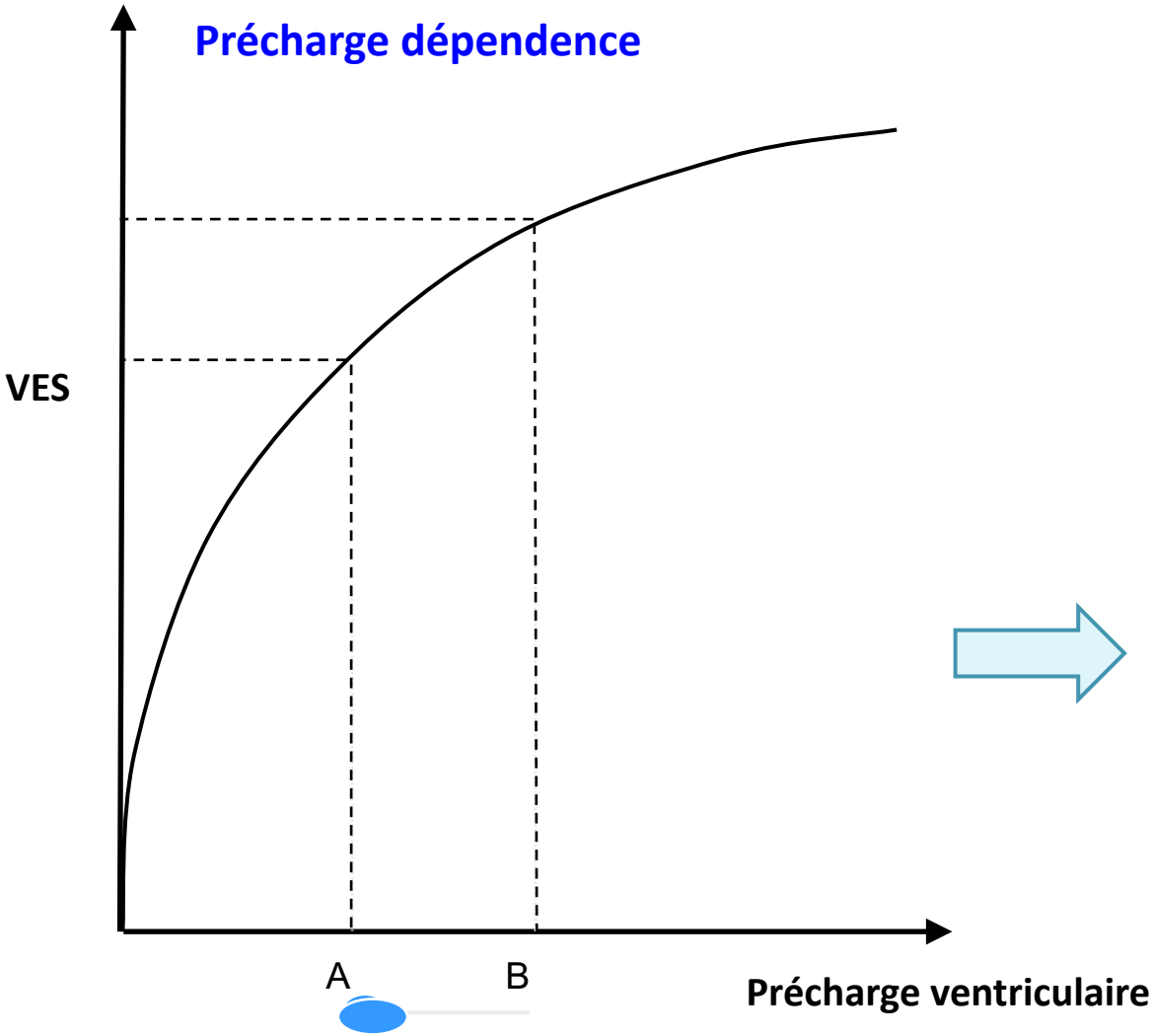
To evaluate Delta (PP) and/or pulse pressure variation (PPV) during (PLR) can be used to evaluate preload responsiveness

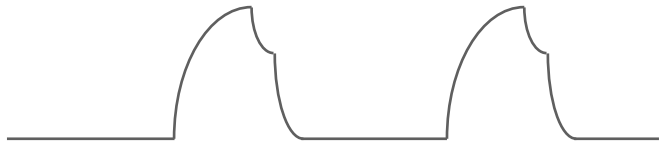



in patients **with spontaneous breathing activity**, **the increase in PP of equal to or higher than 2 mmHg during PLR** may be **helpful to discriminate** preload **responders** from **non-responders** with fair accuracy

- Analyse des valeurs de la pression artérielle statique
- **Analyse de la variation dynamique de la pression artérielle**
- Monitorage continue du débit cardiaque

