Les Indicateurs de l'oxygénation tissulaire

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Introduction

- L’oxygène (O2) alimente le fonctionnement de la mitochondrie.
- > 95% de l’O2:utilisé pour fabriquer l’ATP (source d’énergie).
- L’EDC est un déficit cellulaire aigu en O2.
- Objectifs macrovasculaires (PA, DC, RVS…): objectifs intermédiaires.
- Marqueurs de l’oxygénation tissulaire
- Microcirculation

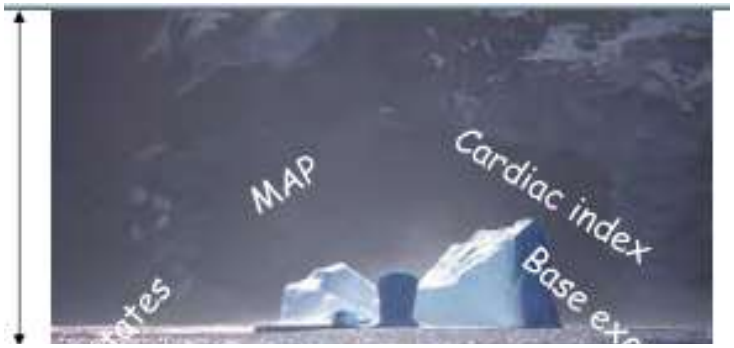
Définition microvasculaire du choc

Shock may be defined as a syndrome in which tissue perfusion is inadequate to meet the metabolic needs of the body. Because the most immediate metabolic nutrient is oxygen, this inadequate perfusion results in tissue hypoxia that has far-reaching effects on the whole orgnanism, individual organ systems, tissue comprising the individual organ systems, and finally the individual cell. Cellular hypoxia leads to cell injury and the initiation of the inflammatory cascade. In situations where the tissue hypoperfusion is rapidly corrected, cell injury is limited; but if treatment is not provided in an expeditious fashion, the shock state may become irreversible with death of the organism. Thus the shock state should truly be viewed as a continuum from subclinical perfusion deficits to frank oragn system dysfunction and death.

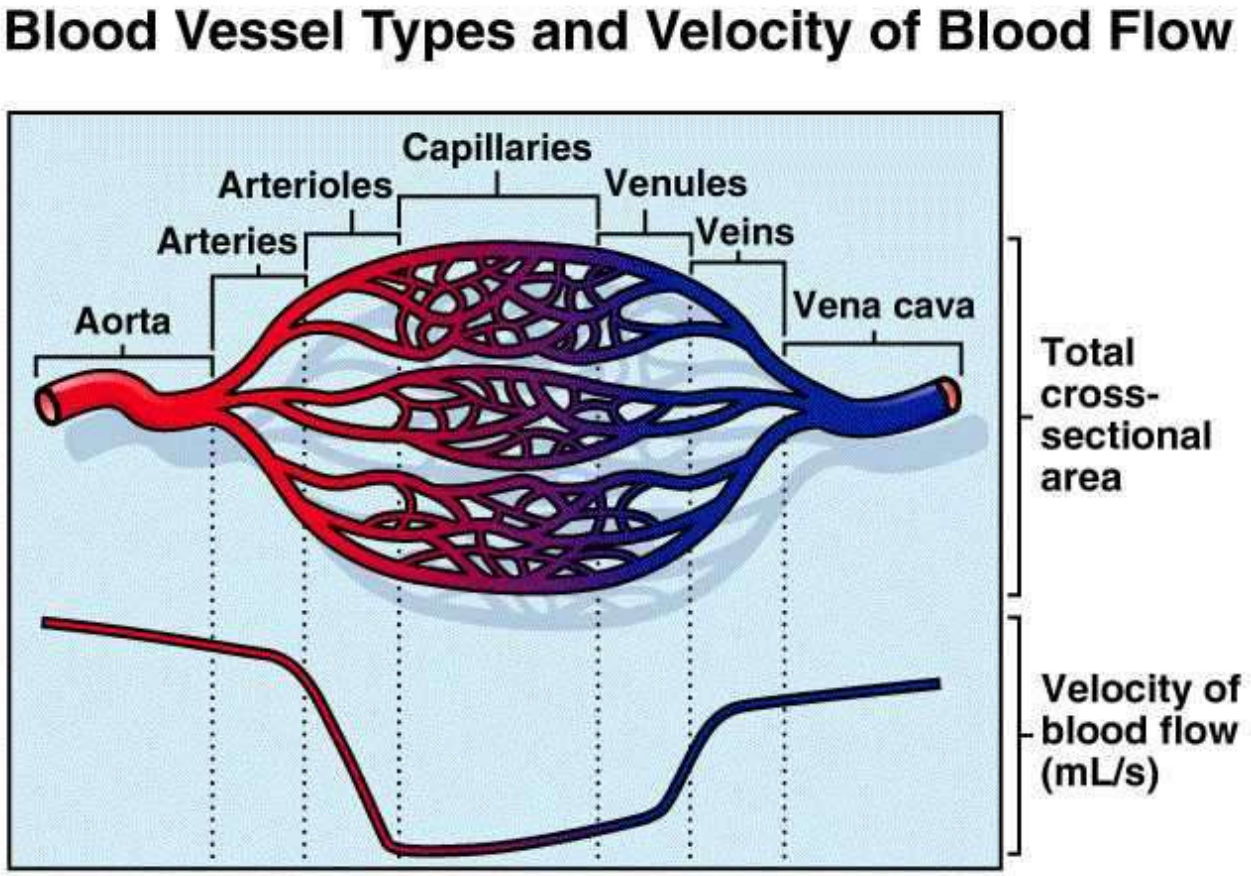
Malhotra AK, Pathophysiology of shock. 2006.

