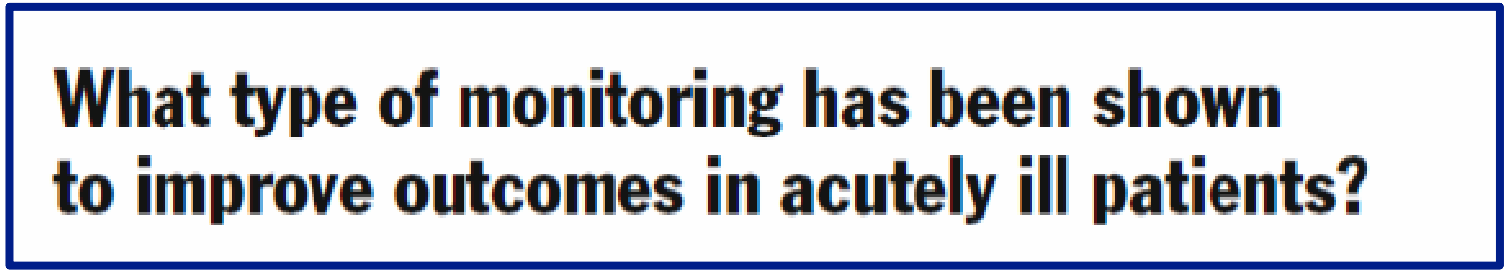
Monitorage Hémodynamique non-invasif au bloc opératoire aujourd'hui

Marie-Evelyne Hamant (IADE) et Pr Matthieu Biais (MAR)

Pôle Anesthésie et de Réanimation - CHU de Bordeaux



What type of monitoring has been shown to improve outcomes in acutely ill patients?

Ospina-Tascon et al. Intensive Care Med 2008

What type of monitoring has been shown to improve outcomes in acutely ill patients?

- PVC : NS sur la mortalité
- CAP: 16 études : 14/16 : NS
- EPEV : NS
- DTO / ETO : mortalité non étudiée
- SvO_2 : 6 études : 2 positives et 4 negatives
- SpO_2: 7 études : NS mortalité

Ospina-Tascon et al. Intensive Care Med 2008

Monitorage Hémodynamique ?

L’utilisation seule d’un outil ne va pas changer le pronostic

« Aucun appareil de surveillance ne va améliorer le devenir des patients SAUF si il est couplé à un traitement spécifique »

Pinsky,M and Vincent, J.L Crit Care Med 2005

Monitorage Hémodynamique non-invasif au bloc opératoire aujourd’hui

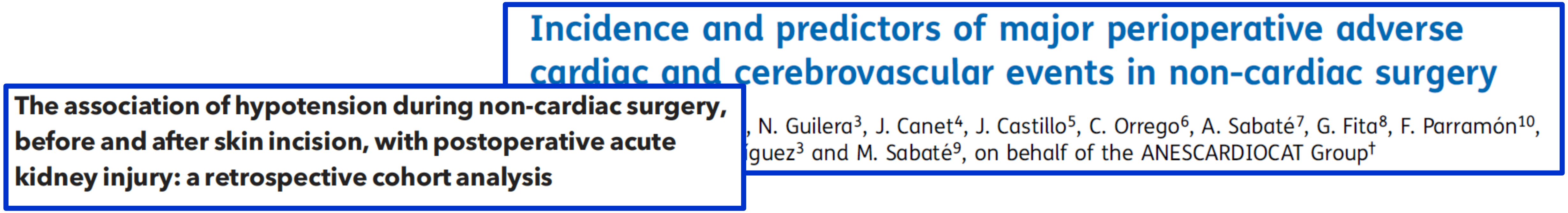
- Pression Artérielle
- Indices Dynamiques
- Débit Cardiaque

Monitorage Hémodynamique non-invasif au bloc opératoire aujourd'hui

Pression Artérielle

Impact de l’hypotension artérielle

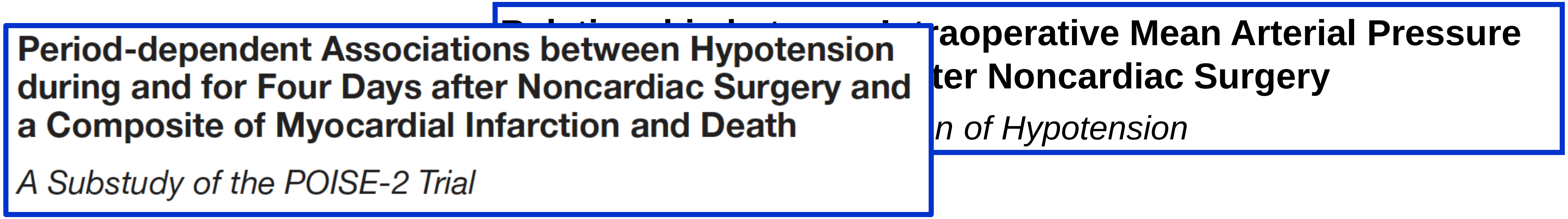
Association entre hypotension artérielle per-opératoire et morbidité post-opératoire



Incidence and predictors of major perioperative adverse cardiac and cerebrovascular events in non-cardiac surgery

, N. Guilera[3], J. Canet[4], J. Castillo[5], C. Orrego[6], A. Sabaté[7], G. Fita[8], F. Parramón[10],
íguez[3] and M. Sabaté[9], on behalf of the ANESCARDIOCAT Group†

The association of hypotension during non-cardiac surgery, before and after skin incision, with postoperative acute kidney injury: a retrospective cohort analysis

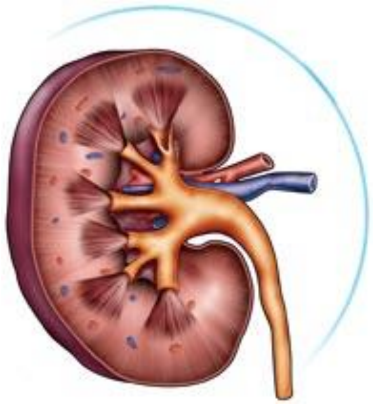


raoperative Mean Arterial Pressure
ter Noncardiac Surgery
n of Hypotension

Period-dependent Associations between Hypotension during and for Four Days after Noncardiac Surgery and a Composite of Myocardial Infarction and Death

A Substudy of the POISE-2 Trial

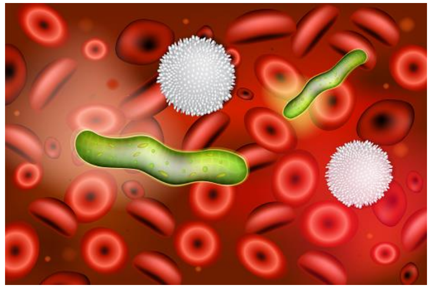
Impact de l’hypotension artérielle



IRA
EER

Ischémie
MINS

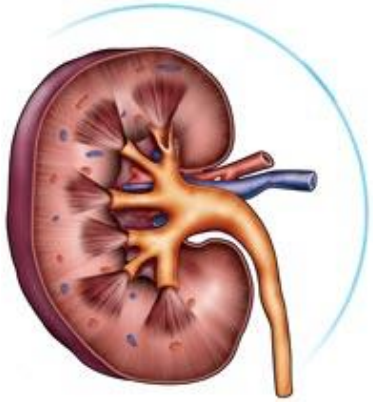
AVC
Delirium



Sepsis
SIRS

Décès

Impact de l’hypotension artérielle



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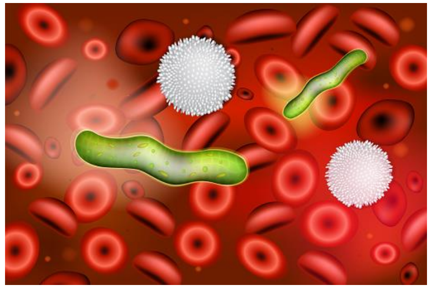


Sepsis
SIRS

Décès

Quelque soient

Durée de l’hypotension artérielle

Cause de l’hypotension artérielle

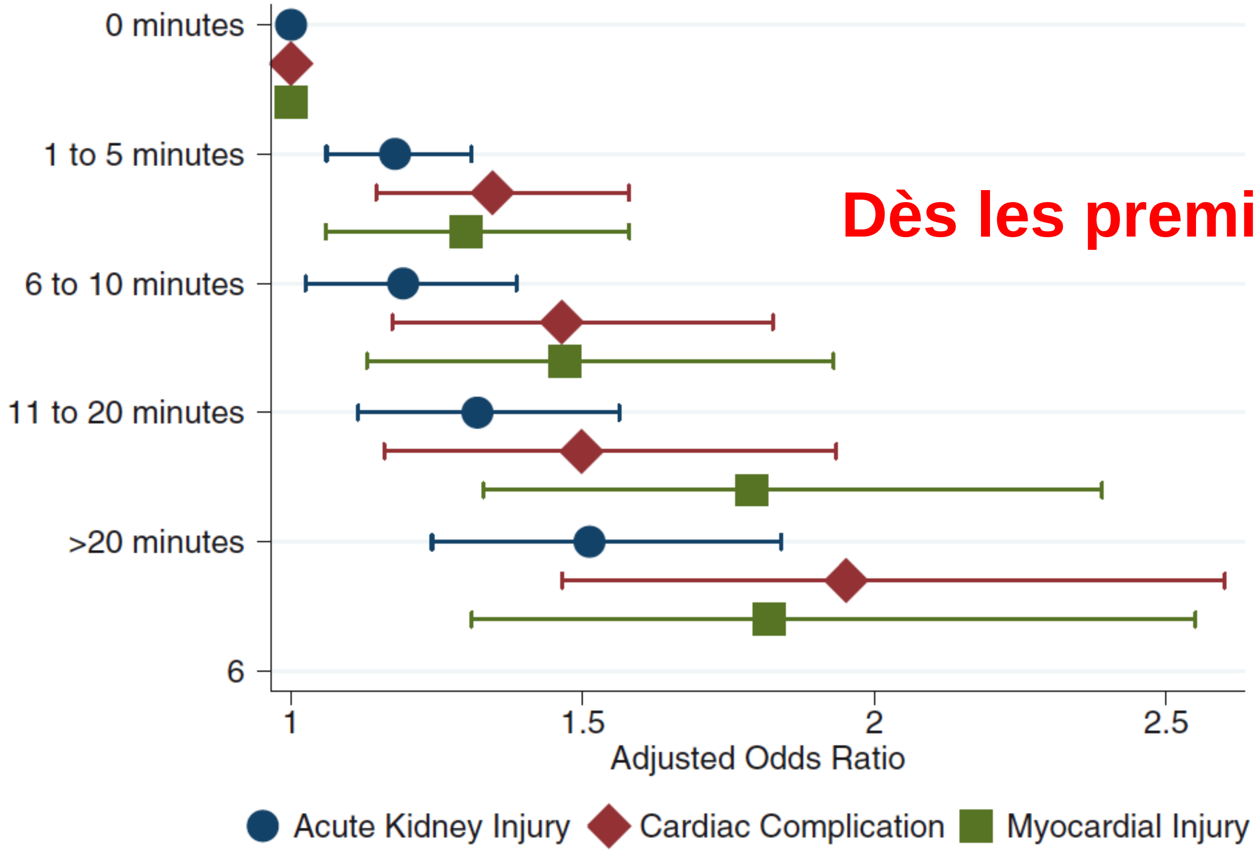
Moment de survenue

Débit cardiaque

Relationship between Intraoperative Mean Arterial Pressure and Clinical Outcomes after Noncardiac Surgery

Toward an Empirical Definition of Hypotension

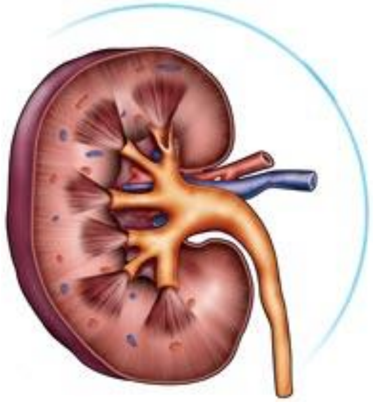
33,330 patients, chirurgie non cardiaque (Cleveland, Ohio)



Dès les premières minutes !!!

Walsh M et al. Anesthesiology 2013

Impact de l’hypotension artérielle



IRA
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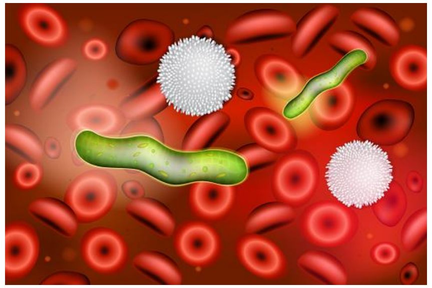

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SIRS

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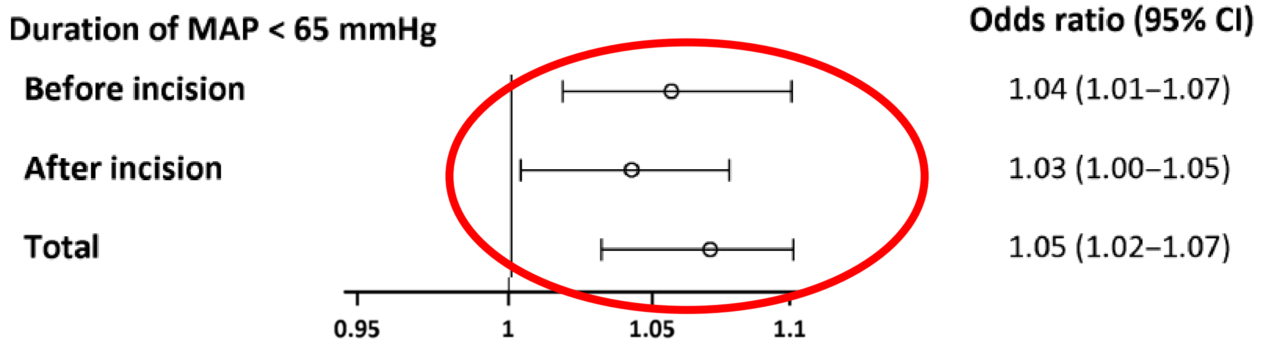
Cause de l’hypotension artérielle

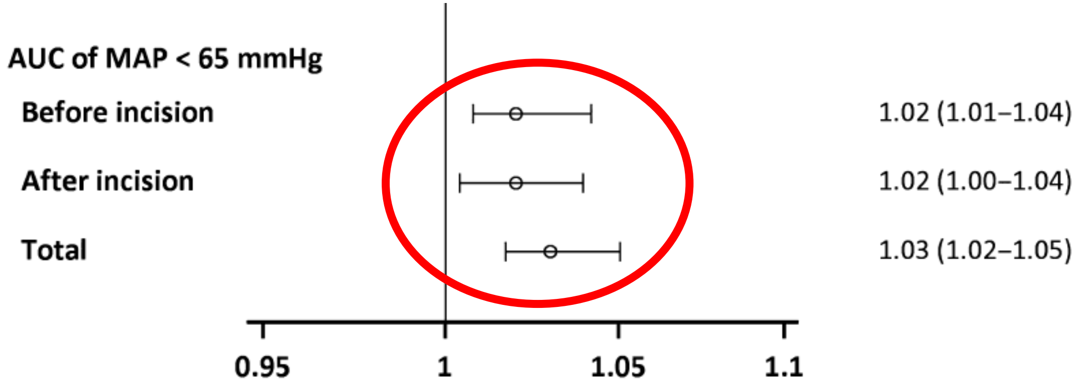
Moment de survenue

Débit cardiaque

The association of hypotension during non-cardiac surgery, before and after skin incision, with postoperative acute kidney injury: a retrospective cohort analysis

42825 patients, chirurgie non cardiaque
Relation hTA **avant ou après incision** et IRA

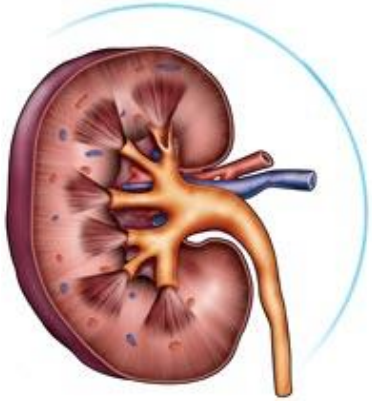




Augmentation du risque d'IRA quelque soit l'origine de l'hypotension artérielle

Maheshwari K et al. Anaesthesia 2018

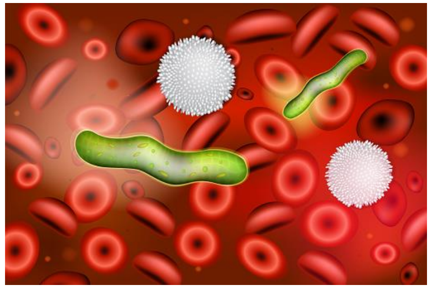
Impact de l’hypotension artérielle



IRA
EER

Ischémie
MINS

AVC
Delirium



Sepsis
SIRS

Décès

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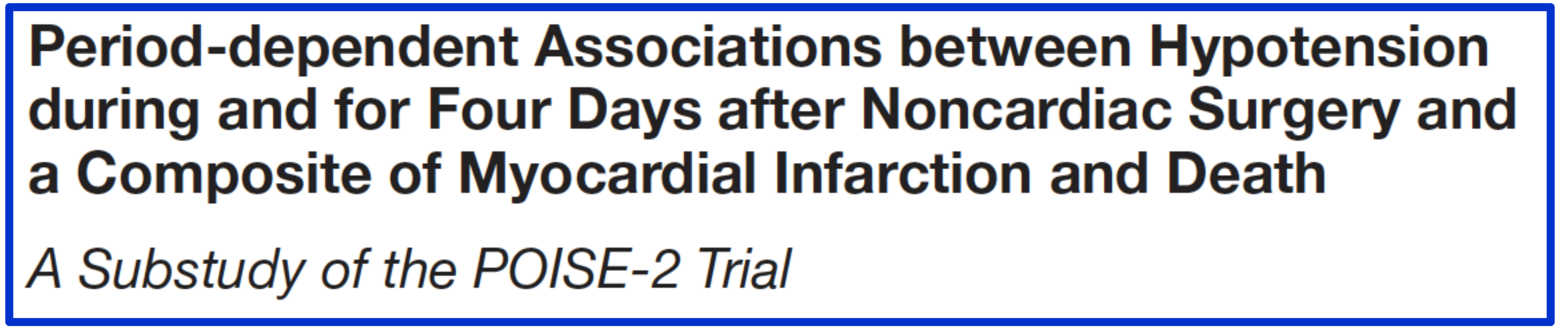
Durée de l’hypotension artérielle