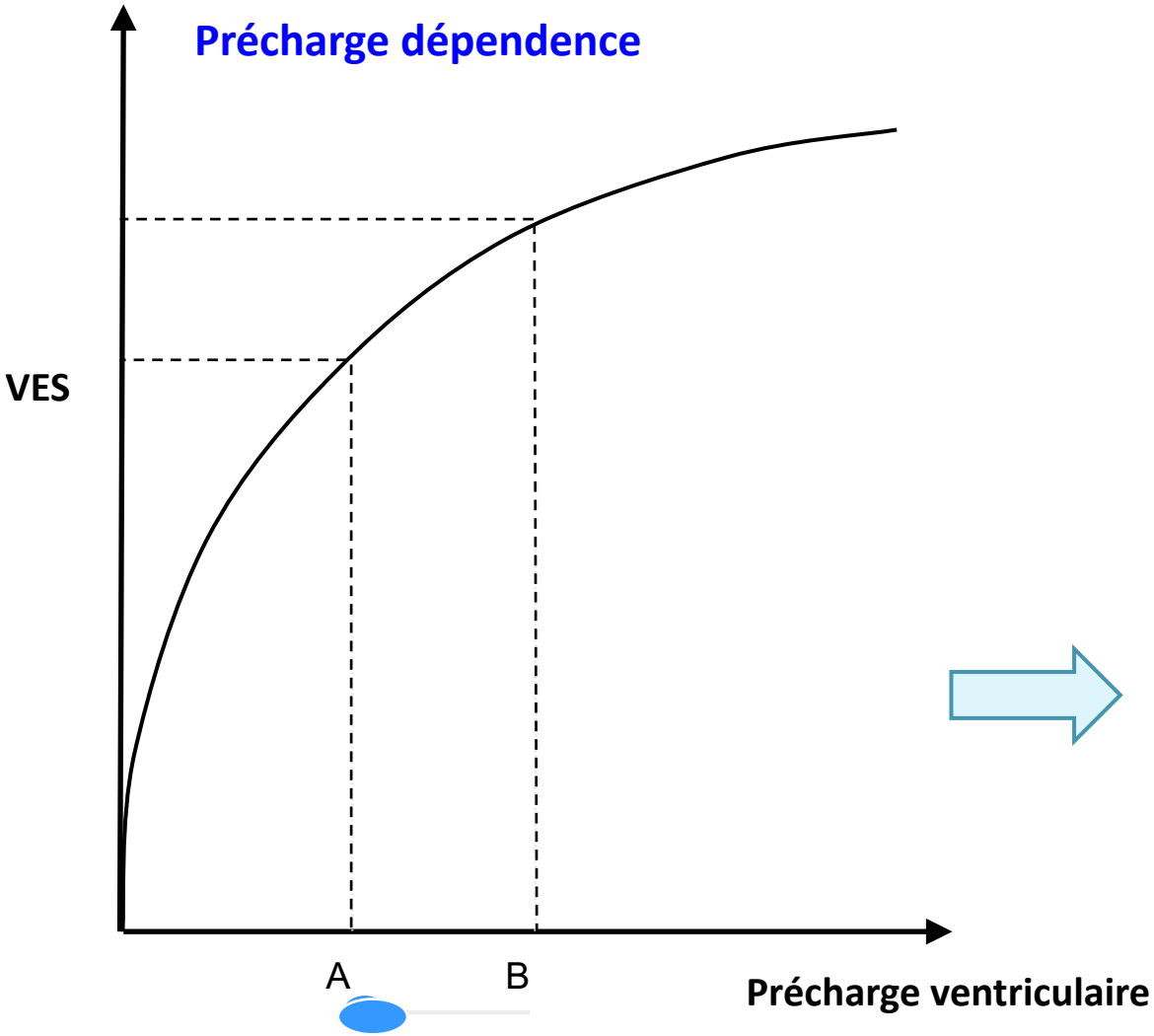
# Intéraction Coeur-Poumon

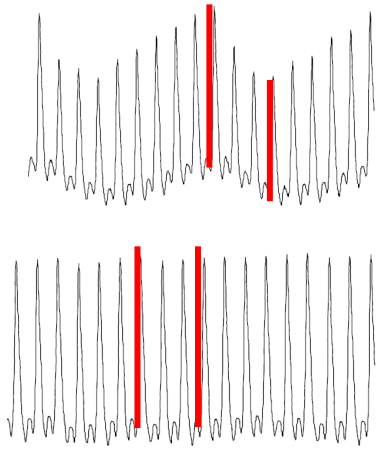


**VM** peut induire **une variation cyclique de la précharge** et **du VES** **en cas précharge dépendance** des deux ventricules

# Intéraction Coeur-Poumon



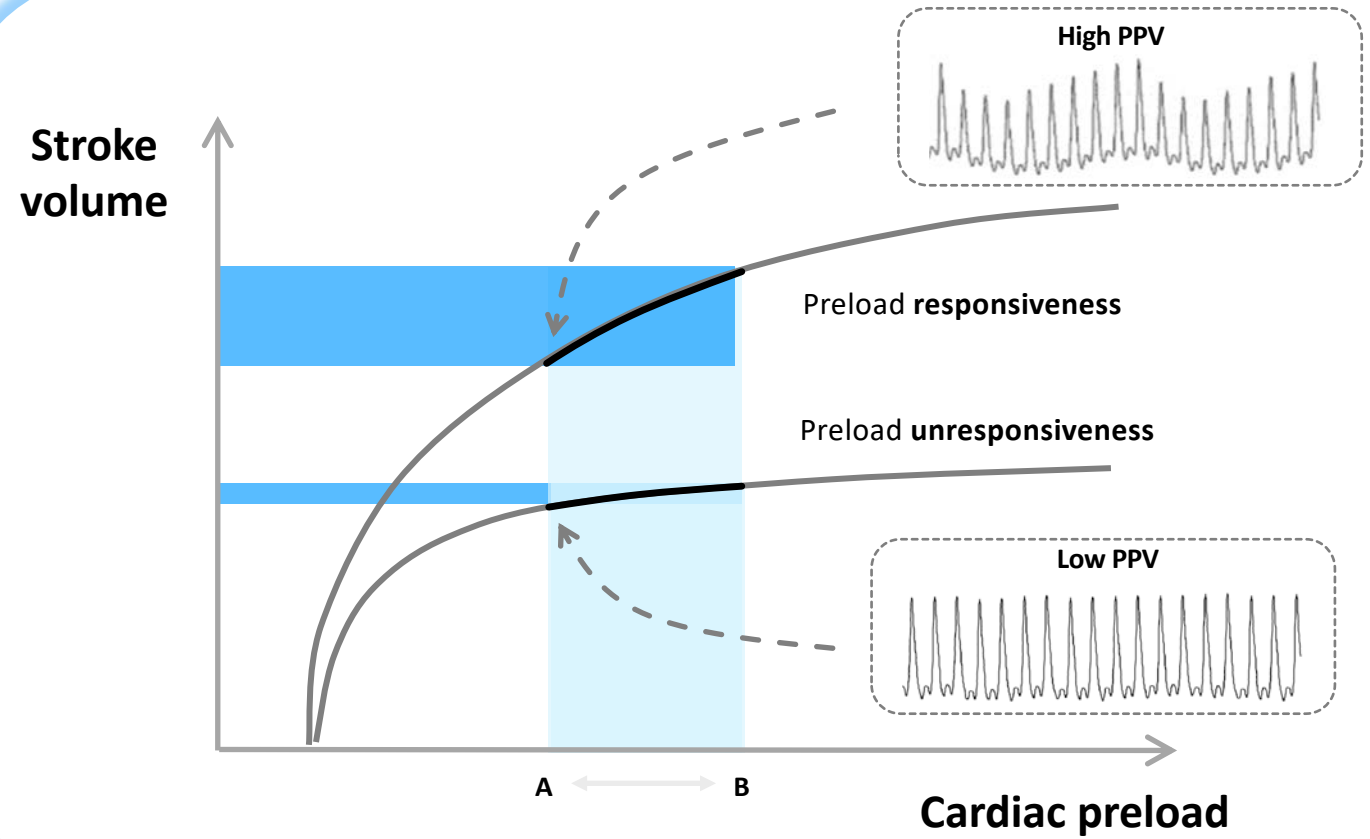
VPP ou delta PP

Avec une valeur constante de la compliance aortique PP peut réfleter VES

# Arterial Pulse Pressure Variation with Mechanical Ventilation

Jean-Louis Teboul[1], Xavier Monnet[1], Denis Chemla[2], and Frédéric Michard[3]