Macrocirculation: partie émergente de l'ice-berg

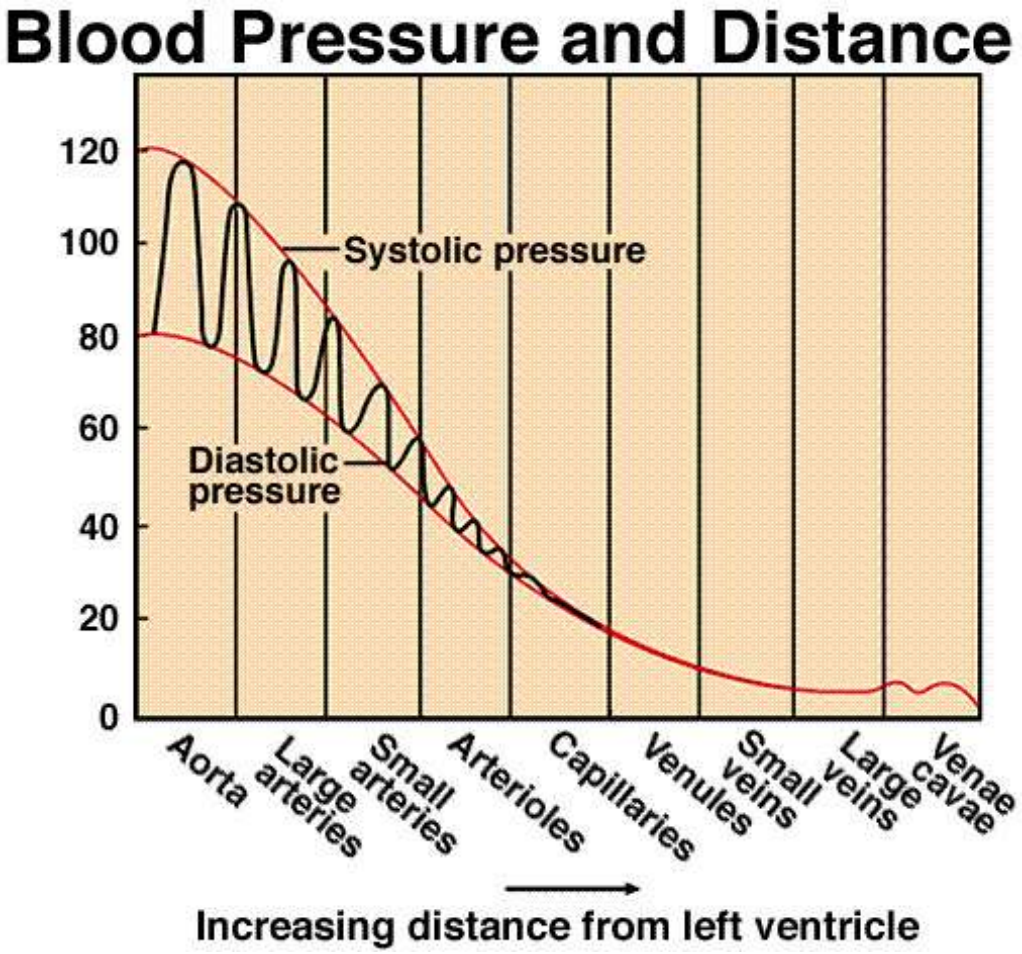
Anomalies macrocirculatoires



Vélocité microcriculatoire

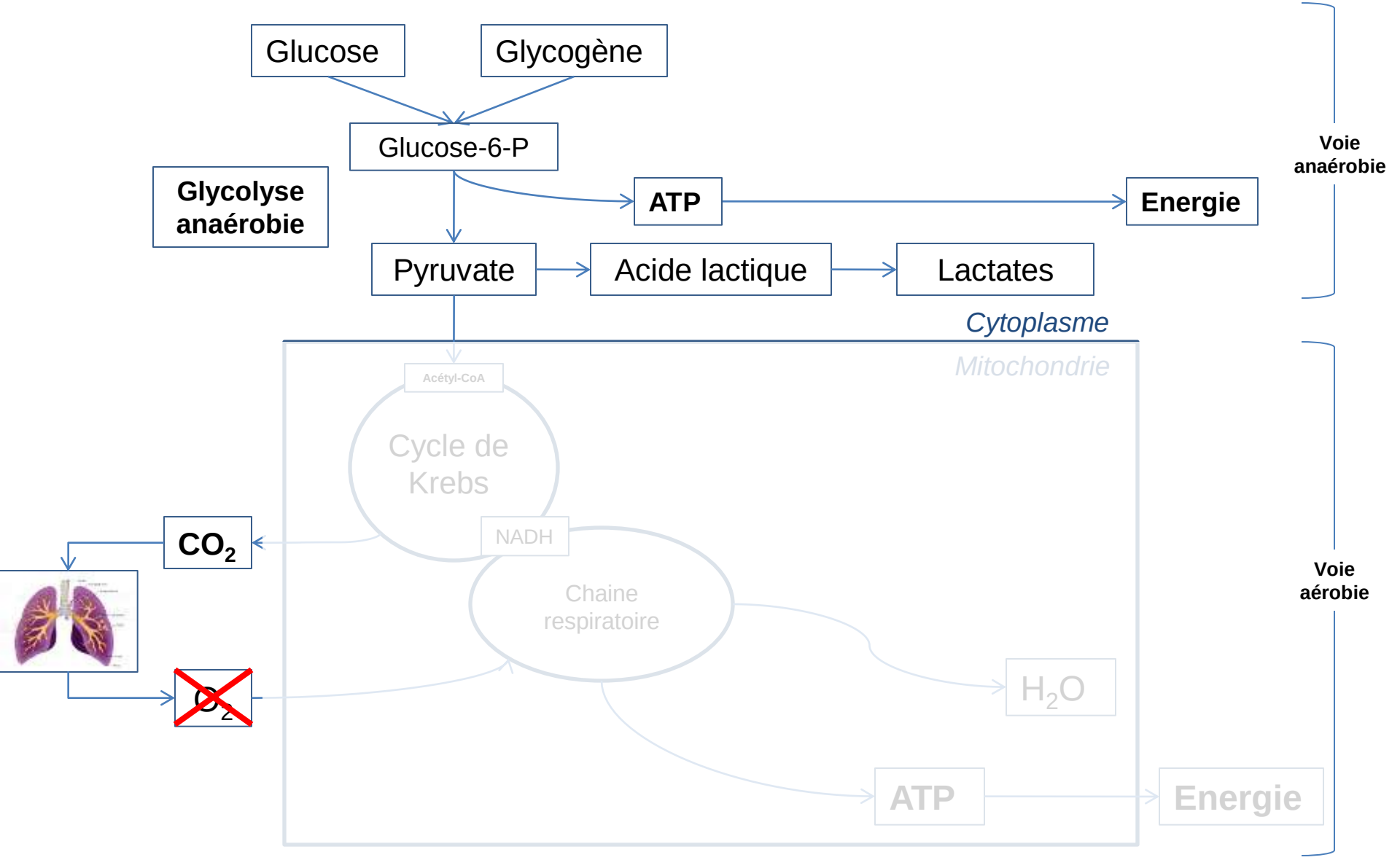


Pression microcirculatoire