Cause de l’hypotension artérielle

Moment de survenue

Débit cardiaque



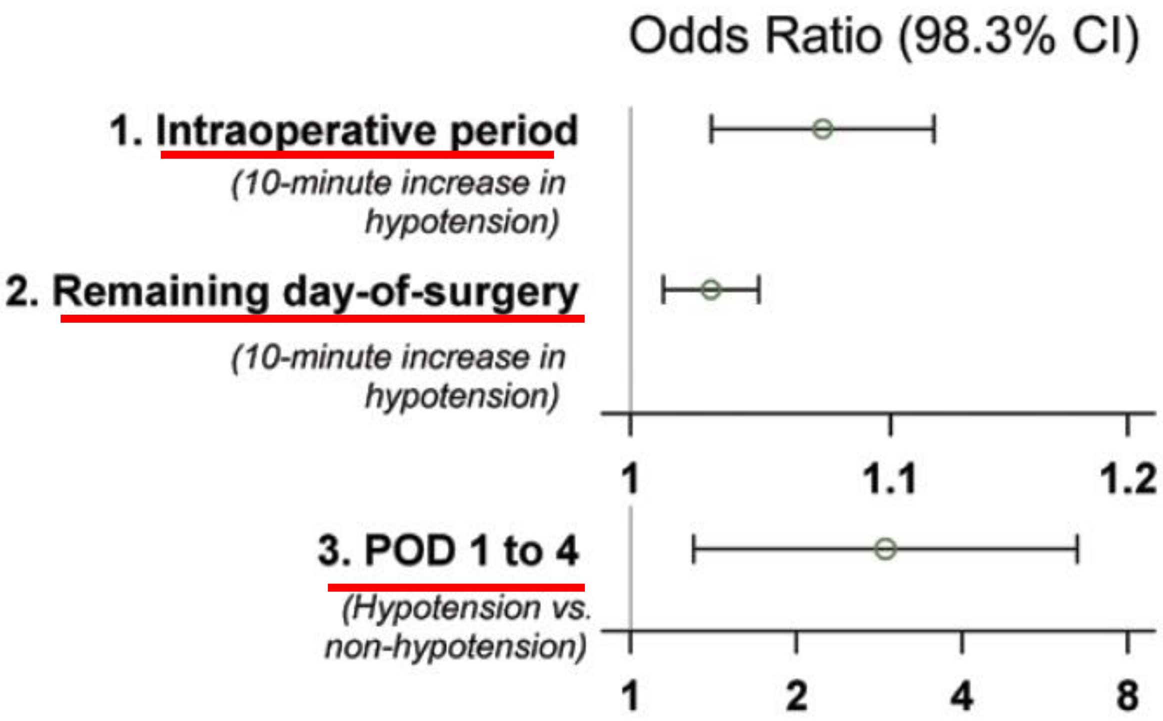
Period-dependent Associations between Hypotension during and for Four Days after Noncardiac Surgery and a Composite of Myocardial Infarction and Death

A Substudy of the POISE-2 Trial

9765 patients, étude ancillaire POISE2

Association hypotension artérielle et morbidité

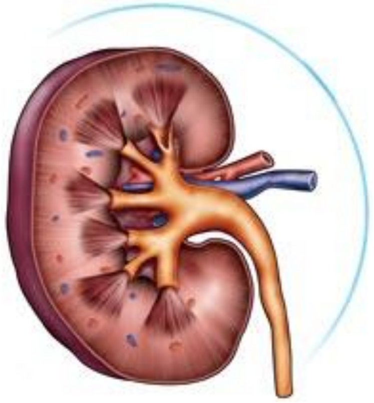
Hypotension post-opératoire : J0 et J1-J4



Hypotension artérielle per et postopératoire augmente les complications cardiaques postopératoires

Sessler D et al. Anesthesiology 2018

Impact de l’hypotension artérielle



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EER

Ischémie
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AVC
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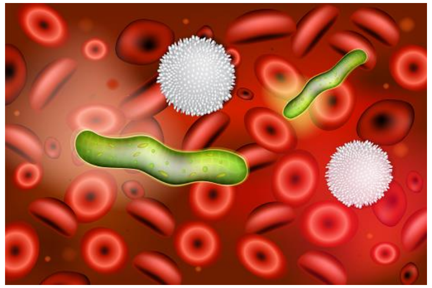


Sepsis
SIRS

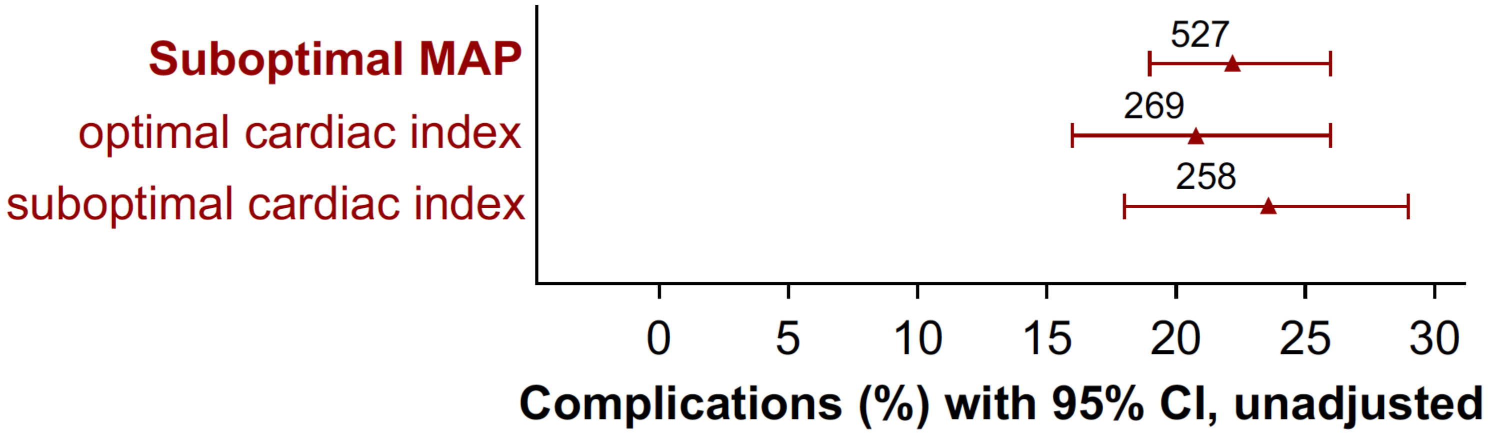
Décès

Quelque soient

Durée de l’hypotension artérielle
Cause de l’hypotension artérielle
Moment de survenue
Débit cardiaque

Association between intraoperative mean arterial pressure and postoperative complications is independent of cardiac index in patients undergoing noncardiac surgery

790 patients, chirurgie non cardiaque, monitorage PAM et IC
Comparaison du % de complications en fonction des groupes PAM
et DC optimaux ou non



Maheshwari et al. Brit J Anaesth 2021

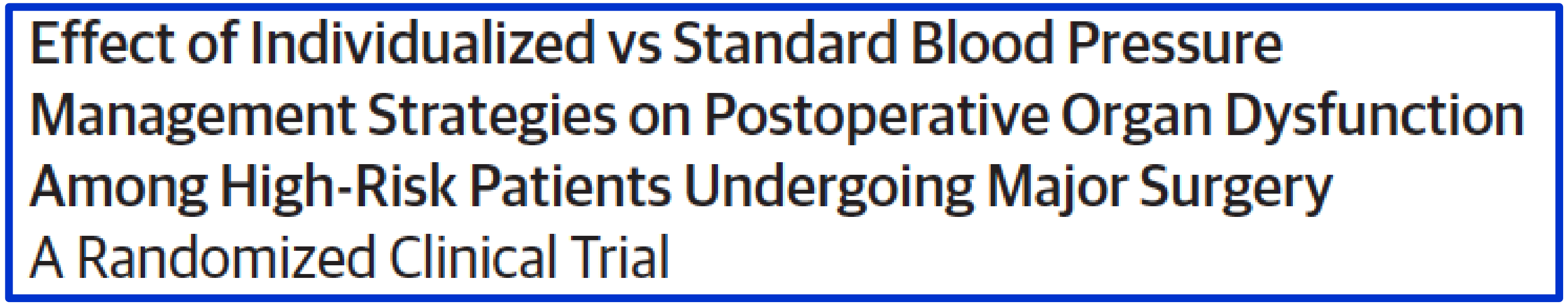
Effect of Individualized vs Standard Blood Pressure Management Strategies on Postoperative Organ Dysfunction Among High-Risk Patients Undergoing Major Surgery
A Randomized Clinical Trial

Essai randomisé
300 patients randomisés
80% d'HTA
95% de chirurgie abdominale

Groupe contrôle
Maximalisation VES
PAS = 80 mmHg

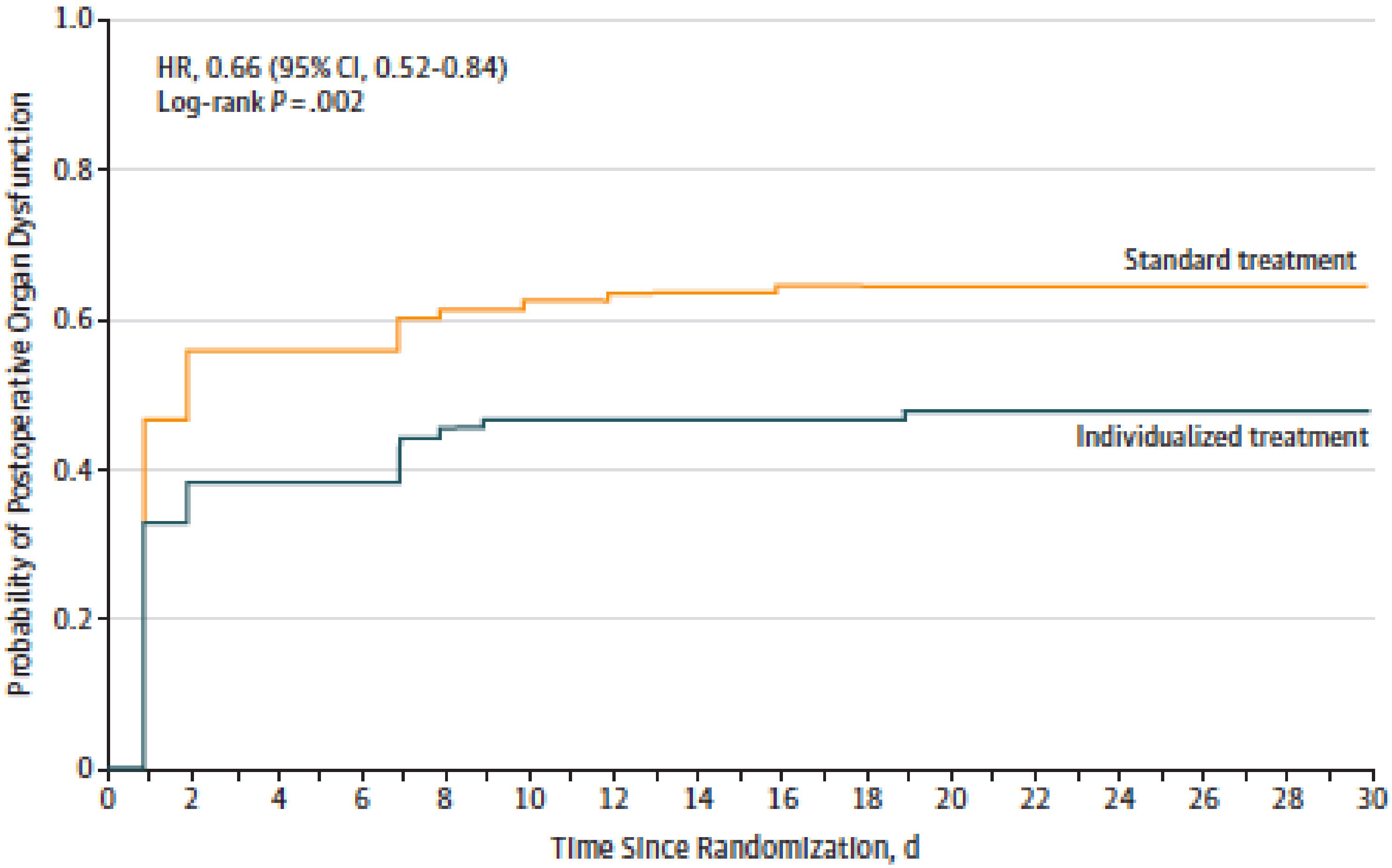
Groupe Interventionnel
Maximalisation VES
PAS = +/-10% valeur basale de
PAS : NORADRENALINE

Futier et al. JAMA 2017



Effect of Individualized vs Standard Blood Pressure Management Strategies on Postoperative Organ Dysfunction Among High-Risk Patients Undergoing Major Surgery

A Randomized Clinical Trial



Diminution des complications postopéraotires

Futier et al. JAMA 2017

Monitorage non-invasif de la pression artérielle

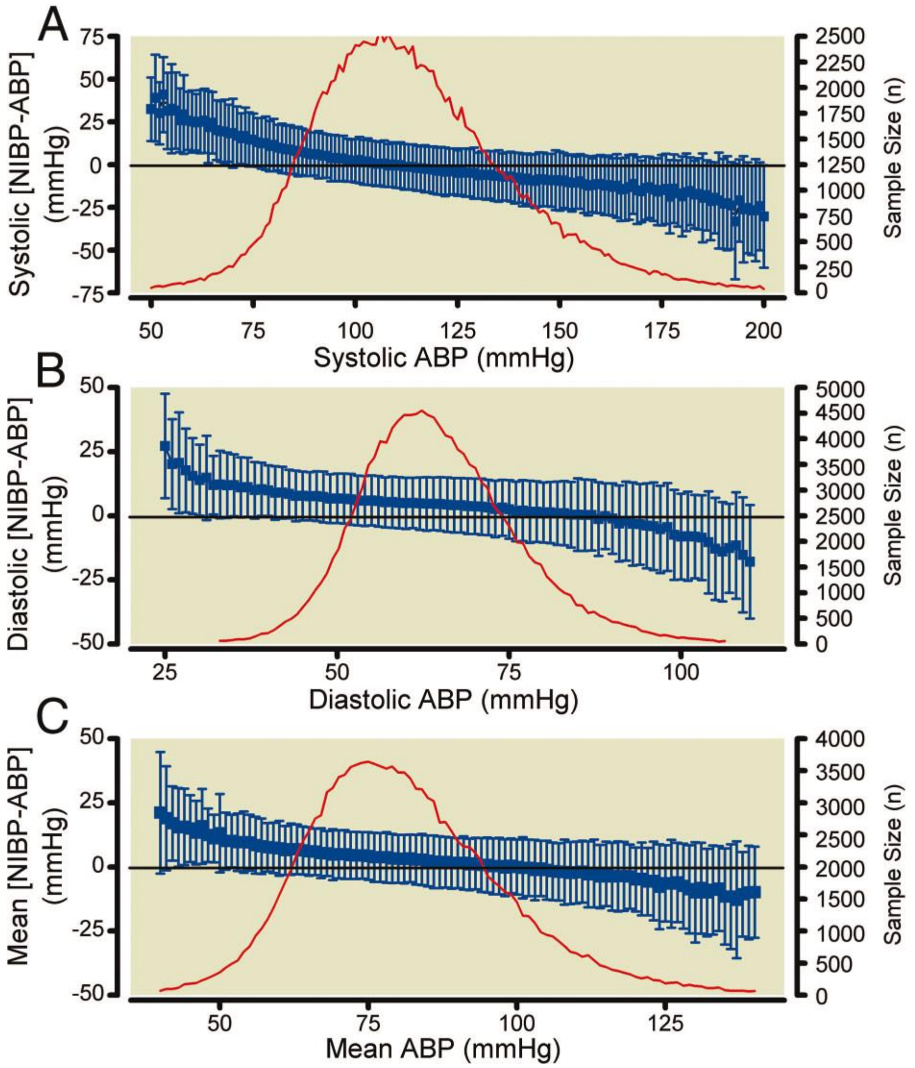
BRASSARDS

Mesures Intermittentes

Invasive and Concomitant Noninvasive Intraoperative Blood Pressure Monitoring

Observed Differences in Measurements and Associated Therapeutic Interventions

vs.



24225 patients, chirurgie non cardiaque
Comparaison PA invasive et brassard

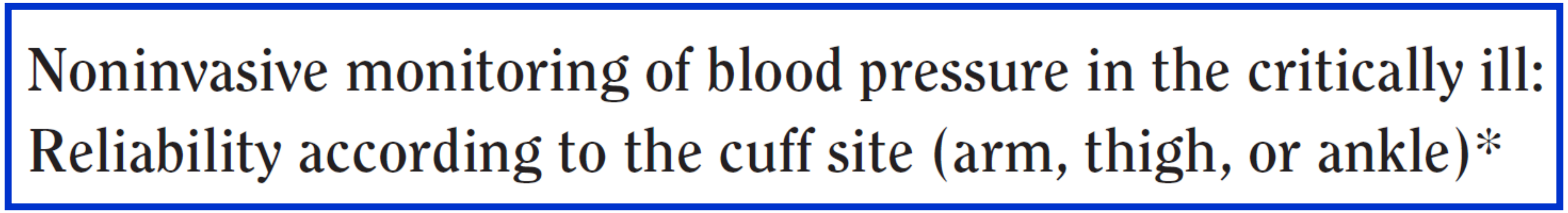
Pressions basses : brassard sur estime la mesure invasive
Pressions hautes : brassard sous-estime la mesure invasive

David B. Wax et al. Anesthesiology 2011

Noninvasive monitoring of blood pressure in the critically ill: Reliability according to the cuff site (arm, thigh, or ankle)*

150 patients, Réanimation
Comparaisons Mesures invasives et non-invasives: bras, cuisse, cheville

Lakhal et al. Crit Care Med 2012



Noninvasive monitoring of blood pressure in the critically ill: Reliability according to the cuff site (arm, thigh, or ankle)*

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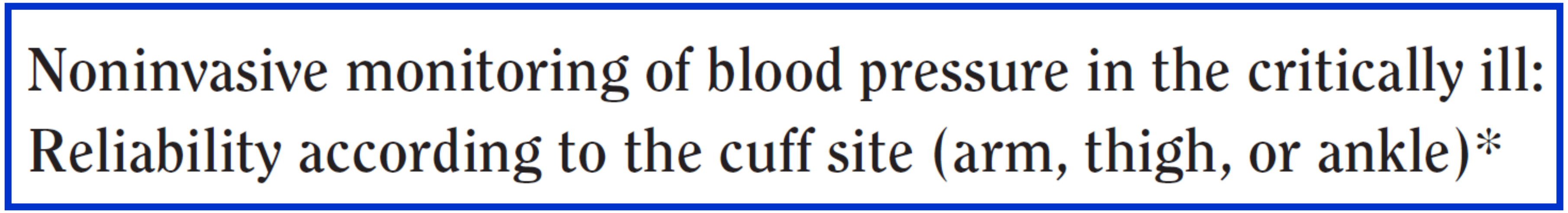
Capacité des mesures non-invasives à identifier une PAM < 65 mmHg

Lakhal et al. Crit Care Med 2012



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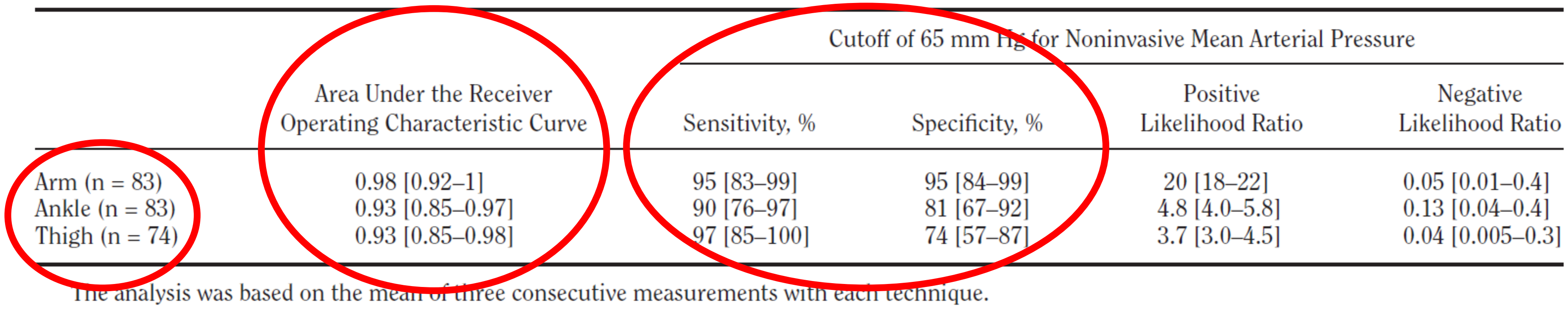
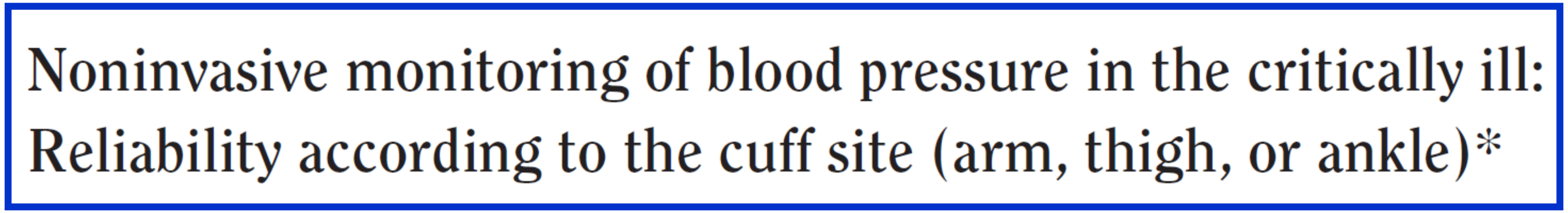


	Area Under the Receiver Operating Characteristic Curve	Cutoff of 65 mm Hg for Noninvasive Mean Arterial Pressure			
		Sensitivity, %	Specificity, %	Positive Likelihood Ratio	Negative Likelihood Ratio
Arm (n = 83)	0.98 [0.92–1]	95 [83–99]	95 [84–99]	20 [18–22]	0.05 [0.01–0.4]
Ankle (n = 83)	0.93 [0.85–0.97]	90 [76–97]	81 [67–92]	4.8 [4.0–5.8]	0.13 [0.04–0.4]
Thigh (n = 74)	0.93 [0.85–0.98]	97 [85–100]	74 [57–87]	3.7 [3.0–4.5]	0.04 [0.005–0.3]

The analysis was based on the mean of three consecutive measurements with each technique.