Am J Respir Crit Care Med Vol 199, Iss 1, pp 22–31, Jan 1, 2019

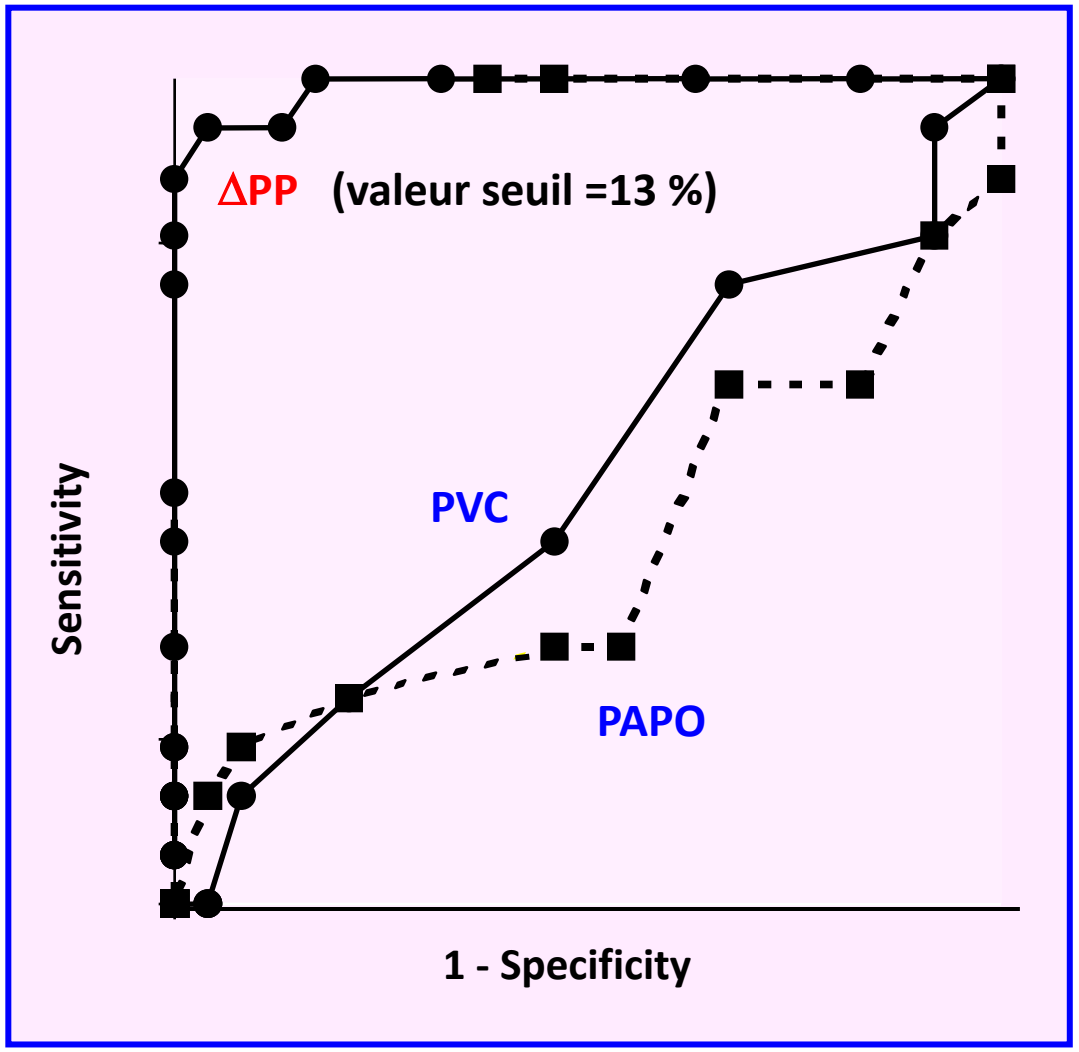



## Physiologie Appliquée

**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 2000,162:134–138

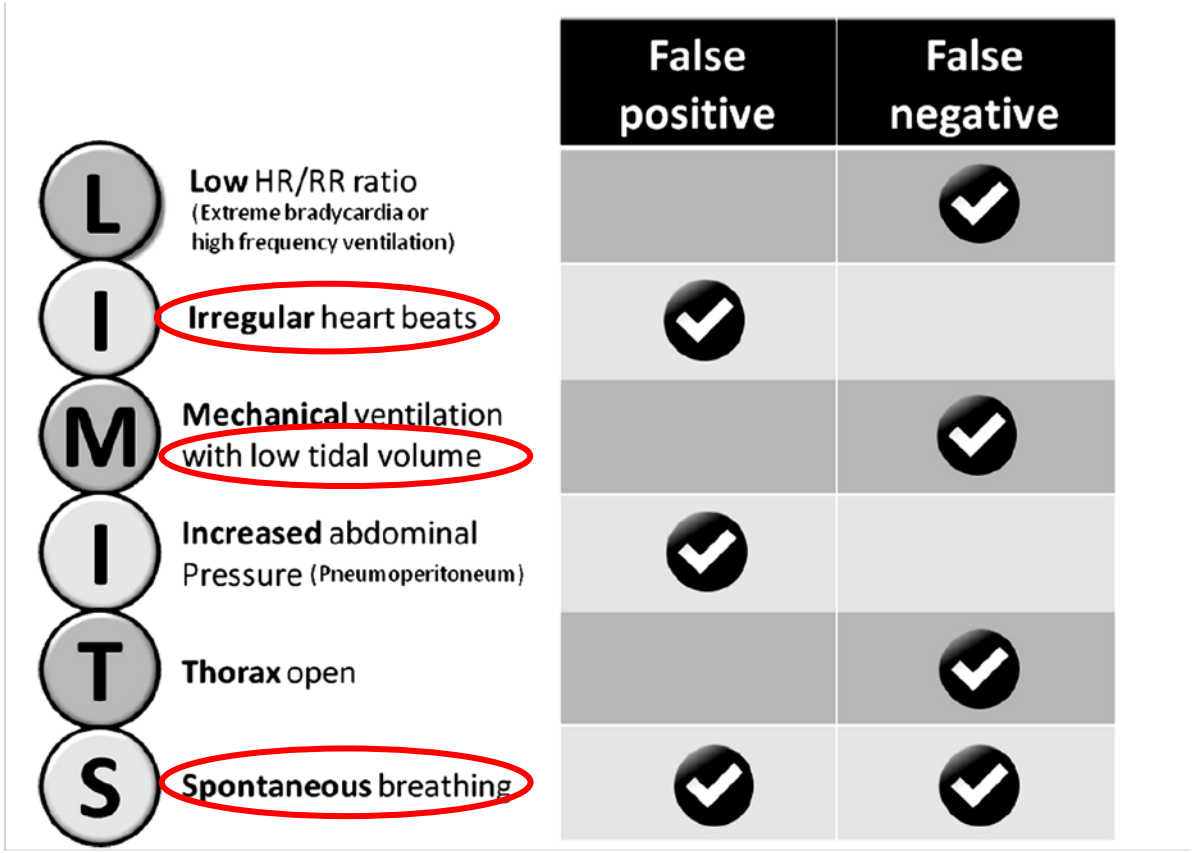



$$\Delta PP = \frac{PP_{max} - PP_{min}}{(PP_{max} + PP_{min}) / 2}$$