Bases physiopathologiques
Oxygénation tissulaire

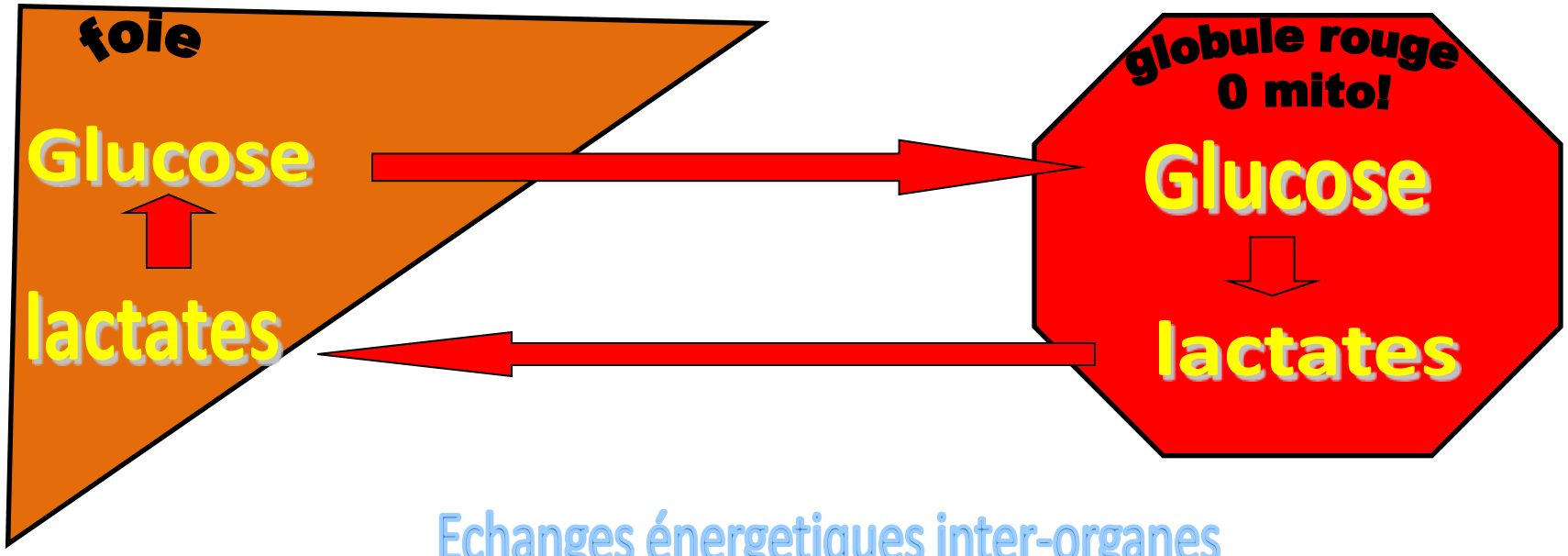
Respiration mitochondriale



Lactates physiologiques ?

- GR= pas de mitochondries
- Le foie “respire” pour les globules rouges...