Mesure au bras est fiable à la phase initiale

Lakhal et al. Crit Care Med 2012



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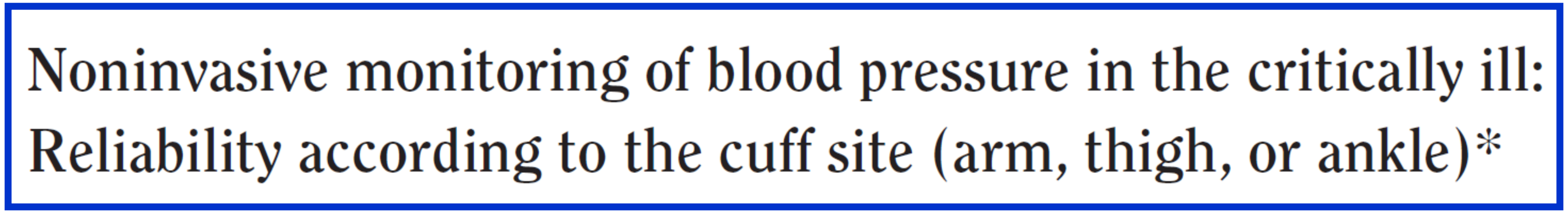
150 patients, Réanimation
Comparaisons Mesures invasives et non-invasives: bras, cuisse, cheville

Capacité à identifier
une variation de 10% de la PAM

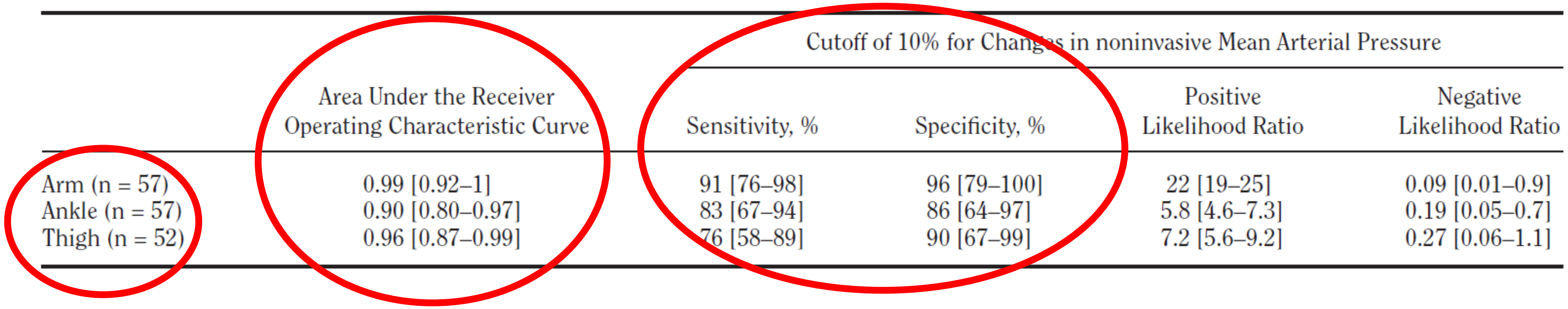
Lakhal et al. Crit Care Med 2012



Noninvasive monitoring of blood pressure in the critically ill: Reliability according to the cuff site (arm, thigh, or ankle)*

150 patients, Réanimation
Comparaisons Mesures invasives et non-invasives: bras, cuisse, cheville

Capacité à identifier une variation de 10% de la PAM



	Area Under the Receiver Operating Characteristic Curve	Cutoff of 10% for Changes in noninvasive Mean Arterial Pressure			
		Sensitivity, %	Specificity, %	Positive Likelihood Ratio	Negative Likelihood Ratio
Arm (n = 57)	0.99 [0.92–1]	91 [76–98]	96 [79–100]	22 [19–25]	0.09 [0.01–0.9]
Ankle (n = 57)	0.90 [0.80–0.97]	83 [67–94]	86 [64–97]	5.8 [4.6–7.3]	0.19 [0.05–0.7]
Thigh (n = 52)	0.96 [0.87–0.99]	76 [58–89]	90 [67–99]	7.2 [5.6–9.2]	0.27 [0.06–1.1]

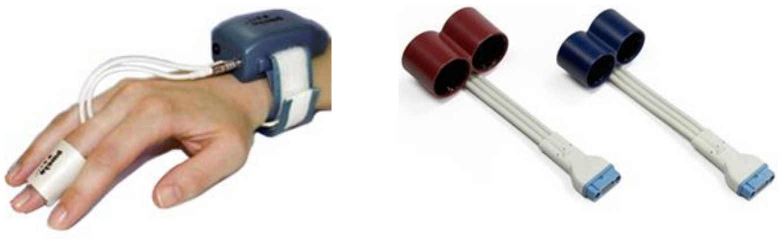
Mesure au bras est fiable à la phase initiale

Lakhal et al. Crit Care Med 2012

Monitorage non-invasif de la pression artérielle

BRASSARDS

Mesures Intermittentes

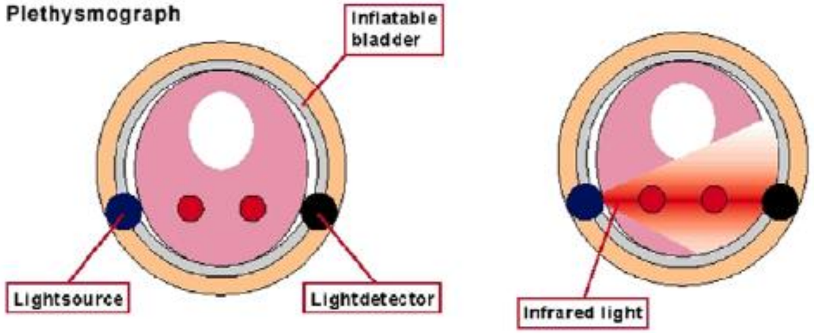


MANCHETTES DIGITALES

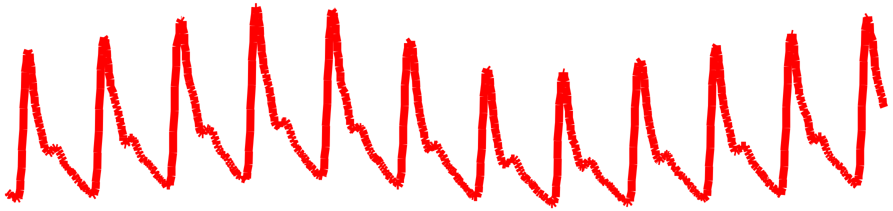
Mesures Continues

Non-Invasif

Méthode du Volume-Clamp


Plethysmograph
Inflatable bladder
Lightsource
Lightdetector
Infrared light

- Manchette digitale avec d**iode électroluminescente** émettrice et réceptrice
- Mesure continue diamètre artères digitales palmaires (pléthysmographie)
- Variation de pression dans la manchette (gonflage et dégonflage) pour maintenir un diamètre artériel constant tout au long du cycle cardiaque
- Pression générée de la manchette = pression intra-artérielle digitale (temps réel)

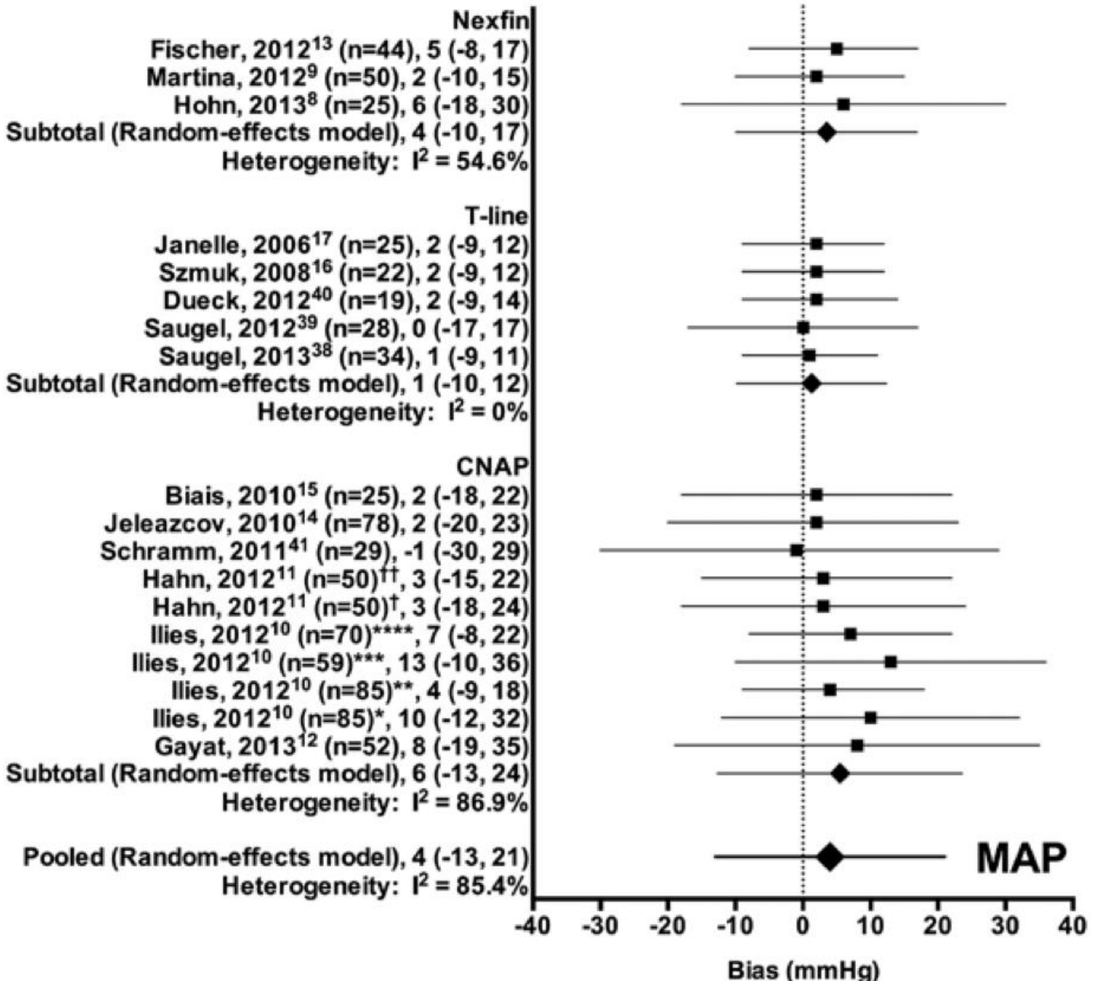


Recommandations

Bias should be ≤ 5 mmHg with a SD ≤ 8 mmHg according to the ANSI/AAMI standards

Accuracy and Precision of Continuous Noninvasive Arterial Pressure Monitoring Compared with Invasive Arterial Pressure

A Systematic Review and Meta-analysis



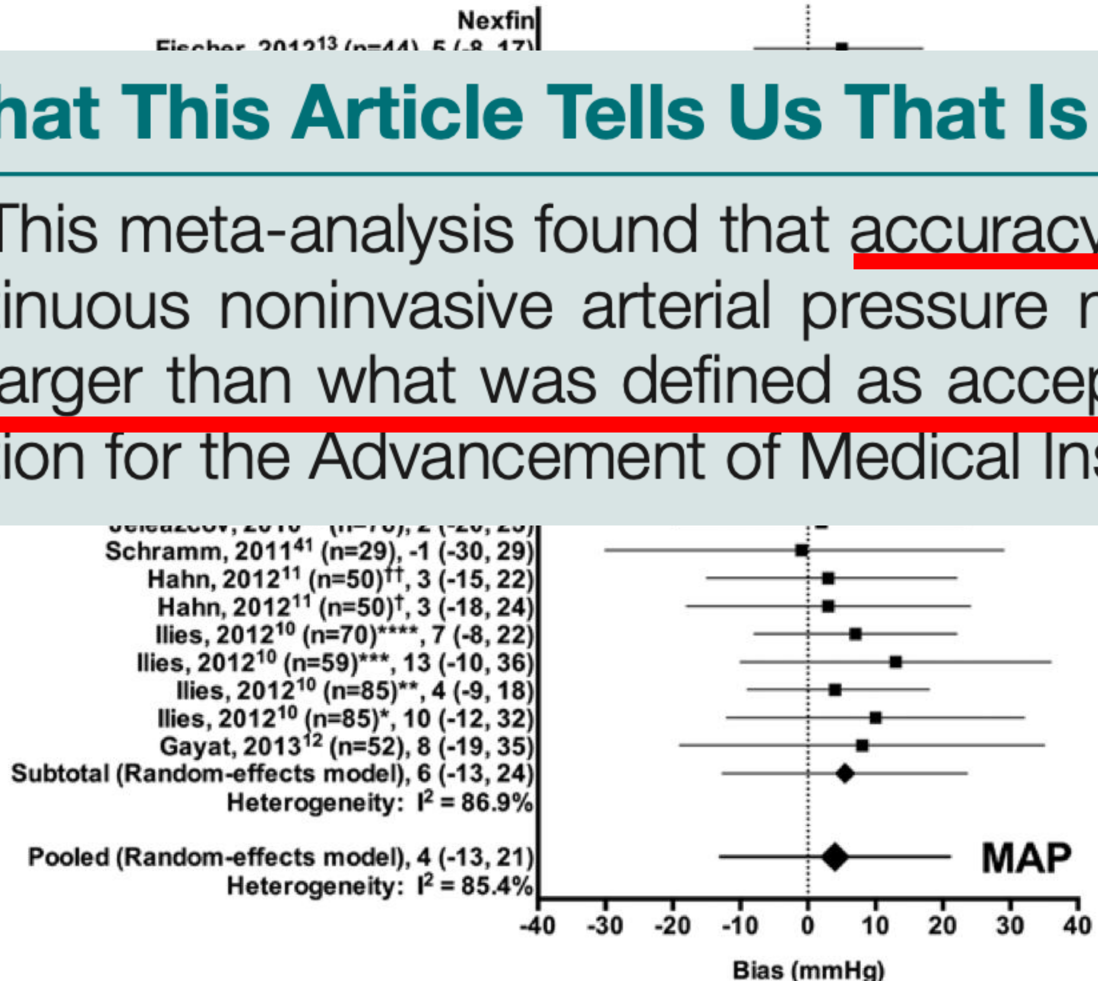
Kim et al. Anesthesiology 2014

Accuracy and Precision of Continuous Noninvasive Arterial Pressure Monitoring Compared with Invasive Arterial Pressure

A Systematic Review and Meta-analysis

What This Article Tells Us That Is New

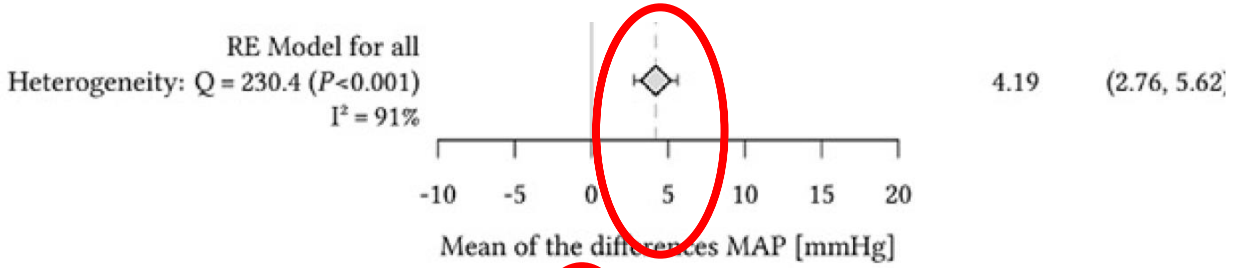
- This meta-analysis found that accuracy and precision of continuous noninvasive arterial pressure monitoring devices are larger than what was defined as acceptable by the Association for the Advancement of Medical Instrumentation.