# Applicability of pulse pressure variation: how many shades of grey?

Frederic Michard[1*], Denis Chemla[2] and Jean-Louis Teboul[3]

*Critical Care* (2015) 19:144



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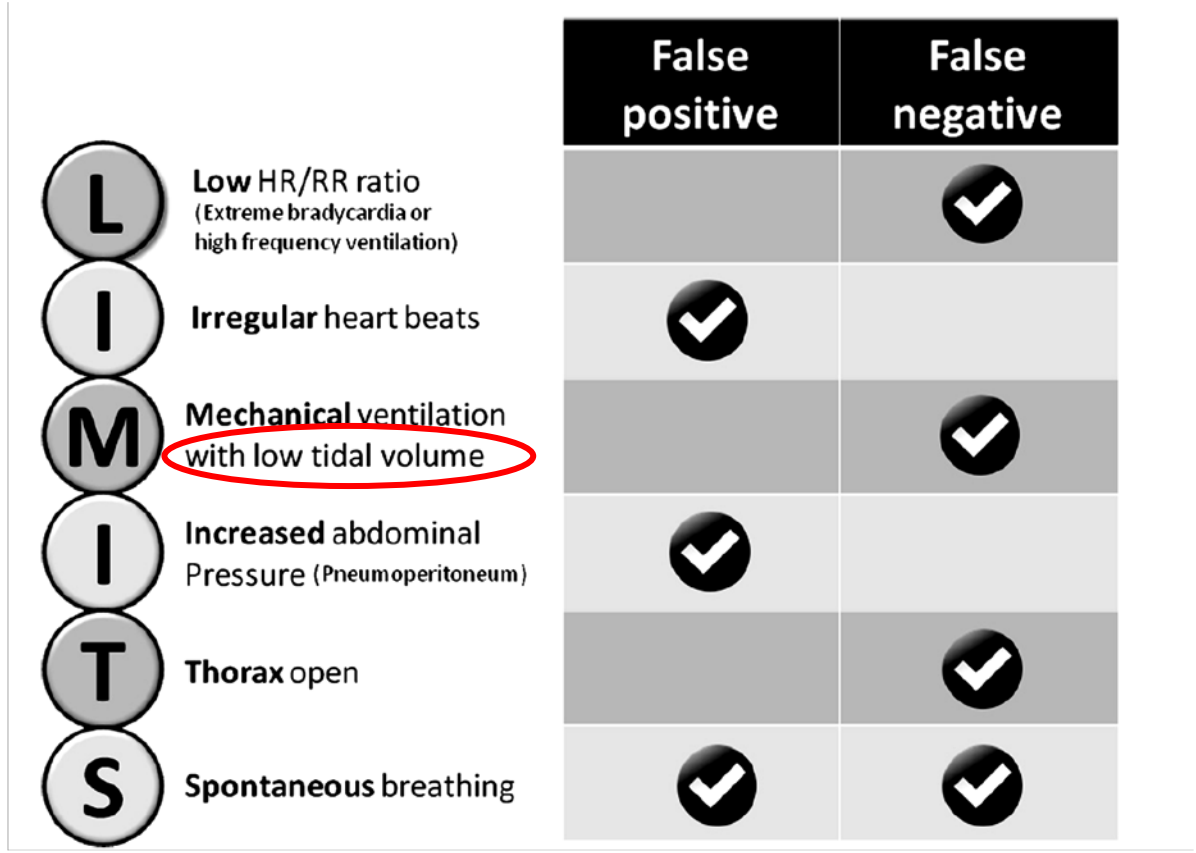
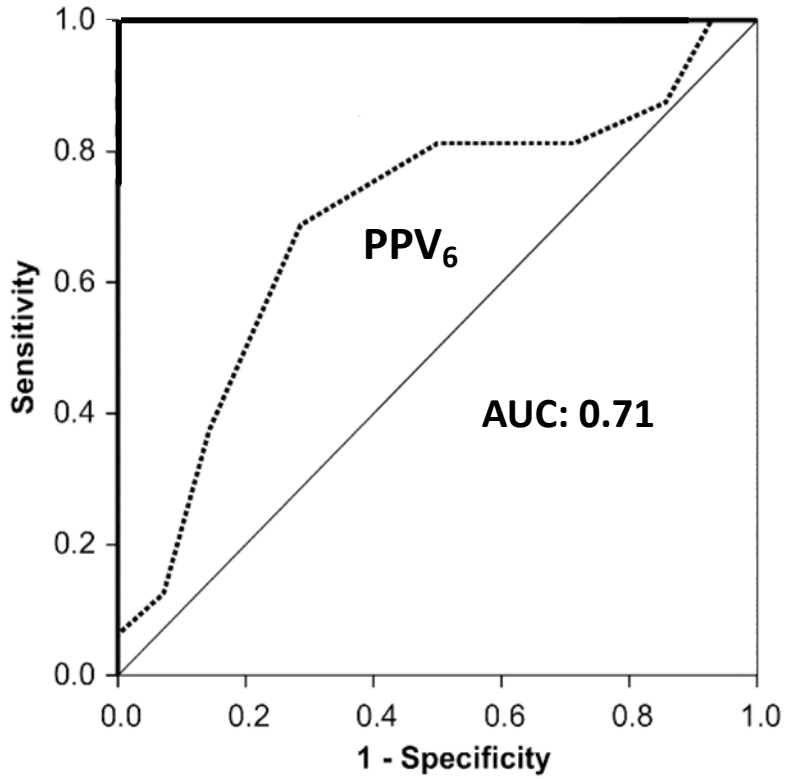