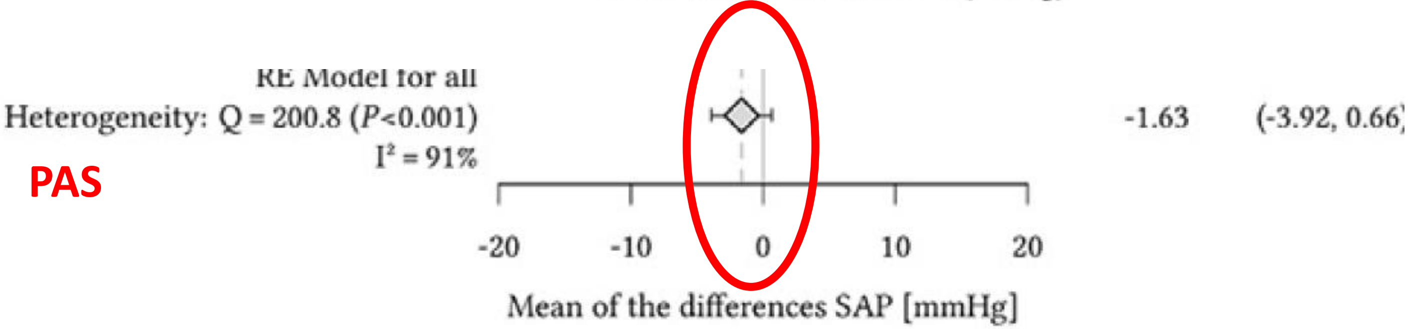
Kim et al. Anesthesiology 2014

Continuous noninvasive pulse wave analysis using finger cuff technologies for arterial blood pressure and cardiac output monitoring in perioperative and intensive care medicine: a systematic review and meta-analysis

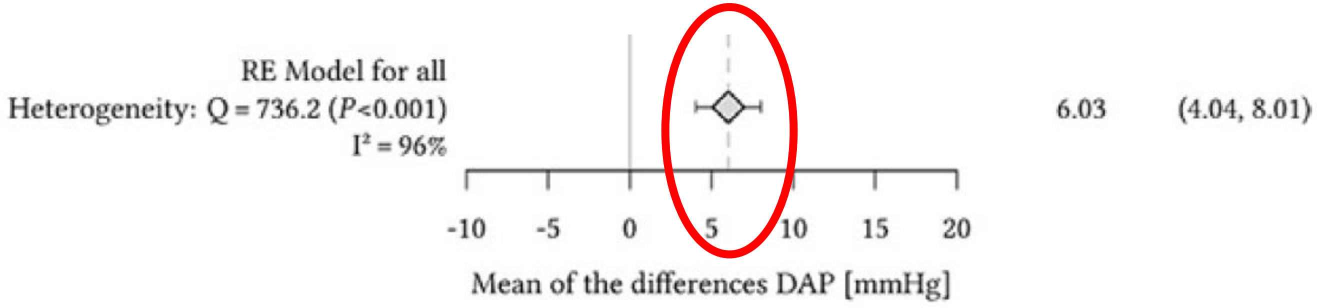
PAM



PAS



PAD



Résultats corrects pour PAS/PAM

Saugel et al. Brit J Anaesth 2021

A Randomized Trial of Continuous Noninvasive Blood Pressure Monitoring During Noncardiac Surgery

320 patients >45 ans, risque intermédiaire ou élevé

Groupe contrôle: Monitorage discontinu (brassard)

Groupe interventionnel: continu non invasif

Objectif : PAM > 65 mmHg

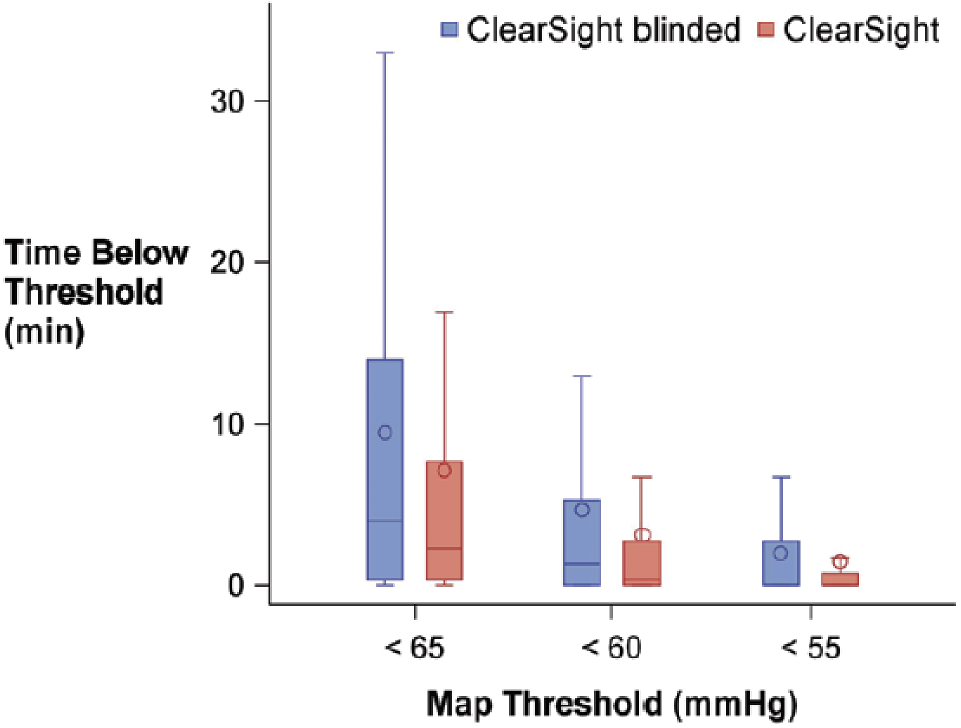
CJP: temps passé au dessous de 65 mmHg

Maheshwari K et al. Anesth Analg 2018

A Randomized Trial of Continuous Noninvasive Blood Pressure Monitoring During Noncardiac Surgery

320 patients >45 ans, risque intermédiaire ou élevé
Groupe contrôle: Monitorage discontinu (brassard)
Groupe interventionnel: continu non invasif
Objectif : PAM > 65 mmHg
CJP: temps passé au dessous de 65 mmHg

Diminution significative de la durée cumulée d'hypotension artérielle



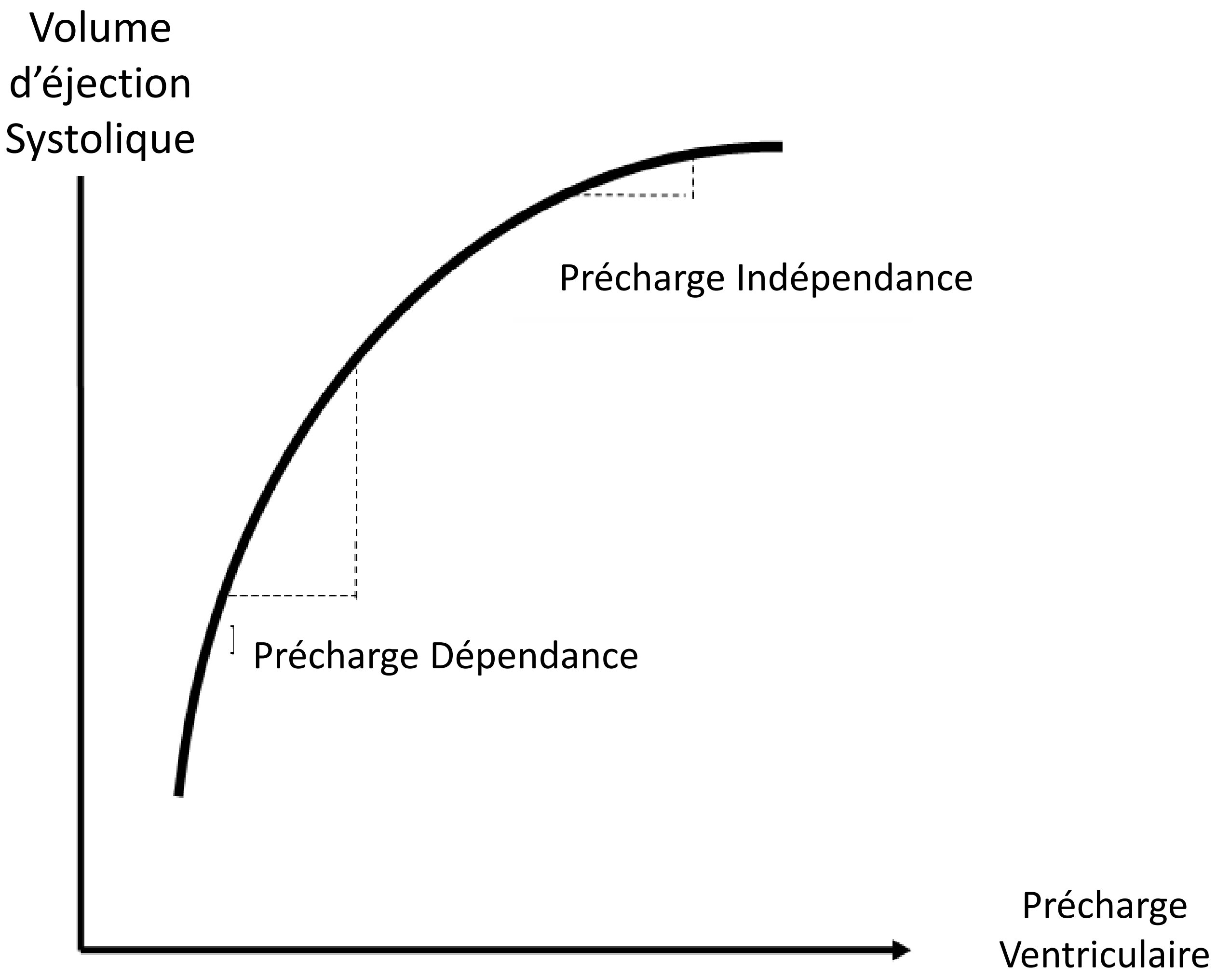
Maheshwari K et al. Anesth Analg 2018

Monitorage Hémodynamique non-invasif au bloc opératoire aujourd’hui

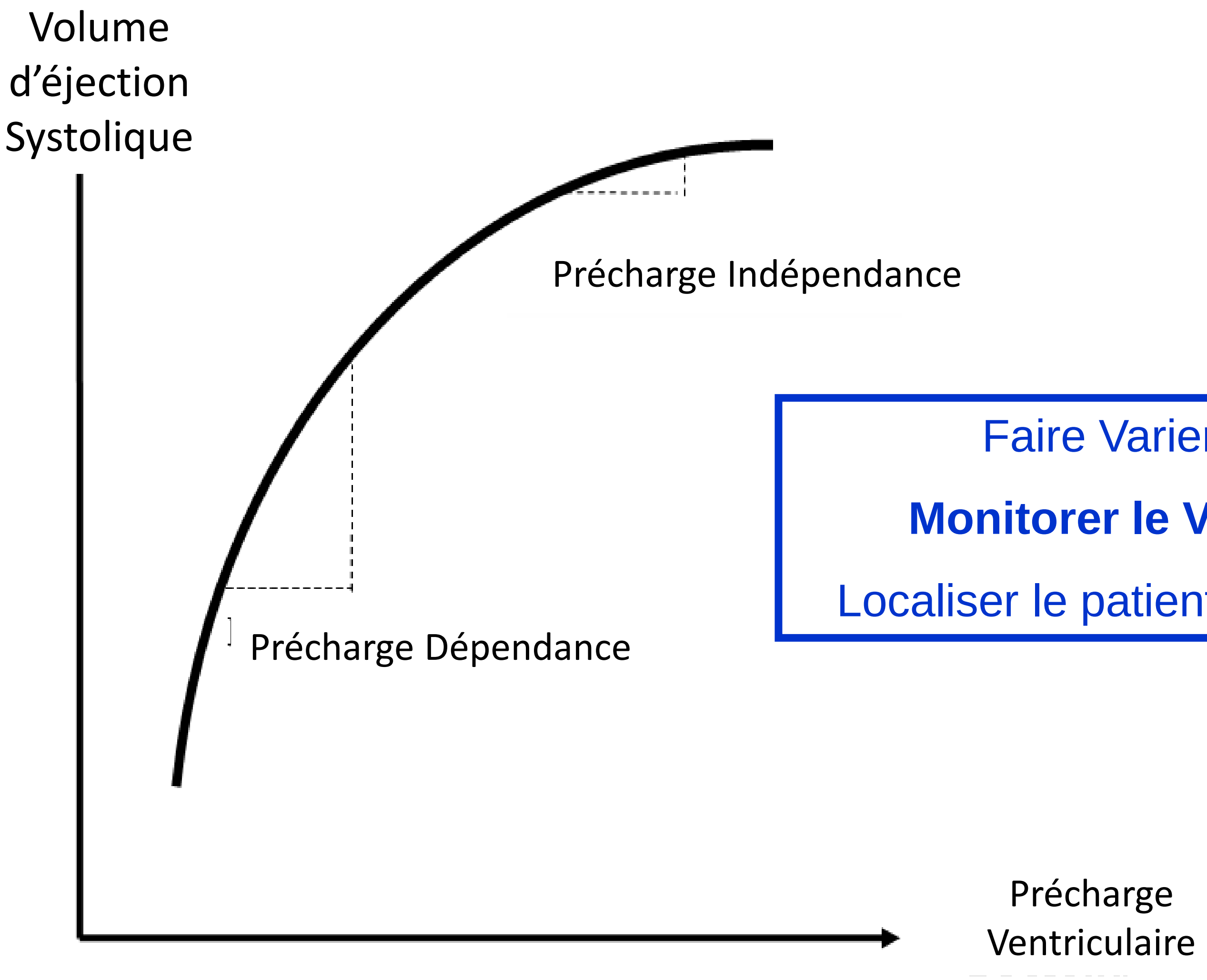
Pression Artérielle

Indices Dynamiques

Indices Dynamiques


Volume
d’éjection
Systolique
Précharge Indépendance
Précharge Dépendance
Précharge
Ventriculaire

Indices Dynamiques

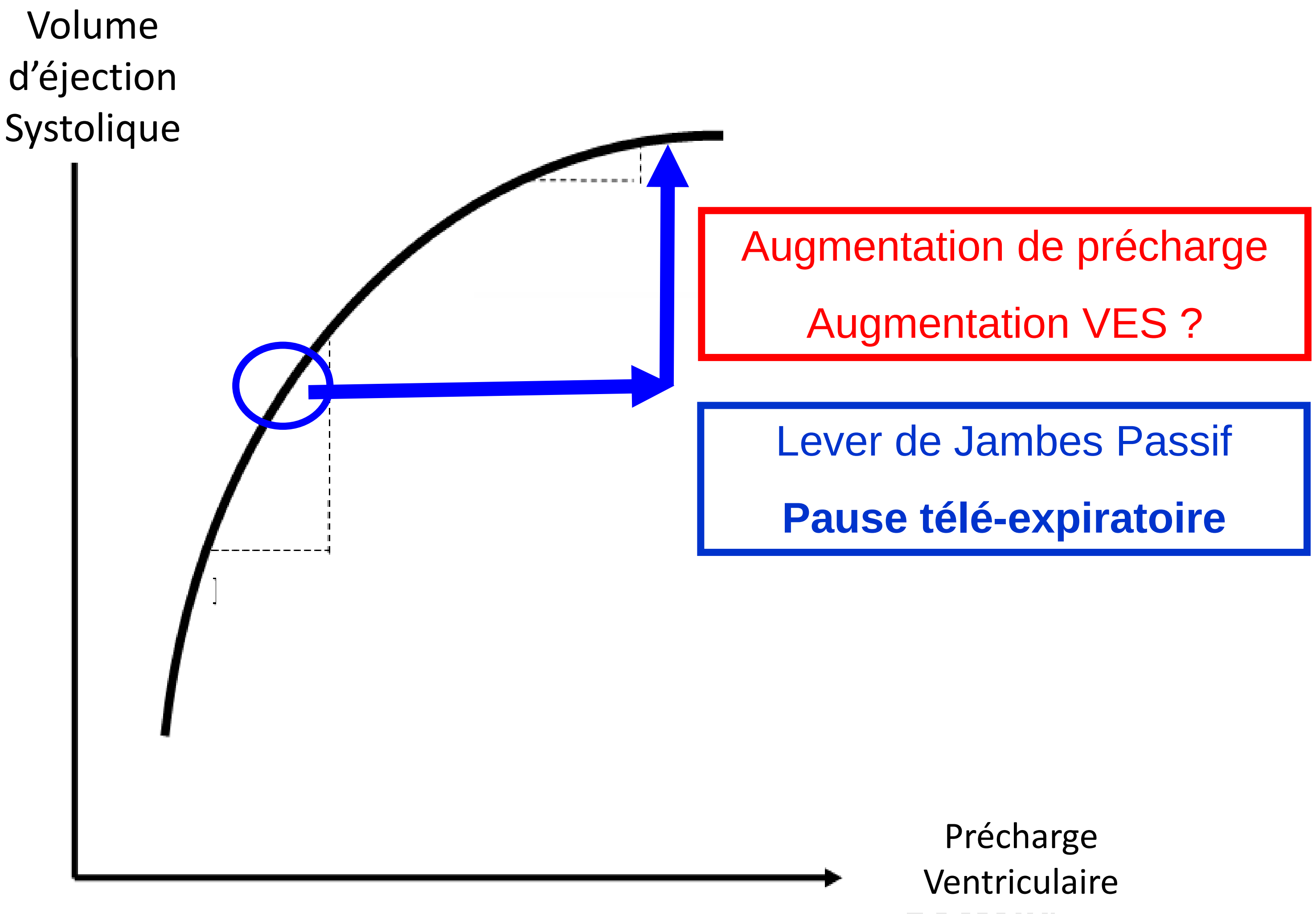

Volume d'éjection Systolique
Précharge Indépendance
Précharge Dépendance
Précharge Ventriculaire

Faire Varier la précharge

Monitorer le VES ou un dérivé

Localiser le patient sur la courbe de FS

Indices Dynamiques


Volume d’éjection Systolique
Précharge Ventriculaire

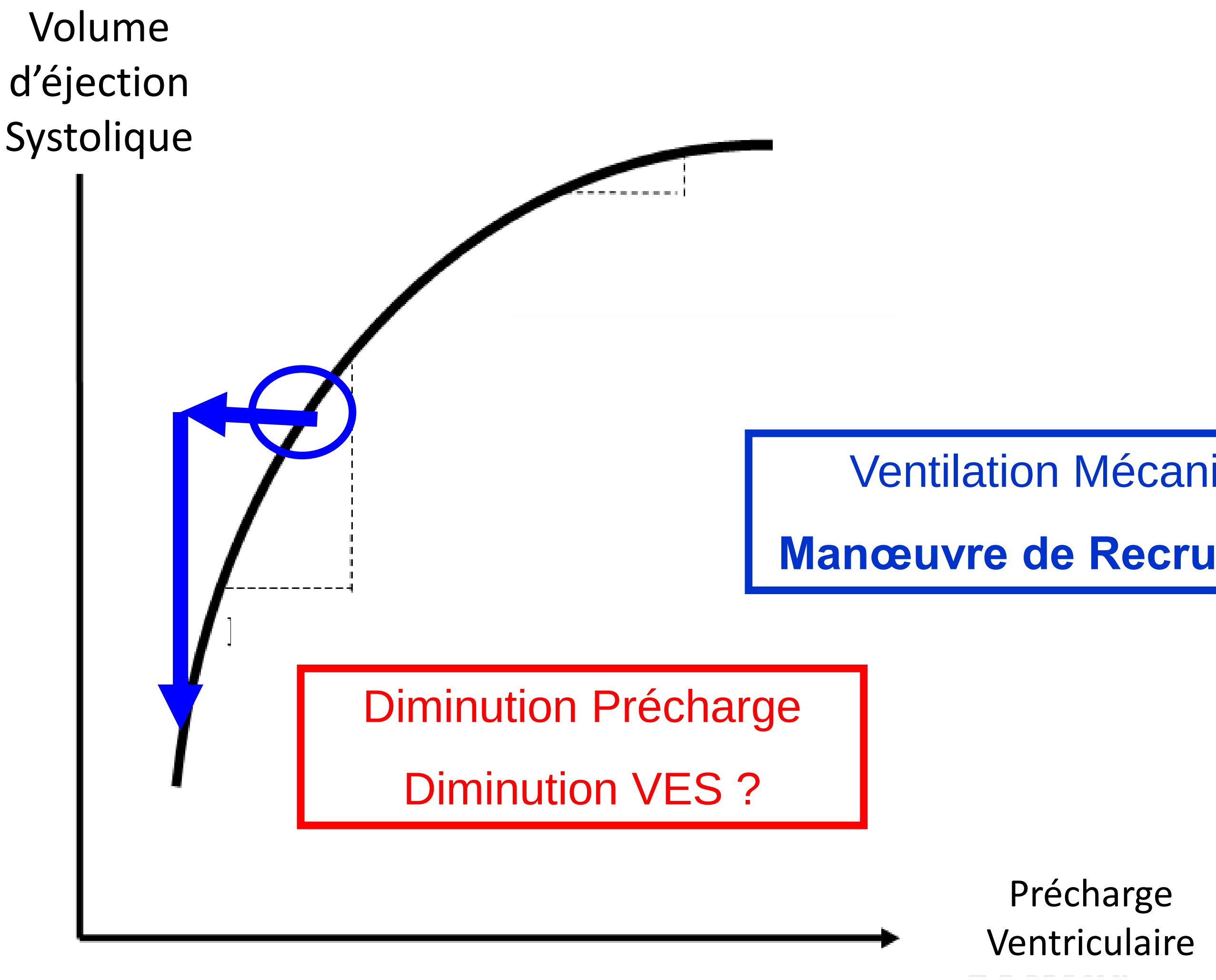
Augmentation de précharge

Augmentation VES ?