## The Changes in Pulse Pressure Variation or Stroke Volume Variation After a "Tidal Volume Challenge" Reliably Predict Fluid Responsiveness During Low Tidal Volume Ventilation

Sheila Nainan Myatra, MD, FCCM[1]; Natesh R. Prabu, MD[1]; Jigeeshu Vasishtha Divatia, MD, FCCM[1]; Xavier Monnet, MD, PhD[2]; Atul Prabhakar Kulkarni, MD, FICCM[1]; Jean-Louis Teboul, MD, PhD[2]

*Crit Care Med* 2017; 45:415–421

- **20** patients en insuffisance circulatoire aigue
- Monitorage continu du débit cardiaque
- Ventilés bas **Volume courant**




**ΔPP** à **6 mL/kg ne peut pas** prédire la réponse au remplissage

## The Changes in Pulse Pressure Variation or Stroke Volume Variation After a "Tidal Volume Challenge" Reliably Predict Fluid Responsiveness During Low Tidal Volume Ventilation

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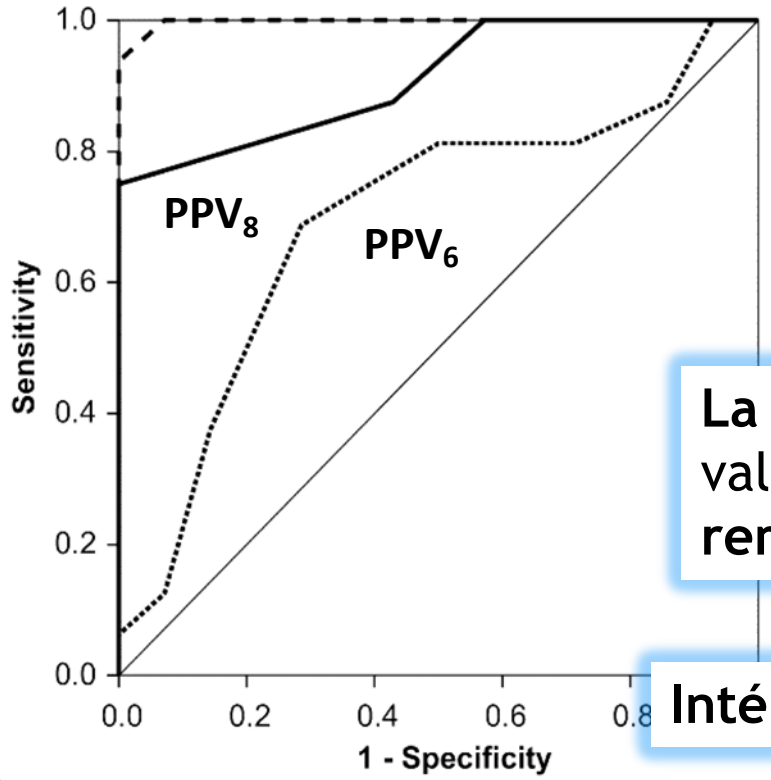
*Crit Care Med* 2017; 45:415–421

$\Delta PPV_{6-8}$ **cut-off 3.5**




**Tidal volume challenge:**

**Augmentation t**ransitoire (1 min)

**du VT de 6** à **8 mL/kg**

**La variation du Delta PP** après **TV challenge** est **supérieure** à la valeur du Delta PP à 6 mL/kg **pour la prédiction de la réponse au remplissage.**