Lever de Jambes Passif

Pause télé-expiratoire

Indices Dynamiques


Volume
d'éjection
Systolique
Précharge
Ventriculaire

Ventilation Mécanique

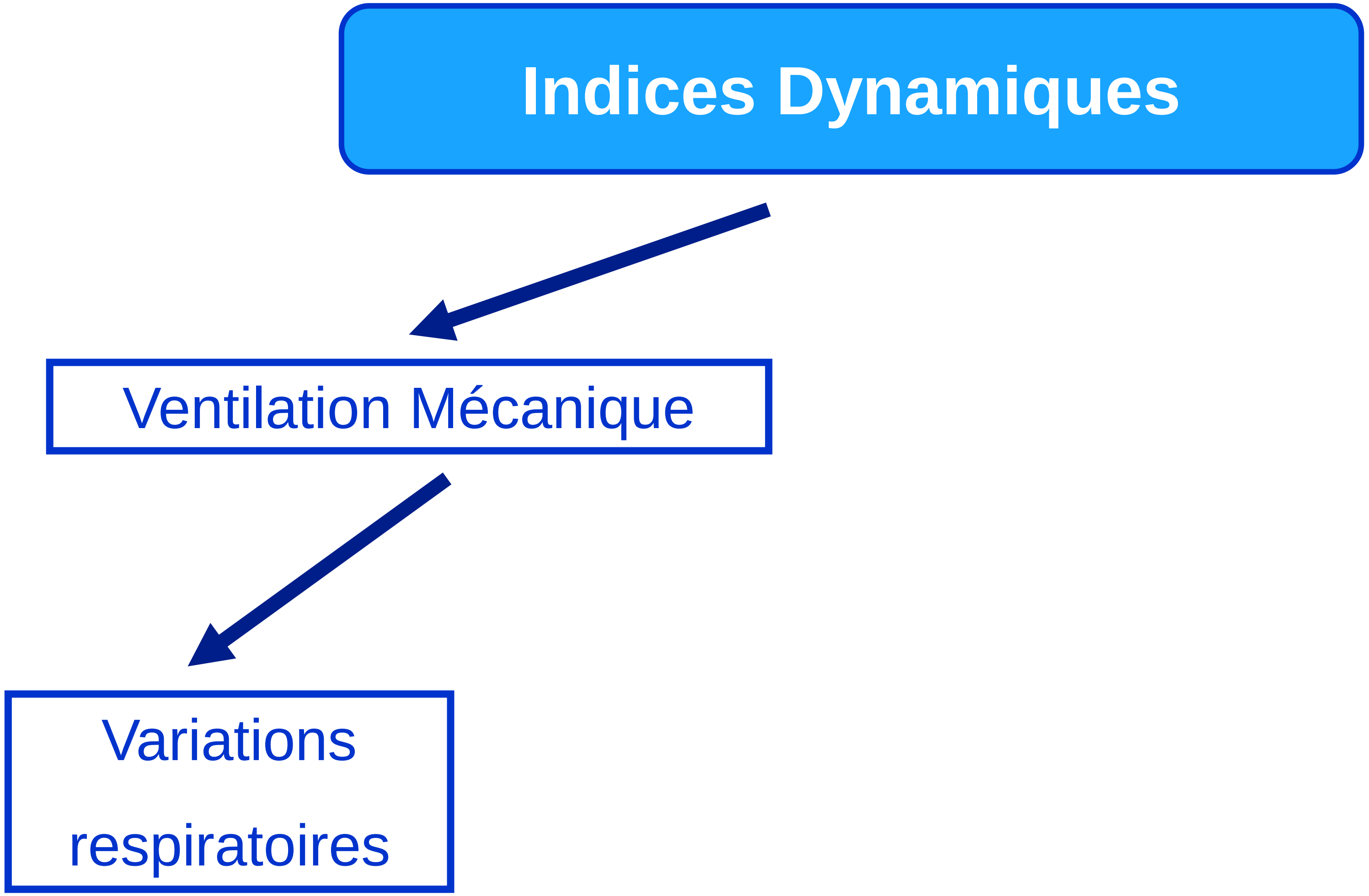
Manœuvre de Recrutement

Diminution Précharge

Diminution VES ?

Indices Dynamiques

Ventilation Mécanique



Indices Dynamiques

Ventilation Mécanique

Variations

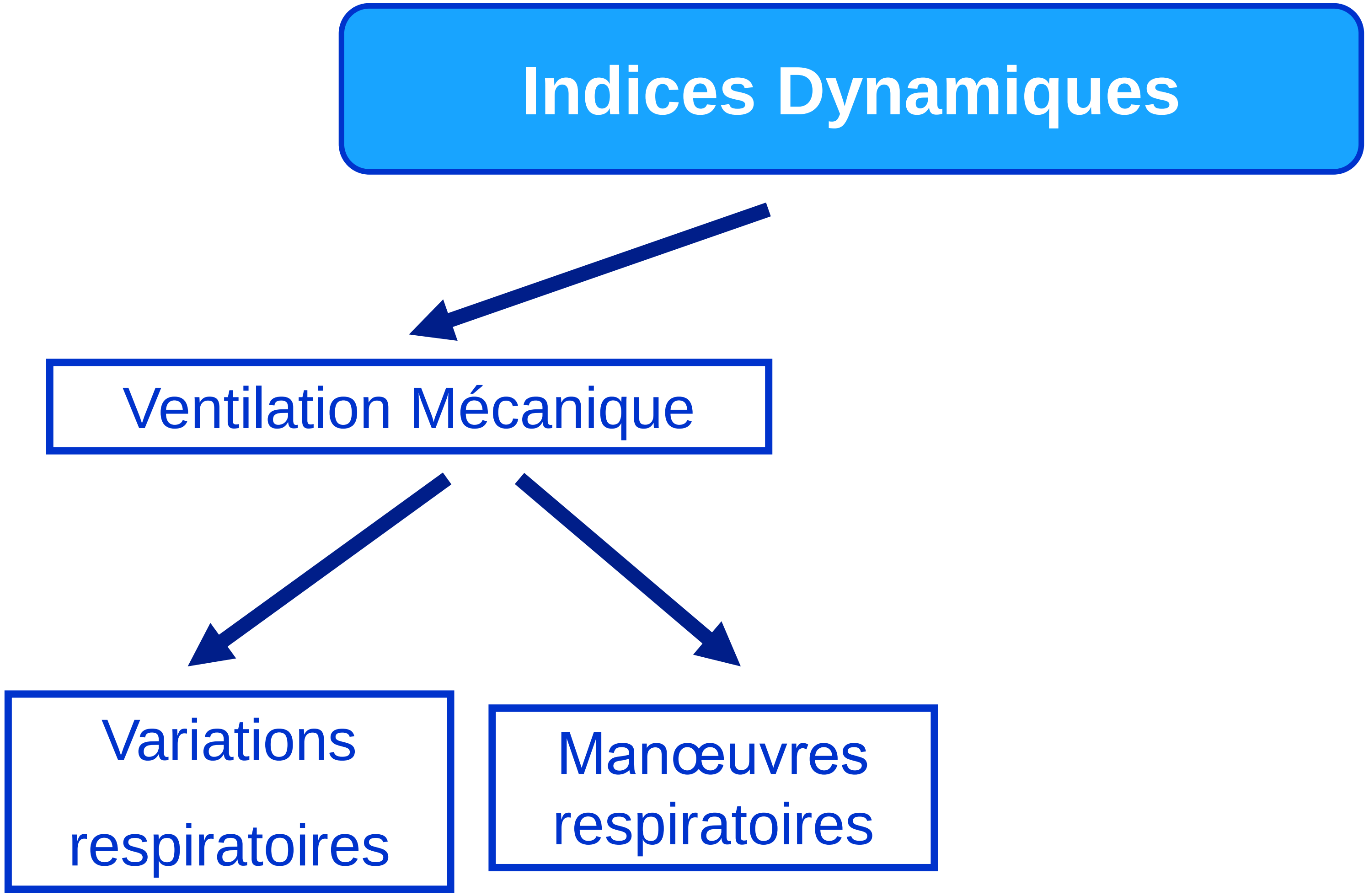
respiratoires

Indices Dynamiques

Ventilation Mécanique

Variations respiratoires

DeltaPP
VVE
PVI



Indices Dynamiques

Ventilation Mécanique

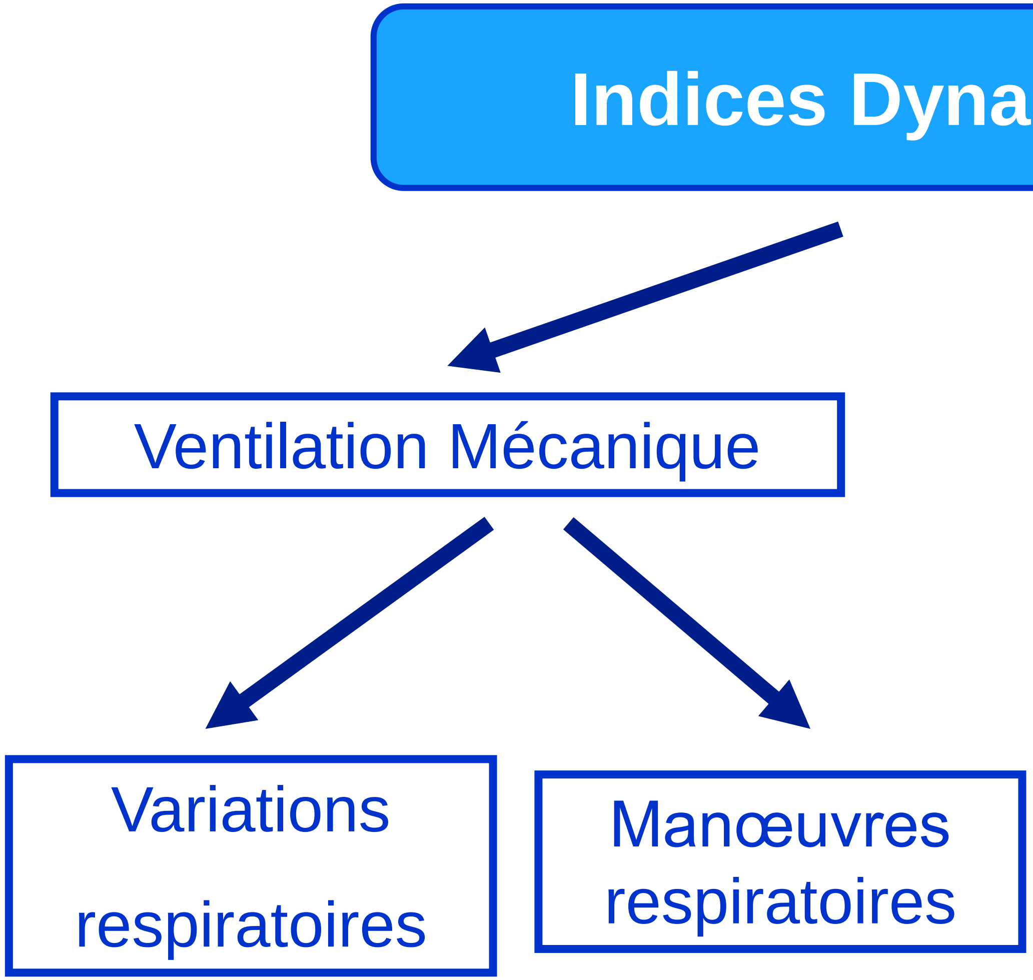
Variations

respiratoires

Manœuvres respiratoires

DeltaPP
VVE
PVI

Indices Dynamiques



Ventilation Mécanique

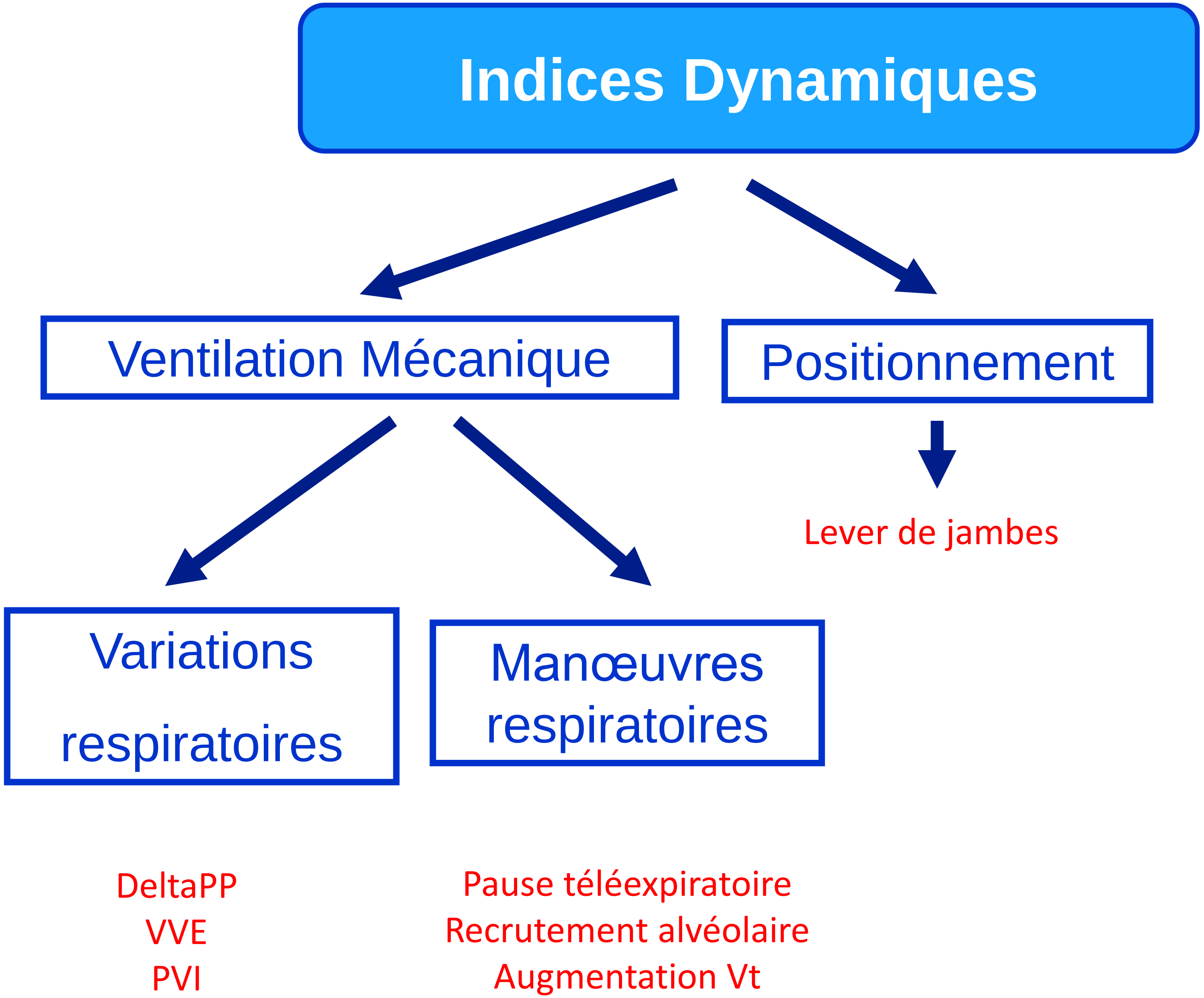
Variations respiratoires

Manœuvres respiratoires

DeltaPP
VVE
PVI

Pause téléexpiratoire
Recrutement alvéolaire
Augmentation Vt

Indices Dynamiques



Ventilation Mécanique

Positionnement

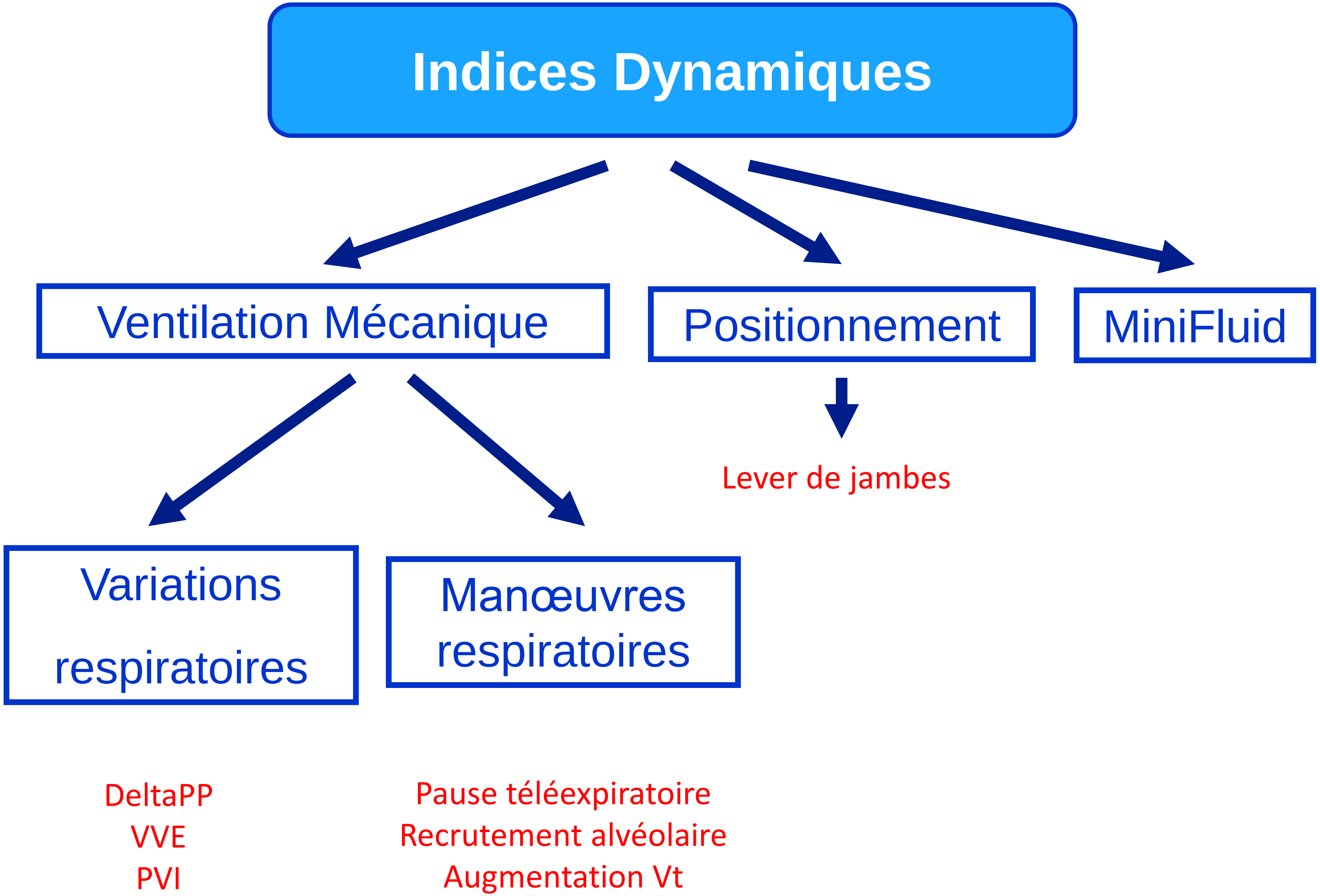
Lever de jambes

Variations respiratoires

Manœuvres respiratoires

DeltaPP
VVE
PVI

Pause téléexpiratoire
Recrutement alvéolaire
Augmentation Vt



Indices Dynamiques

Ventilation Mécanique

Positionnement

MiniFluid

Lever de jambes

Variations respiratoires

Manœuvres respiratoires

DeltaPP
VVE
PVI

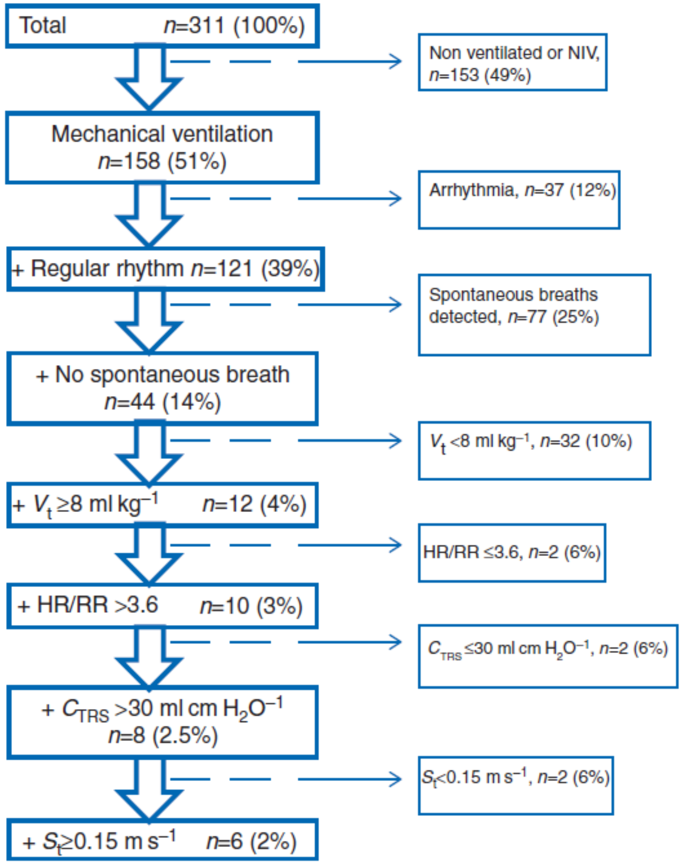
Pause téléexpiratoire
Recrutement alvéolaire
Augmentation Vt

Indices Dynamiques

- Ventilation Mécanique
  - Variations respiratoires
    - DeltaPP
    - VVE
    - PVI
  - Manœuvres respiratoires
    - Pause téléexpiratoire
    - Recrutement alvéolaire
    - Augmentation Vt
- Positionnement
  - Lever de jambes
- MiniFluid

TRES PEU DE DONNEES AVEC LE NON INVASIF +++

Evaluation of pulse pressure variation validity criteria in critically ill patients: a prospective observational multicentre point-prevalence study†



Total *n*=311 (100%)

Non ventilated or NIV, *n*=153 (49%)

Mechanical ventilation *n*=158 (51%)

Arrhythmia, *n*=37 (12%)

+ Regular rhythm *n*=121 (39%)

Spontaneous breaths detected, *n*=77 (25%)

+ No spontaneous breath *n*=44 (14%)

V_t <8 ml kg^{-1}, *n*=32 (10%)

+ V_t ≥8 ml kg^{-1} *n*=12 (4%)

HR/RR ≤3.6, *n*=2 (6%)

+ HR/RR >3.6 *n*=10 (3%)

C_{TRS} ≤30 ml cm H_2O^{-1}, *n*=2 (6%)

+ C_{TRS} >30 ml cm H_2O^{-1} *n*=8 (2.5%)

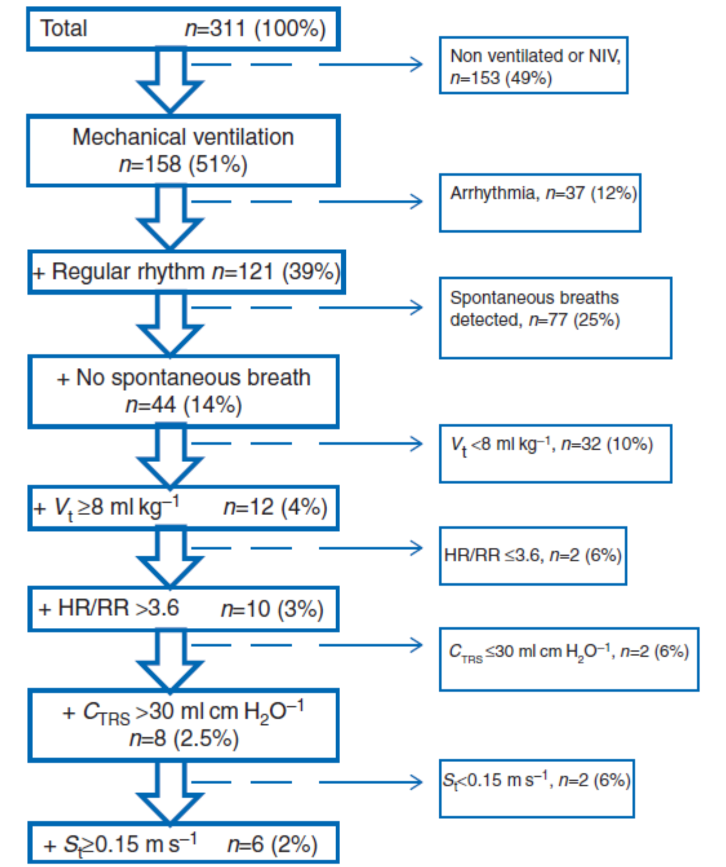
S_t<0.15 m s^{-1}, *n*=2 (6%)

+ S_t≥0.15 m s^{-1} *n*=6 (2%)

Total *n*=311 (100%)

Mahjoub et al. Brit J Anaesth 2014

Evaluation of pulse pressure variation validity criteria in critically ill patients: a prospective observational multicentre point-prevalence study†



Total n=311 (100%)

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V_t <8 ml kg^{-1}, n=32 (10%)

+ $V_t \geq 8$ ml kg^{-1} n=12 (4%)

HR/RR ≤3.6, n=2 (6%)

+ HR/RR >3.6 n=10 (3%)

$C_{TRS} \leq 30$ ml cm H_2O^{-1}, n=2 (6%)

+ C_{TRS} >30 ml cm H_2O^{-1} n=8 (2.5%)

S_t<0.15 m s^{-1}, n=2 (6%)

+ $S_t \geq 0.15$ m s^{-1} n=6 (2%)

Total n=311 (100%)

PPV utilisable chez 4% des patients ventilés

Mahjoub et al. Brit J Anaesth 2014

Monitorage Hémodynamique non-invasif au bloc opératoire aujourd'hui

- Pression Artérielle
- Indices Dynamiques
- **Débit Cardiaque**

Monitorage Hémodynamique non-invasif au bloc opératoire aujourd'hui

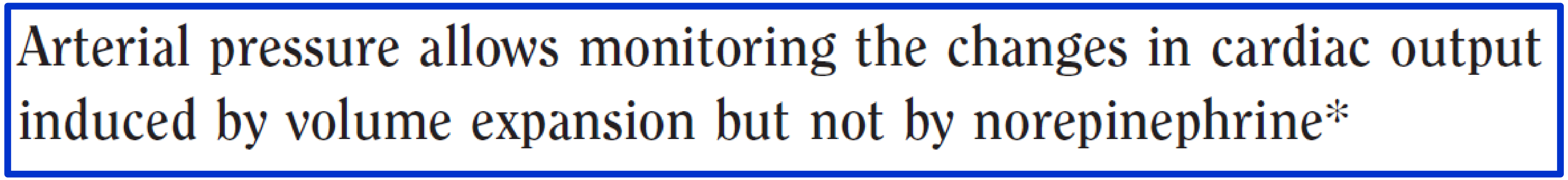
Pression Artérielle

Indices Dynamiques

Débit Cardiaque

1. POURQUOI MONITORER LE DEBIT CARDIAQUE ?

Le monitorage de la pression artérielle n’est-il pas suffisant ?



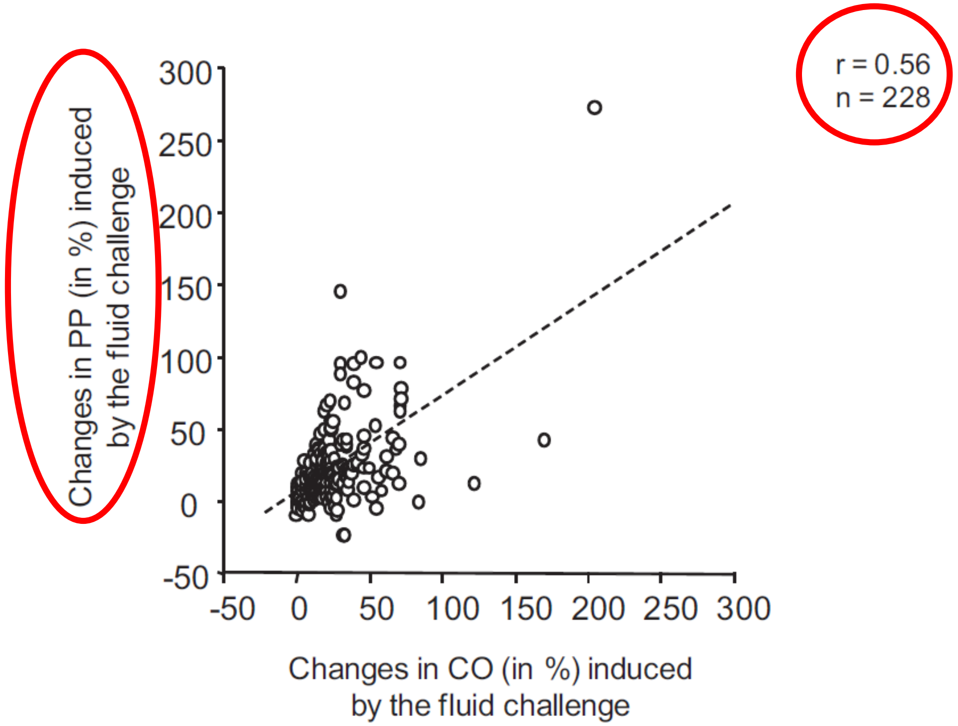
Arterial pressure allows monitoring the changes in cardiac output induced by volume expansion but not by norepinephrine*

228 patients: expansion volémique
145 patients : introduction / augmentation NAD

Monnet et al. Crit Care Med 2011

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

228 patients: expansion volémique
145 patients : introduction / augmentation NAD

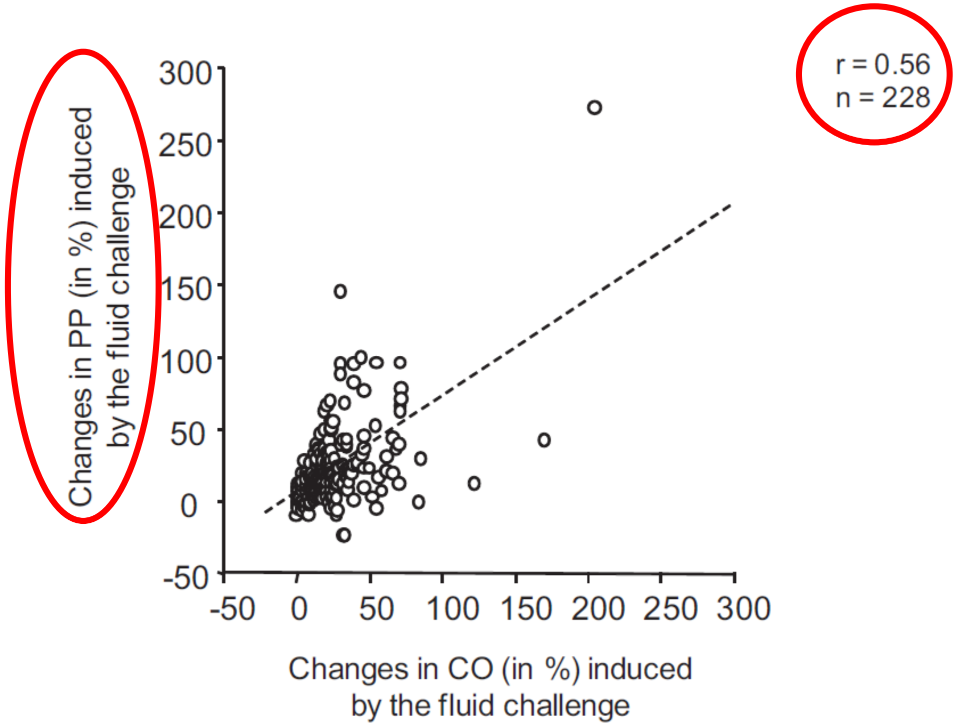


Remplissage Vasculaire
(n=228)

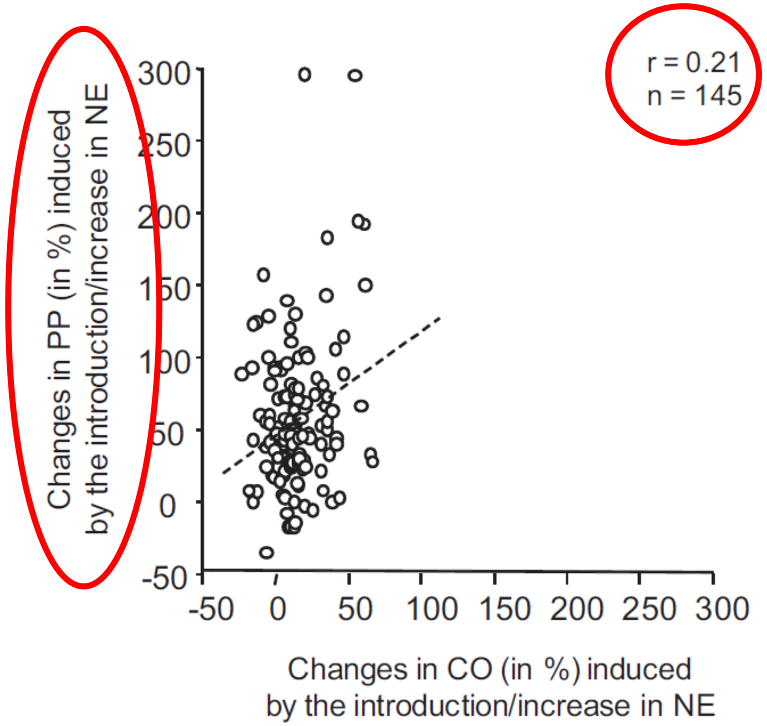
Monnet et al. Crit Care Med 2011

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

228 patients: expansion volémique
145 patients : introduction / augmentation NAD



Remplissage Vasculaire
(n=228)



Introduction ou ↑ NAD
(n=145)

Monnet et al. Crit Care Med 2011

Pourquoi Monitorer le Débit Cardiaque ?

La Pression Artérielle ne suffit-elle pas ?

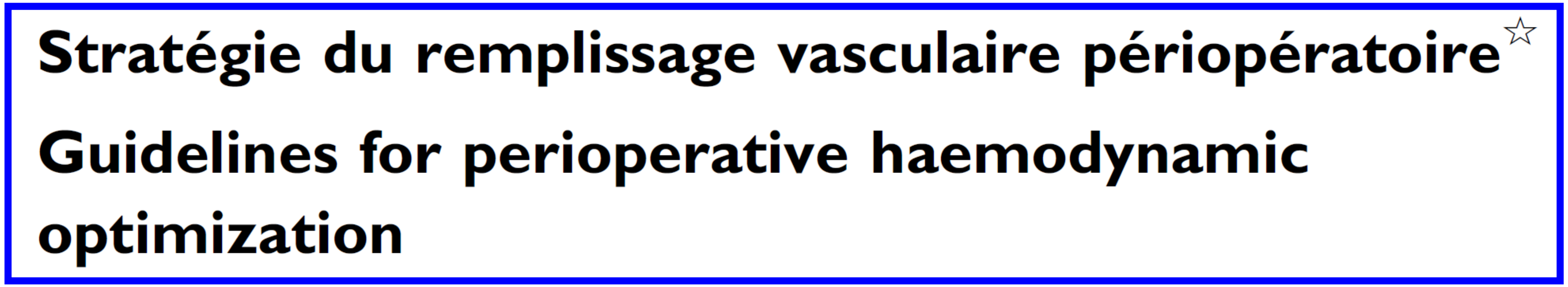
NON

Il faut mesurer le débit cardiaque car les variations de pression artérielle ne reflètent pas les variations de débit cardiaque

La mesure de la pression artérielle est-elle suffisante ?

La pression artérielle est régulée

Une pression artérielle normale n’exclue pas un débit cardiaque insuffisant


Stratégie du remplissage vasculaire périopératoire☆

Guidelines for perioperative haemodynamic optimization

Recommandation 1

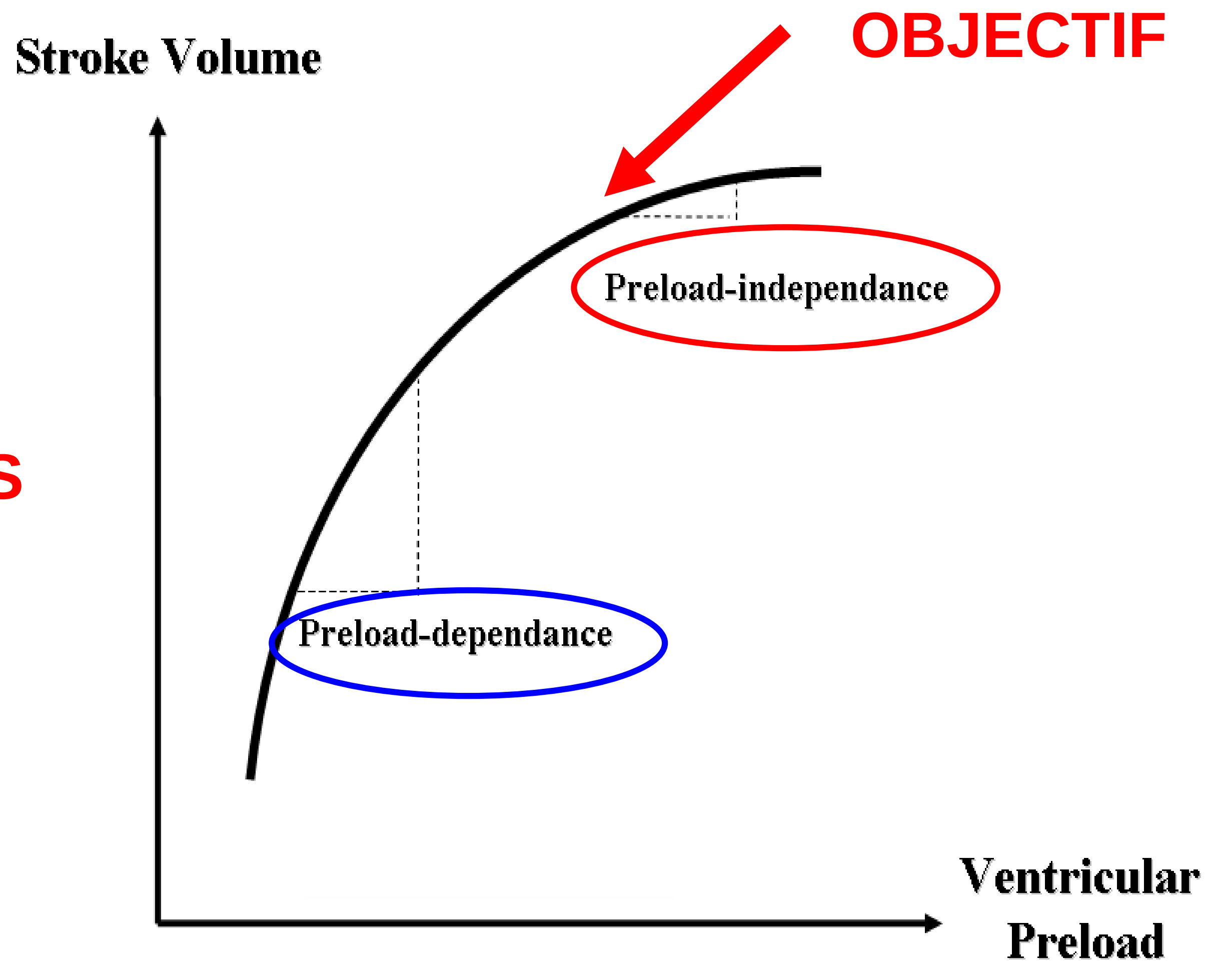
Chez les patients chirurgicaux considérés « à haut risque », il est recommandé de titrer le remplissage vasculaire per-opératoire en se guidant sur une mesure du volume d'éjection systolique (VES) dans le but de réduire la morbidité postopératoire, la durée de séjour hospitalier, et le délai de reprise d'une alimentation orale des patients de chirurgie digestive. **GRADE 1+.**