**Intérêt pratique : pas de nécessité de mesure du débit cardiaque**

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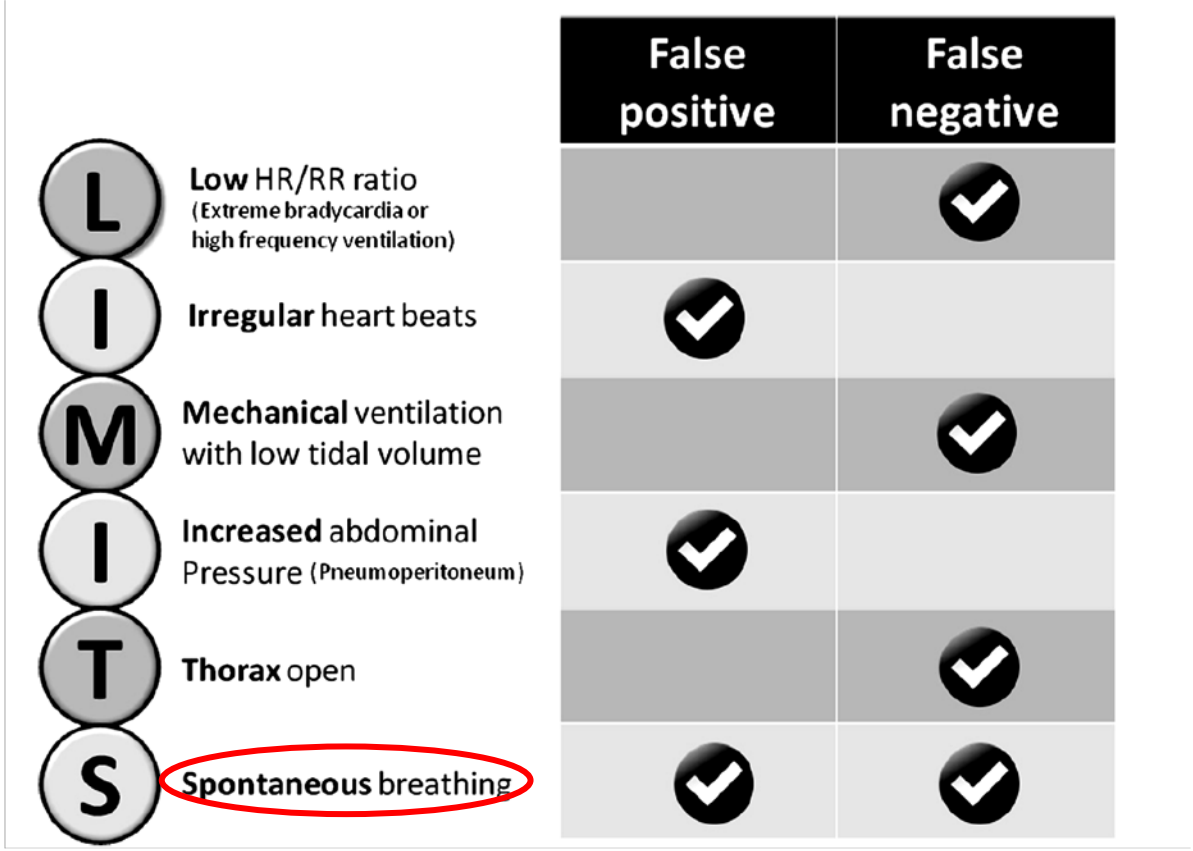
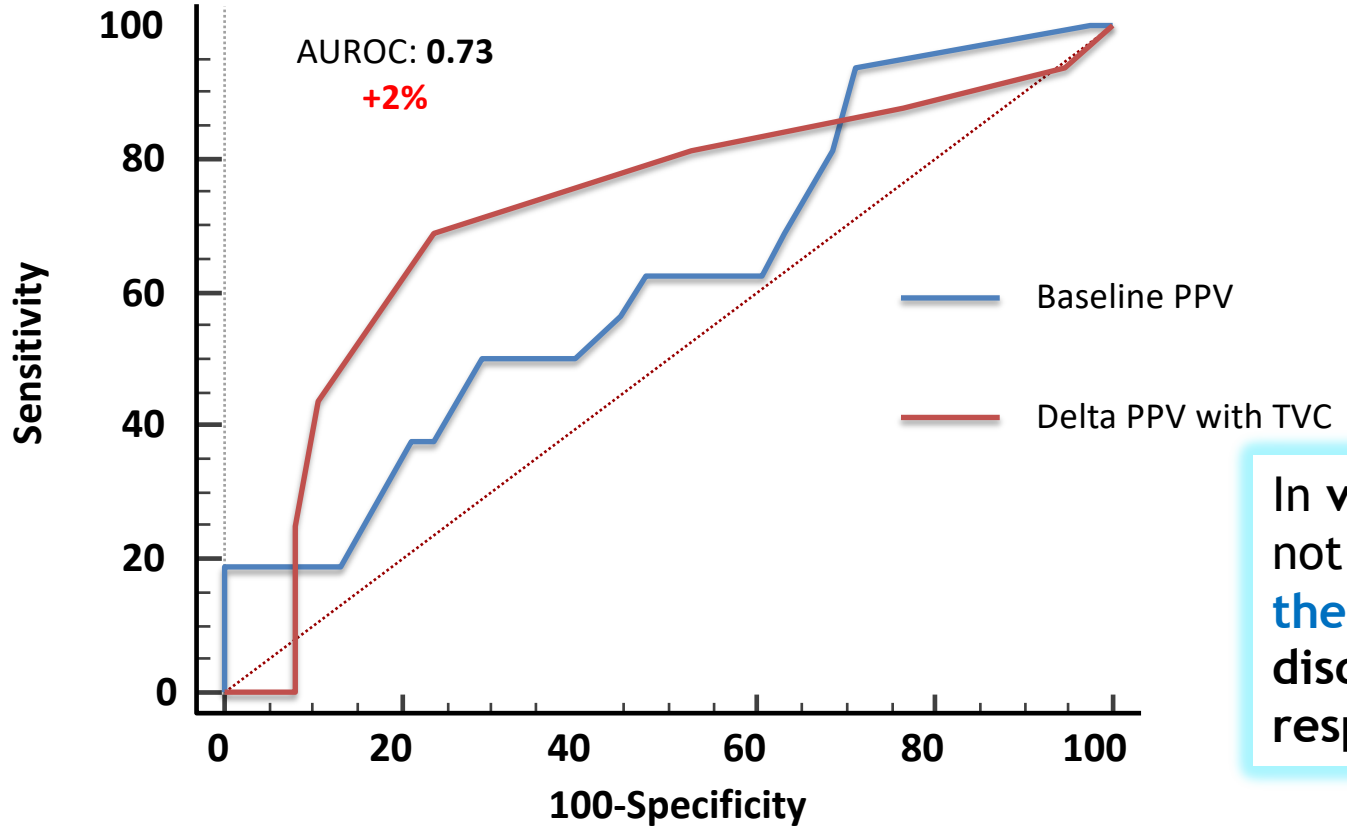


## Changes in pulse pressure variation to assess preload responsiveness in mechanically ventilated patients with spontaneous breathing activity: an observational study

Olfa Hamzaoui[1,*], Rui Shi[2,3], Simone Carelli[2], Benjamin Sztrymf[1,3], Dominique Prat[1], Frederic Jacobs[1], Xavier Monnet[2,3], Corentin Gouëzel[1] and Jean-Louis Teboul[2,3]

*British Journal of Anaesthesia* 2021

- **54 patients** VM mais avec **cycles de VS**
- Tester précharge dépendance
- Augmentation de **l'ITV>12%**




In **ventilated patients with SB activity**, PPV does not predict preload responsiveness. However, **the the increase in PPV during a TVC** help **discriminating preload responders from non-responders** with moderate accuracy

**Changes in pulse pressure variation to assess preload responsiveness in mechanically ventilated patients with spontaneous breathing activity: an observational study**

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*British Journal of Anaesthesia* 2021