Vallet et al. Ann Fr Anesth Réanim 2013

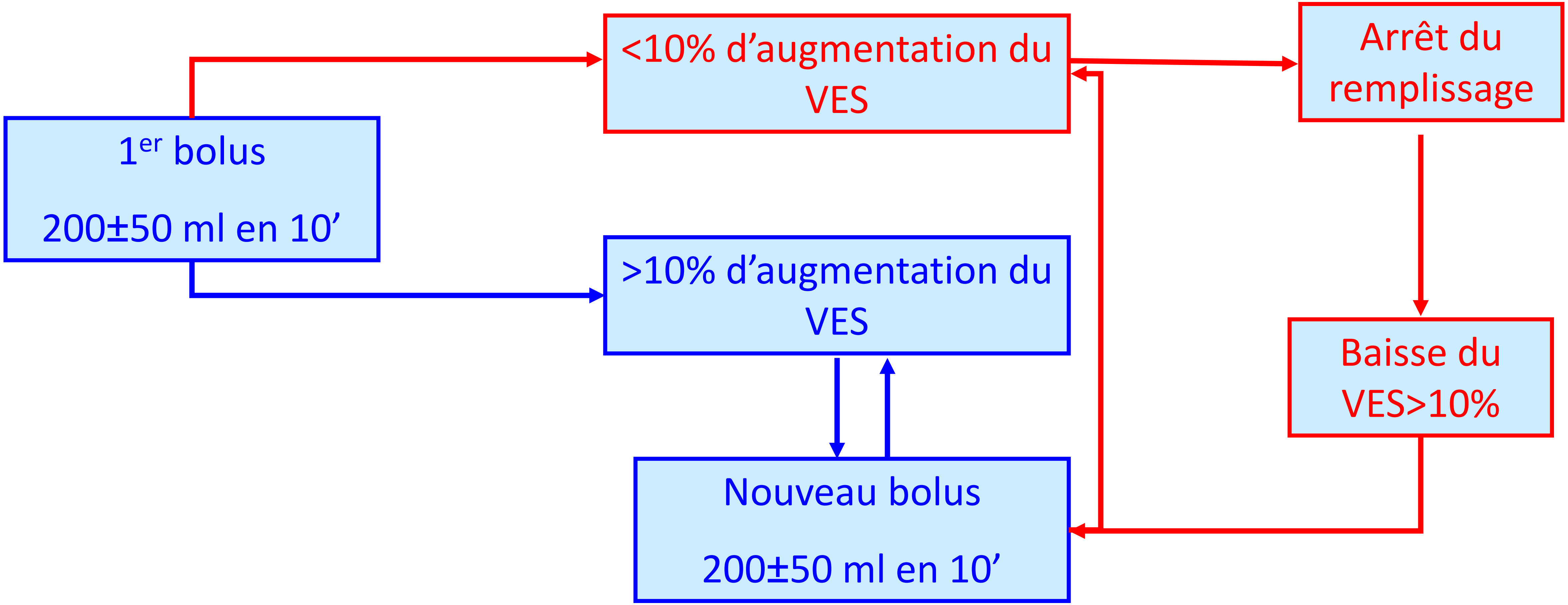
Pourquoi monitorer le débit cardiaque ?

Optimisation du DC/VES = MAXIMALISATION

Titration du remplissage pour maximaliser le VES



Protocole recommandé par la SFAR



1er bolus

200±50 ml en 10’

<10% d’augmentation du VES

Arrêt du remplissage

>10% d’augmentation du VES

Baisse du VES>10%

Nouveau bolus

200±50 ml en 10’

Niveau de Preuve

META ANALYSES

- **Optimisation Hémodynamique diminue:**
  - **Insuffisance rénale aigüe**

    Brienza et al. Crit Care Med 2009
  - **Complications Gastro-intestinales**

    Giglio et al. Br J Anaesth 2009
  - **Infections Postopératoires (Pneumoathies, IU …)**

    Dalfino et al. Crit Care 2011
  - **Morbidité et Mortalité**

    Hamilton et al. Anesth Analg 2011
  - **Morbidité et Durée de séjour**

    Pearse et al. JAMA 2014

Monitorage Hémodynamique non-invasif au bloc opératoire aujourd'hui

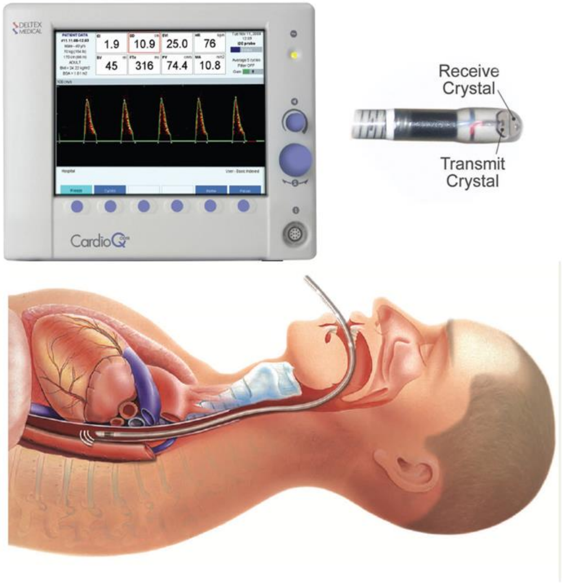
Pression Artérielle

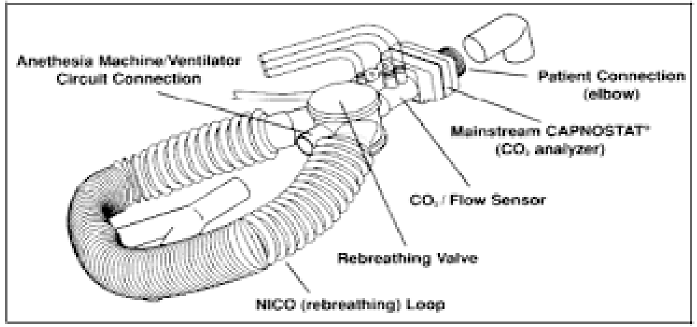
Indices Dynamiques

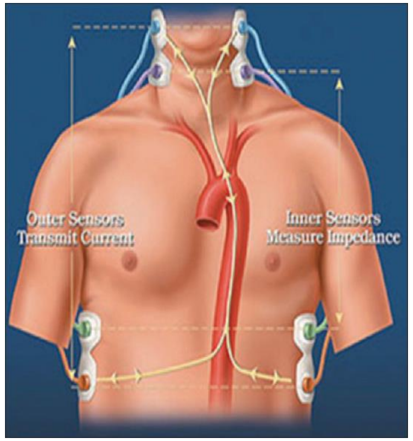
Débit Cardiaque

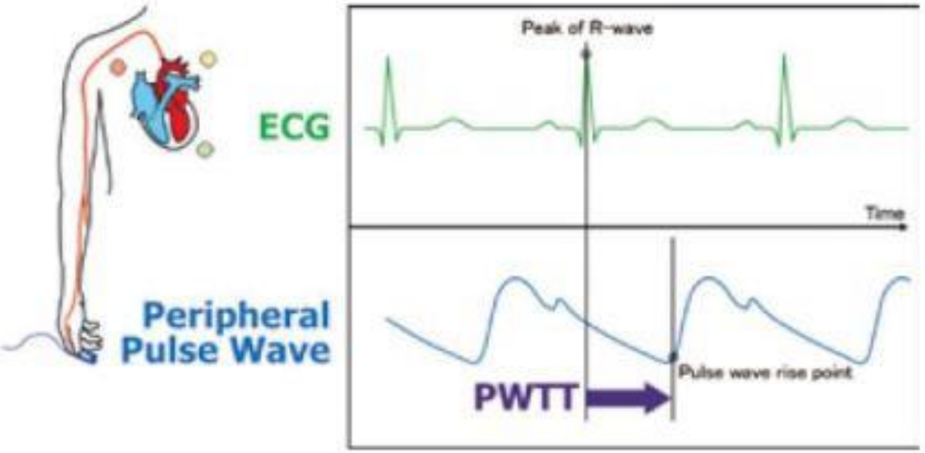
1. POURQUOI MONITORER LE DEBIT CARDIAQUE ?
2. **LE MONITORAGE NON INVASIF EST-IL FIABLE ?**

Monitorage non-invasif du débit cardiaque


CardioQ
Receive Crystal
Transmit Crystal


Anesthesia Machine/Ventilator Circuit Connection
Patient Connection (elbow)
Mainstream CAPNOSTAT® (CO_2 analyzer)
CO_2 / Flow Sensor
Rebreathing Valve
NICO (rebreathing) Loop

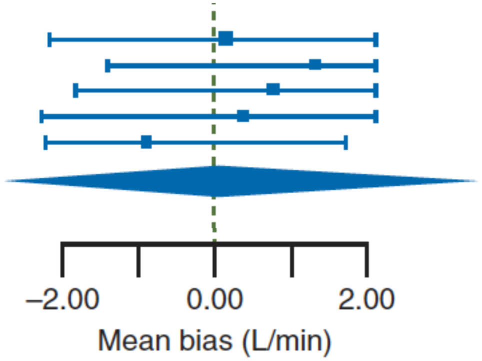

Outer Sensors Transmit Current
Inner Sensors Measure Impedance


ECG
Peak of R-wave
Time
Peripheral Pulse Wave
PWTT
Pulse wave rise point

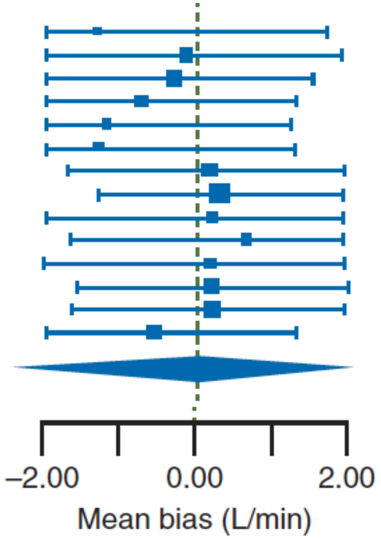
Accuracy and precision of non-invasive cardiac output monitoring devices in perioperative medicine: a systematic review and meta-analysis†

Evaluation des dispositifs de monitorage non invasifs du débit cardiaque , 37 études

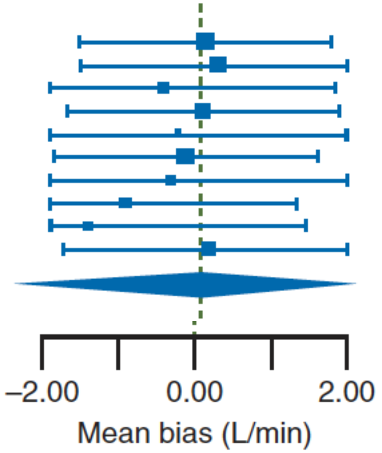
Temps de transit de l’onde de pouls



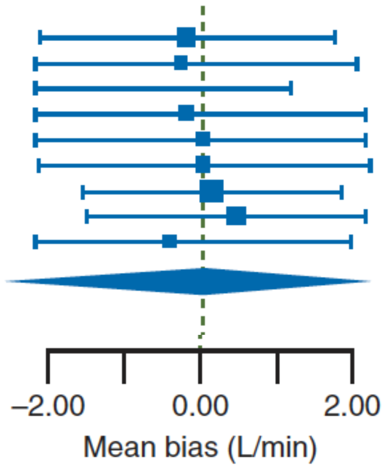
Réinhalation de CO2



Bioimpédence



Analyse contour onde de pouls



Biais élevés

Pourcentage d’erreur: 47% (>30%)

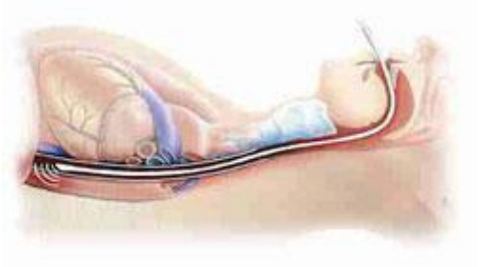
Etudes hétérogènes +++ (I^2=83%)

Joosten et al. Brit J Anaesth 2017

Doppler Oesophagien

- Avantages
  - Non invasive
  - Valeur absolue estimée
  - Capacité à detecter les variations de DC

Dark et al. Intensive Care Med 2004



- Limites
  - Difficultés à garder un signal de bonne qualité
  - Entraînement nécessaire

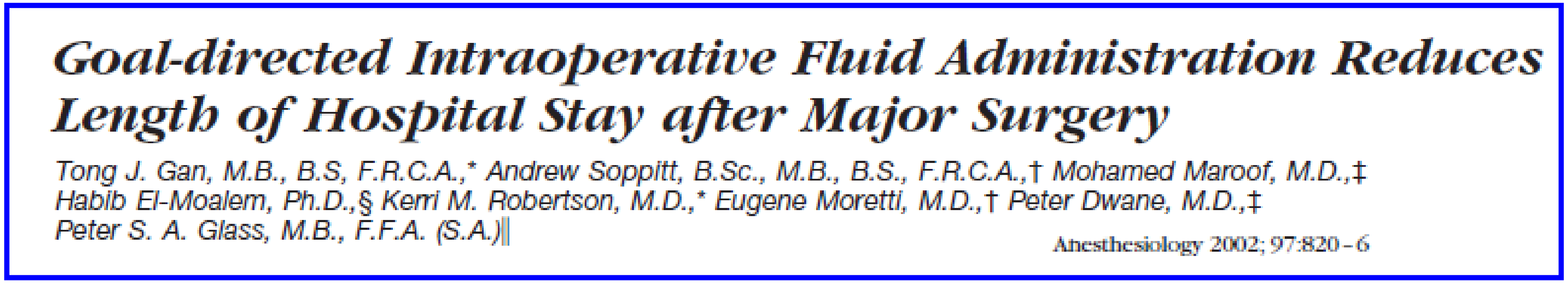
Lefrant et al. Intensive Care Med 1998

Monitorage Hémodynamique non-invasif au bloc opératoire aujourd’hui

Pression Artérielle

Débit Cardiaque

1. POURQUOI MONITORER LE DEBIT CARDIAQUE ?
2. LE MONITORAGE NON INVASIF EST-IL FIABLE ?
3. **L’UTILISATION DE CE TYPE DE DISPOSITIF AMELIORE-T-IL LE DEVENIR DES PATIENTS ?**



Goal-directed Intraoperative Fluid Administration Reduces Length of Hospital Stay after Major Surgery

Tong J. Gan, M.B., B.S, F.R.C.A., Andrew Soppitt, B.Sc., M.B., B.S., F.R.C.A.,† Mohamed Maroof, M.D.,‡*
Habib El-Moalem, Ph.D.,§ Kerri M. Robertson, M.D., Eugene Moretti, M.D.,† Peter Dwane, M.D.,‡*
Peter S. A. Glass, M.B., F.F.A. (S.A.)||

Anesthesiology 2002; 97:820-6

100 patients, chirurgie majeure

Optimisation du VES par remplissage vasculaire

Diminution morbidité

Réduction durée de séjour

Perioperative non-invasive haemodynamic optimisation using photoplethysmography: A randomised controlled trial and meta-analysis

160 patients, chirurgie colo-rectale,

Bras contrôle: optimisation PAM 65 mmHg, remplissage vasopresseurs

Bras interventionnel : idem + optimisation VES par remplissage

CJP: complications à J30

Fischer et al. ACCPM 2020

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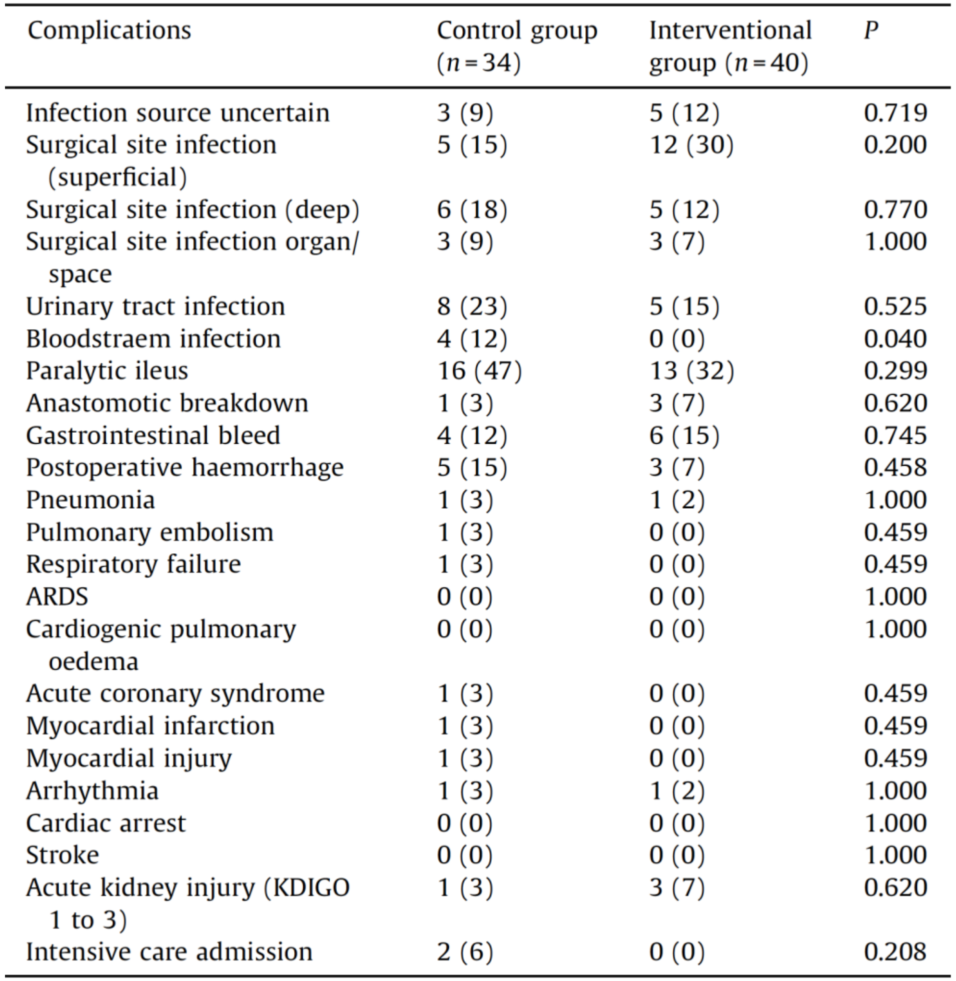