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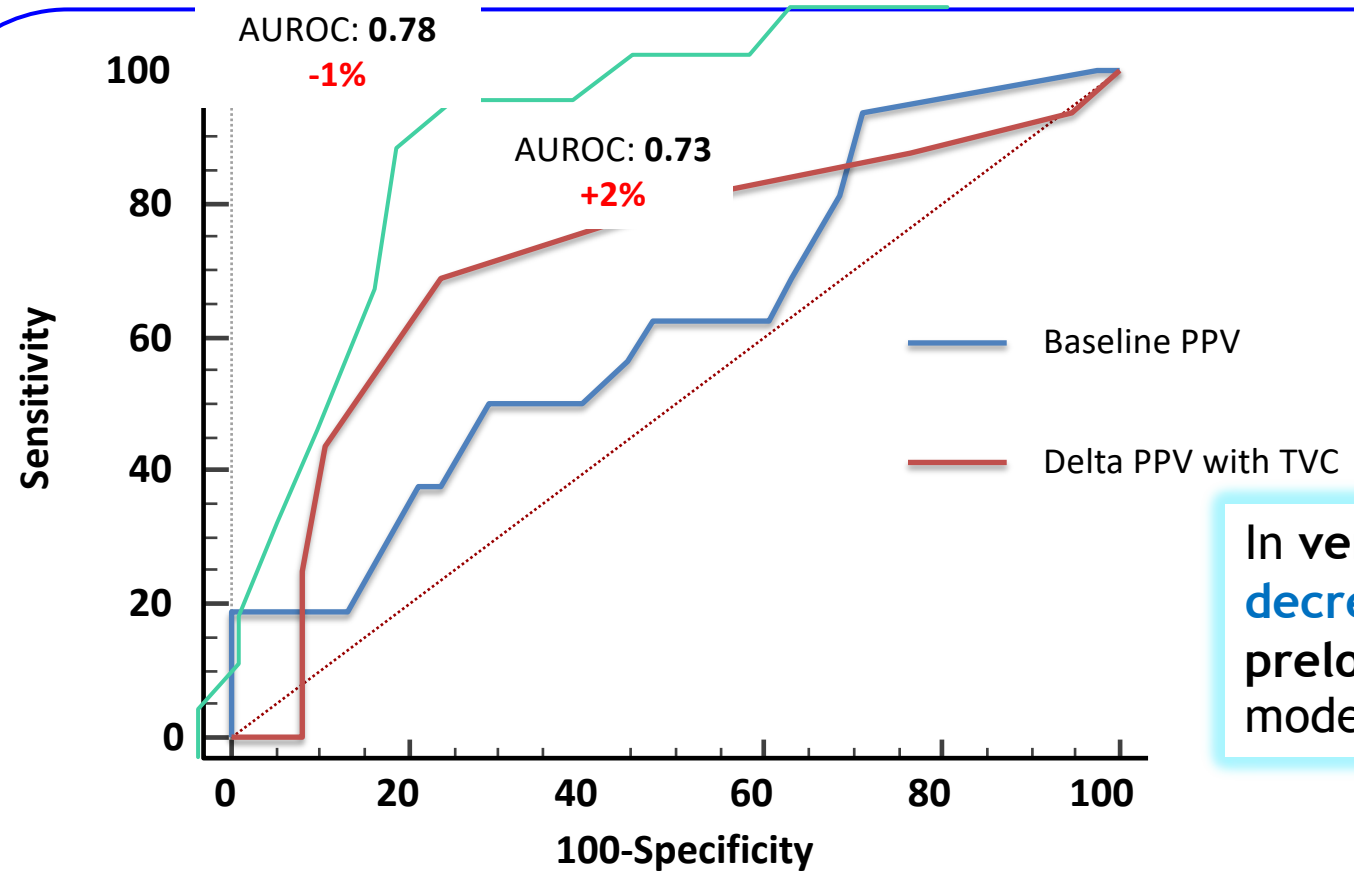
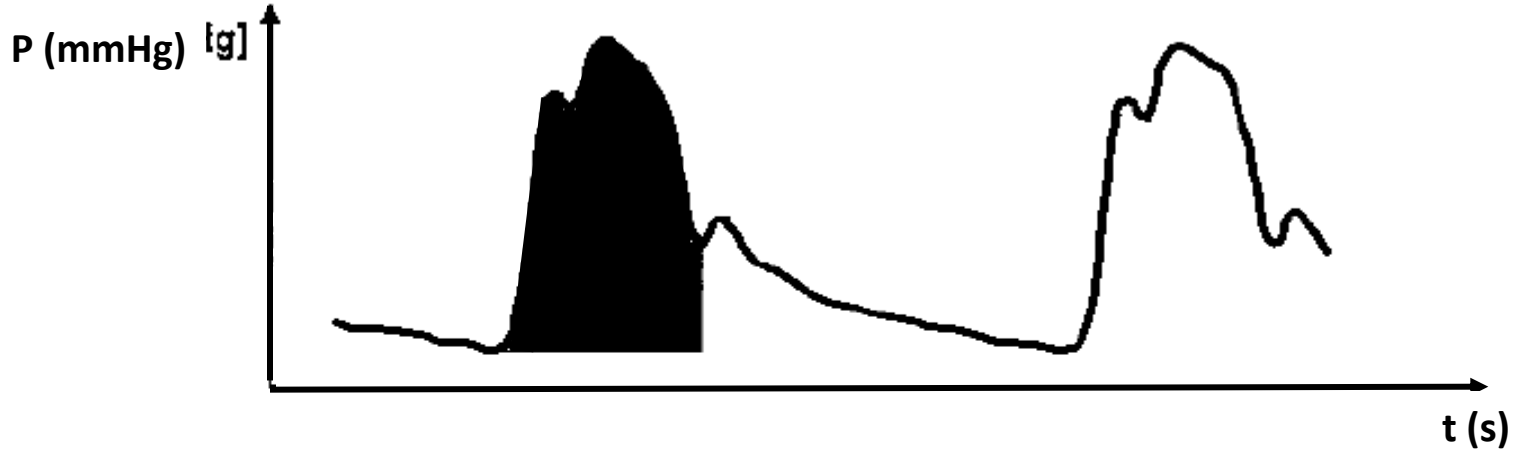



In **ventilated patients with SB activity**, **the decrease of PPV during PLR** help **discriminating preload responders from non-responders** with moderate accuracy

- Analyse des valeurs de la pression artérielle statique
- Analyse de la variation dynamique de la pression artérielle
- **Monitorage continue du débit cardiaque**