Complications	Control group ($n = 34$)	Interventional group ($n = 40$)	*P*
Infection source uncertain	3 (9)	5 (12)	0.719
Surgical site infection (superficial)	5 (15)	12 (30)	0.200
Surgical site infection (deep)	6 (18)	5 (12)	0.770
Surgical site infection organ/ space	3 (9)	3 (7)	1.000
Urinary tract infection	8 (23)	5 (15)	0.525
Bloodstraem infection	4 (12)	0 (0)	0.040
Paralytic ileus	16 (47)	13 (32)	0.299
Anastomotic breakdown	1 (3)	3 (7)	0.620
Gastrointestinal bleed	4 (12)	6 (15)	0.745
Postoperative haemorrhage	5 (15)	3 (7)	0.458
Pneumonia	1 (3)	1 (2)	1.000
Pulmonary embolism	1 (3)	0 (0)	0.459
Respiratory failure	1 (3)	0 (0)	0.459
ARDS	0 (0)	0 (0)	1.000
Cardiogenic pulmonary oedema	0 (0)	0 (0)	1.000
Acute coronary syndrome	1 (3)	0 (0)	0.459
Myocardial infarction	1 (3)	0 (0)	0.459
Myocardial injury	1 (3)	0 (0)	0.459
Arrhythmia	1 (3)	1 (2)	1.000
Cardiac arrest	0 (0)	0 (0)	1.000
Stroke	0 (0)	0 (0)	1.000
Acute kidney injury (KDIGO 1 to 3)	1 (3)	3 (7)	0.620
Intensive care admission	2 (6)	0 (0)	0.208

Fischer et al. ACCPM 2020

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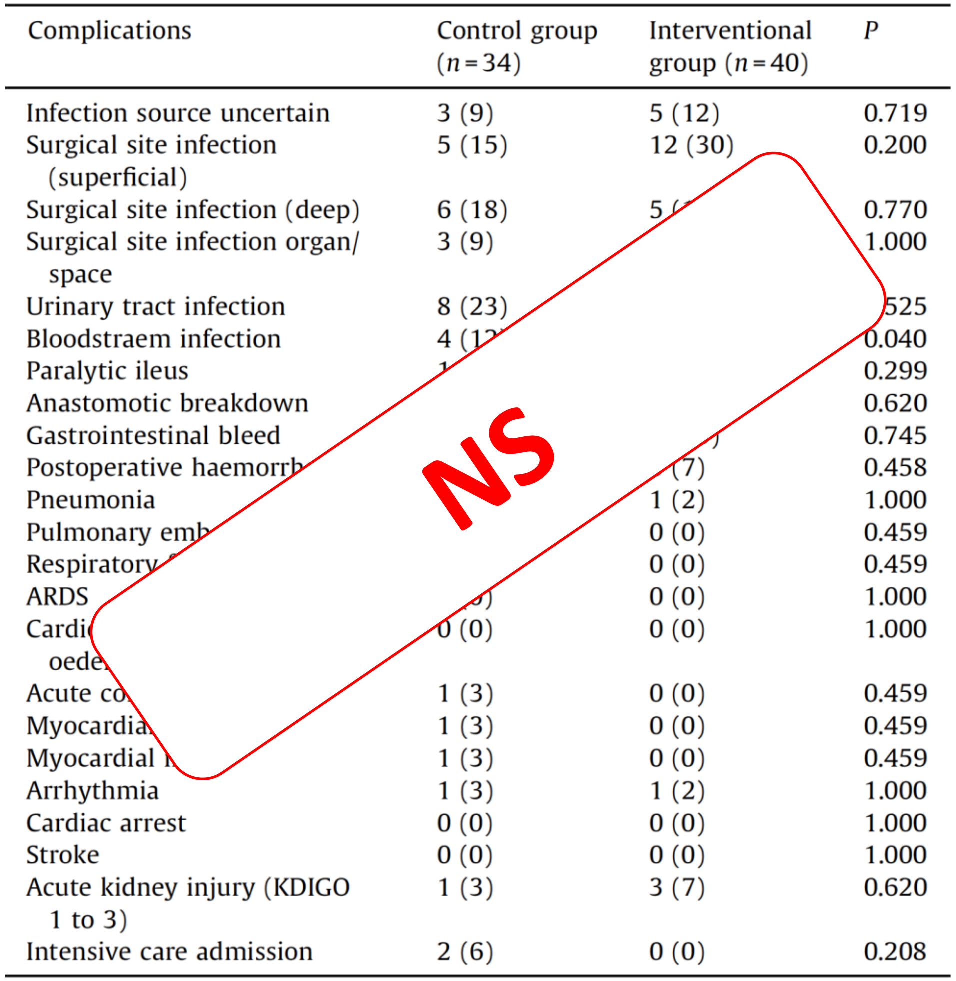

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ARDS	)	0 (0)	1.000
Cardi oede	0 (0)	0 (0)	1.000
Acute co	1 (3)	0 (0)	0.459
Myocardia	1 (3)	0 (0)	0.459
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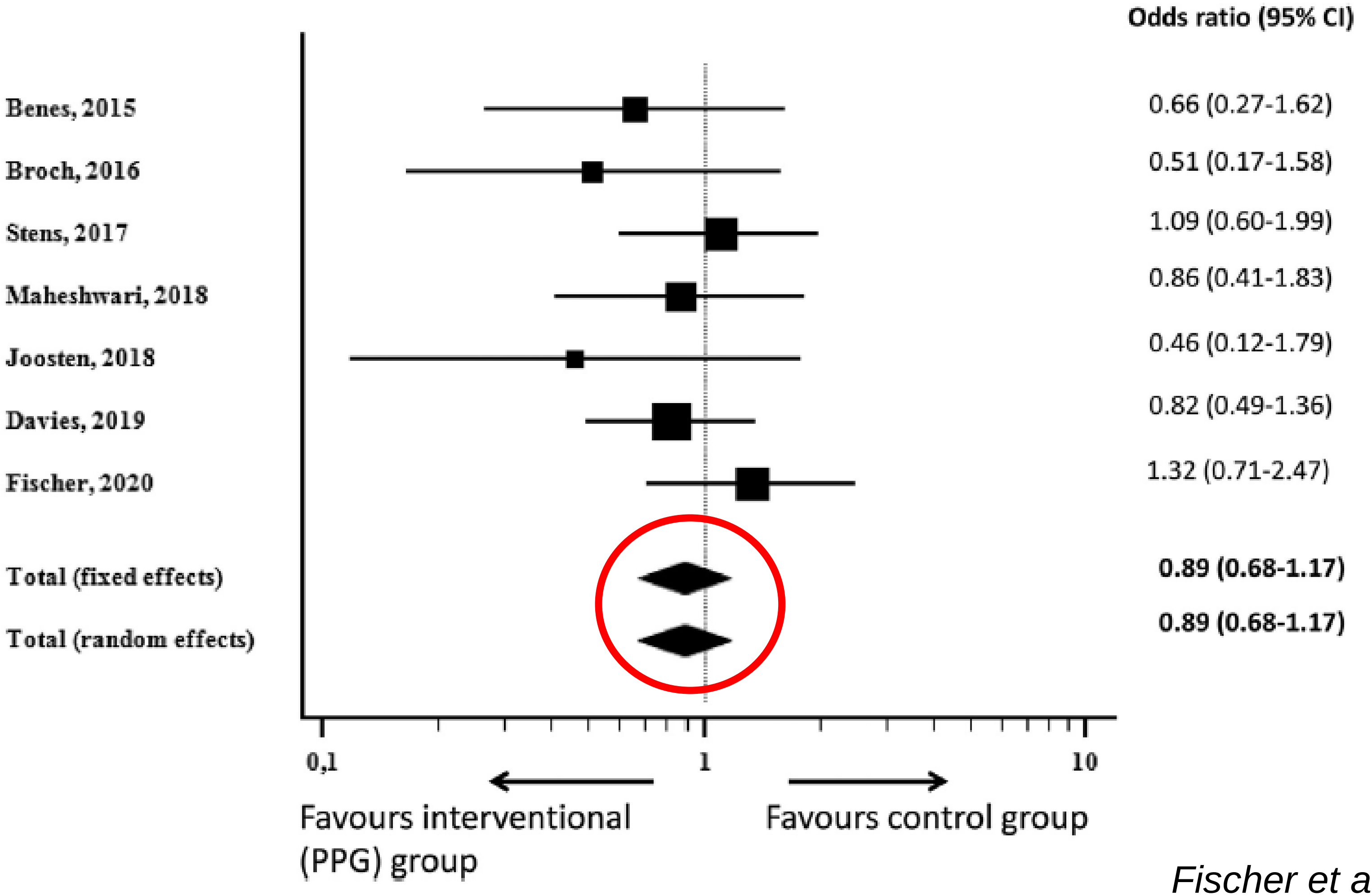
NS

Fischer et al. ACCPM 2020

Perioperative non-invasive haemodynamic optimisation using photoplethysmography: A randomised controlled trial and meta-analysis

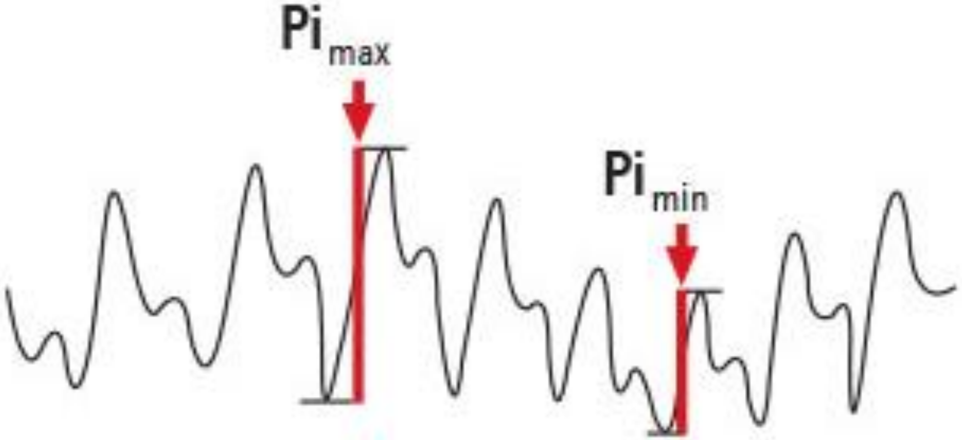


Fischer et al. ACCPM 2020

Individualized Fluid Management Using the Pleth Variability Index

A Randomized Clinical Trial

7.0
17.0
7.0
SpHb g/dL
20
PVi
Radical 7


Pi max
Pi min

$$PVi = \frac{Pi_{max} - Pi_{min}}{Pi_{max}} \times 100$$

Fischer et al. Anesthesiology 2020

Individualized Fluid Management Using the Pleth Variability Index

A Randomized Clinical Trial

447 patients, chirurgie orthopédique (PTH / PTG)
PAM 65 mmHg (contrôle) + PVI < 13% (interventionnel)
CJP: durée hospitalisation

Fischer et al. Anesthesiology 2020

Individualized Fluid Management Using the Pleth Variability Index

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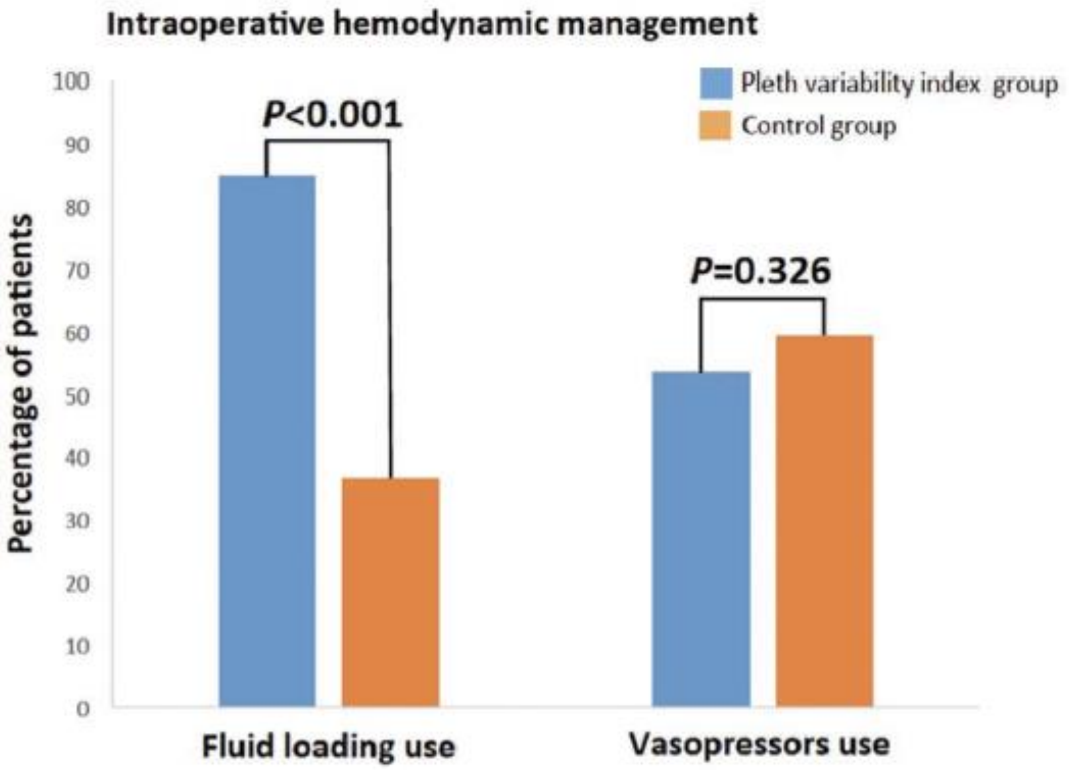

Fischer et al. Anesthesiology 2020

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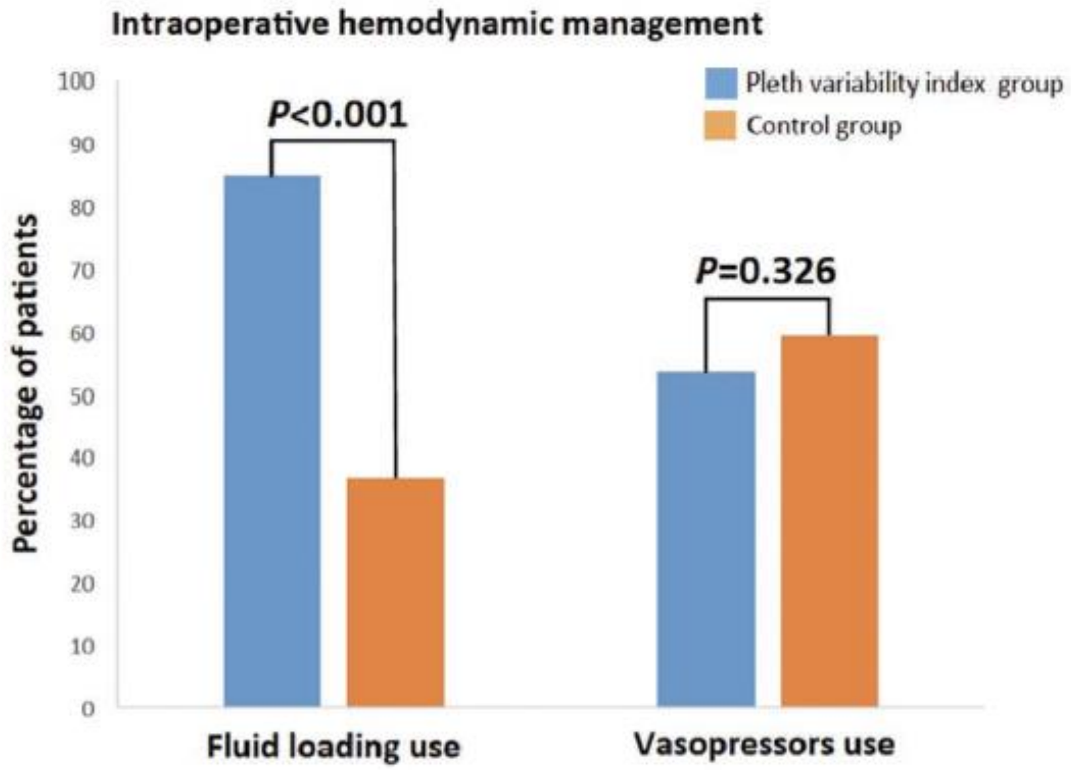

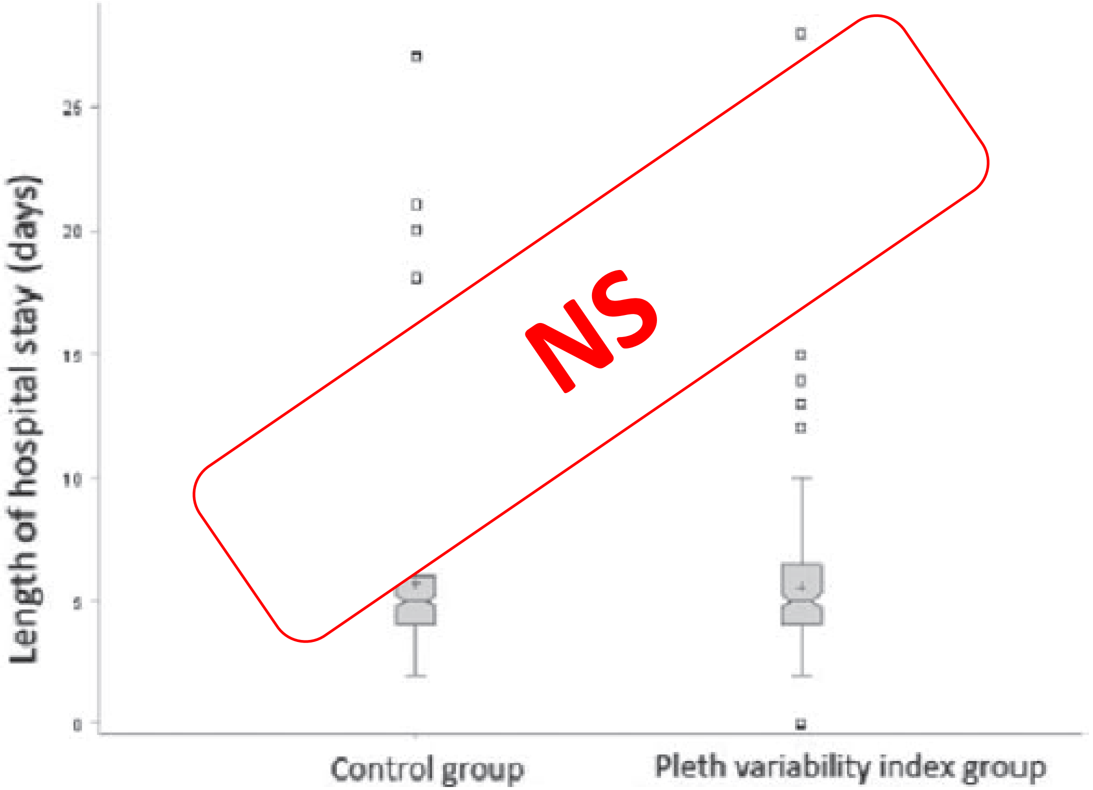

Fischer et al. Anesthesiology 2020

TAKE HOME MESSAGES

- **Pression Artérielle**
  - Relation hypotension artérielle ⇔ morbidité
- **Indices Dynamiques**
  - Beaucoup de limites au bloc opératoire
  - Peu de données avec le non invasif
- **Débit Cardiaque**
  - Monitorage non invasif du débit cardiaque : valeur absolue peu fiable
  - Pas d'étude d'outcome positive sauf avec le doppler oesophagien

MERCI !!