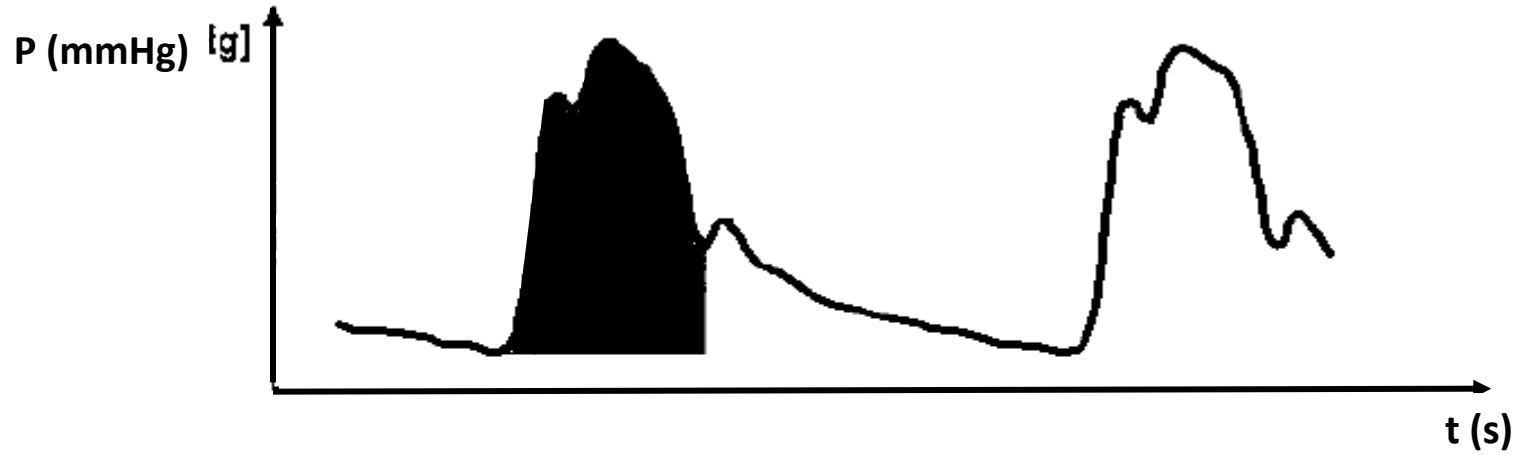
# L’analyse de l’onde de pouls




L’ algorithme est dérivé de l’**algorithme initial de Wesseling**

**Volume d’éjection systolique: l’aire sous la partie systolique de la courbe / impedance aortique**

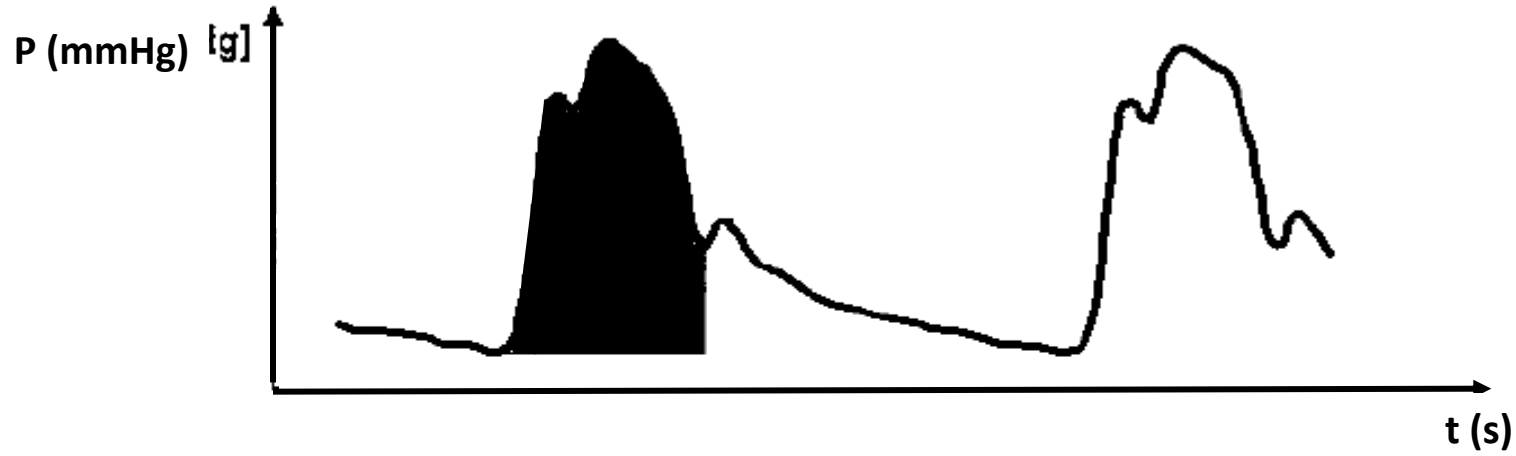
# L'analyse de l'onde de pouls




$$PCCO = cal \cdot HR \cdot \int_{systole} (P(t)/SVR + C(p) \cdot dP/dt)\, dt$$

- Facteur de calibration Spécifique au patient (determiné à la thermodilution)
- Surface sous la courbe
- compliance
- La forme de la courbe

# L’analyse de l’onde de pouls




$$PCCO = cal \cdot HR \cdot \int_{systole} (P(t)/SVR + C(p) \cdot dP/dt)\, dt$$

At **the time of calibration**, **arterial compliance is** calculated from the time constant of the pressure decay in diastole (τ) and SVR (compliance= τ /SVR).

**Compliance and resistance** are **updated beat-to-beat** according to a proprietary algorithm

Effects of changes in vascular tone on the agreement between pulse contour and transpulmonary thermodilution cardiac output measurements within an up to 6-hour calibration-free period*

Olfa Hamzaoui, MD; Xavier Monnet, MD, PhD; Christian Richard, MD; David Osman, MD; Denis Chemla, MD, PhD; Jean-Louis Teboul, MD, PhD

Crit Care Med 2008; 36:434–440

**Seven subsets of CI pairs:** intervals of time elapsed from the previous calibration

**Percentage error** = 2 SD/mean ≈ **35 %** … > 30 %

**n = 400**

| Intervals of Time (Elapsed from the Previous Calibration) | n | $r^2$ | $p$ | Bias ± SD, L/min/m$^2$ | Percentage Error |
|---|---|---|---|---|---|
| Within the first half hour | 60 | .79 | <.001 | 0.04 ± 0.47 | 27 |
| Between 30 mins and 1 hr | 72 | .74 | <.001 | 0.07 ± 0.46 | 26 |
| Between 1 and 2 hrs | 66 | .72 | <.001 | 0.09 ± 0.58 | 32 |
| Between 2 and 3 hrs | 59 | .65 | <.001 | 0.16 ± 0.66 | |
| Between 3 and 4 hrs | 45 | .65 | <.001 | 0.03 ± 0.63 | |
| Between 4 and 5 hrs | 47 | .62 | <.001 | 0.14 ± 0.63 | |
| Between 5 and 6 hrs | 51 | .62 | <.001 | 0.13 ± 0.66 | 36 |

**the percentage error was <30%** only **in the two first ones** (27% and 26%, respectively).

# Que doit-on retenir?

**La pression artérielle est un vrai outil de monitorage**

- Toutes les **composantes statiques** de la pression artérielle(**PAS**, **PAD, PAM et PP**) sont **importantes à considérer** lors de la prise en charge des patients en réanimation
  - **PAS** : reflète **la postcharge VG**
  - **PAD :** peut être utilisé **comme « trigger » pour débuter les vasopresseurs**
  - **PAM** : **une cible thérapeutique**
  - PP : peut être utilisé comme **un substitut du VES**

- La **variabilité de la PP (deltaPP) sous VM** peut-être utilisée comme un indicateur de **précharge dépendance**. Les **variations** de **deltaPP** lors de **tests dynamiques (PLR, TVC)** peuvent aider si deltaPP non interprétable

- L'analyse **en temps réel** de **l'onde de pouls** permet de **mesurer et de monitorer** battement par battement **le débit cardiaque**

Merci pour votre attention