Cycle de CORI

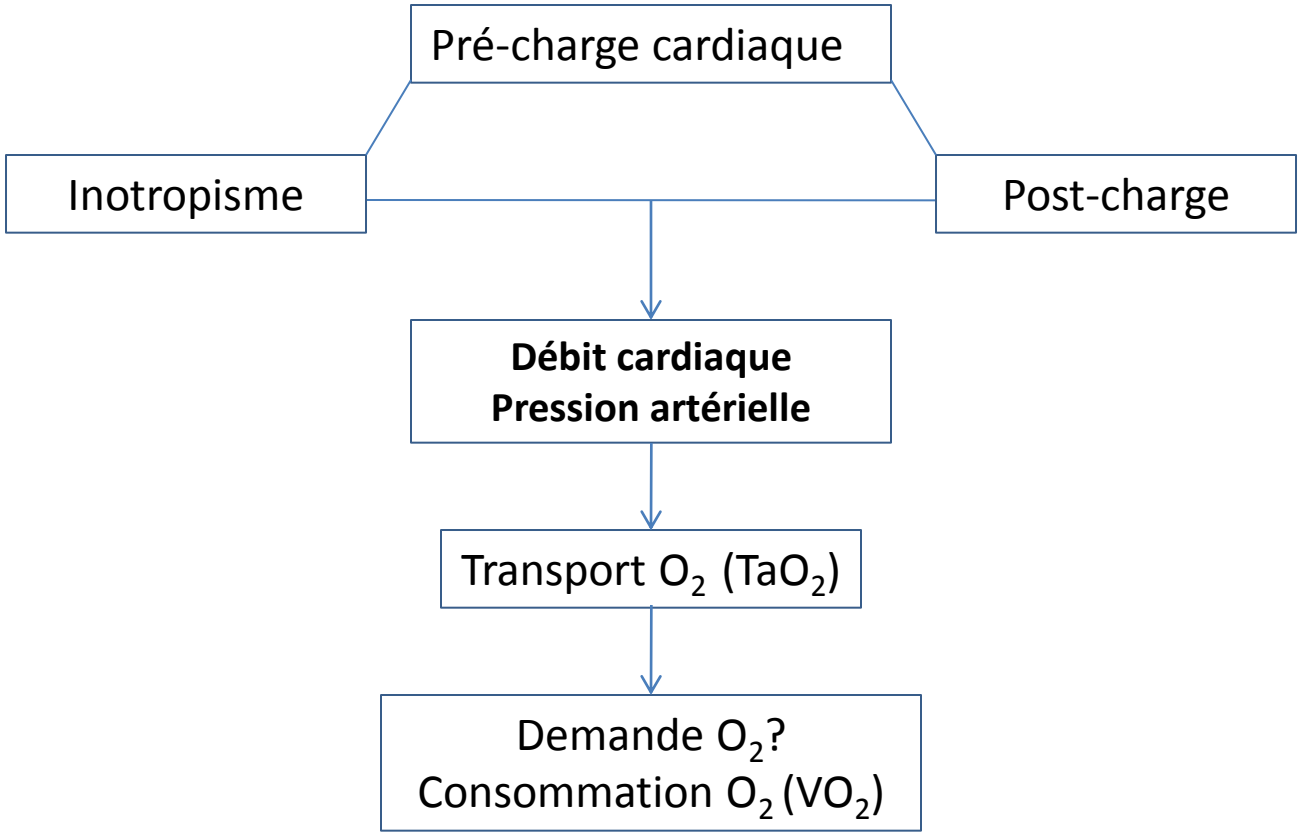


Echanges énergetiques inter-organes

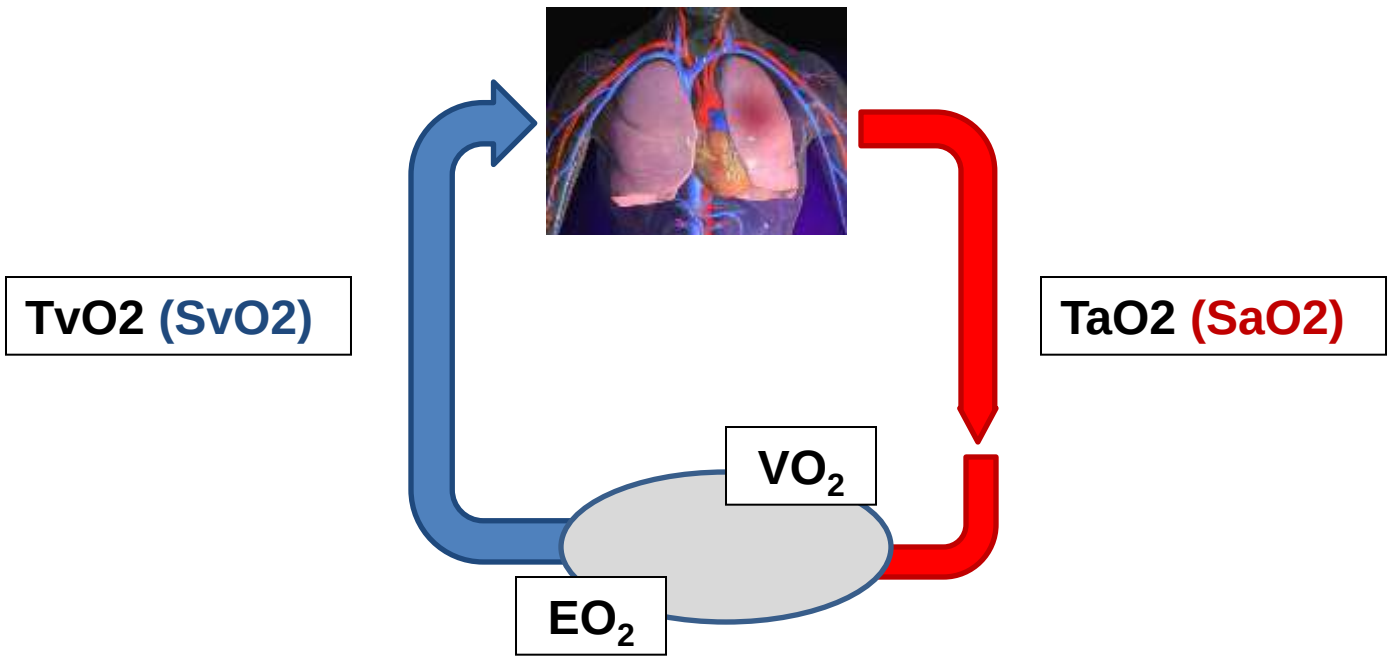
Lactates= marqueur de l'oxygénation cellulaire

Delta PCO_2= marqueur de la balance entre le transport et besoins métaboliques

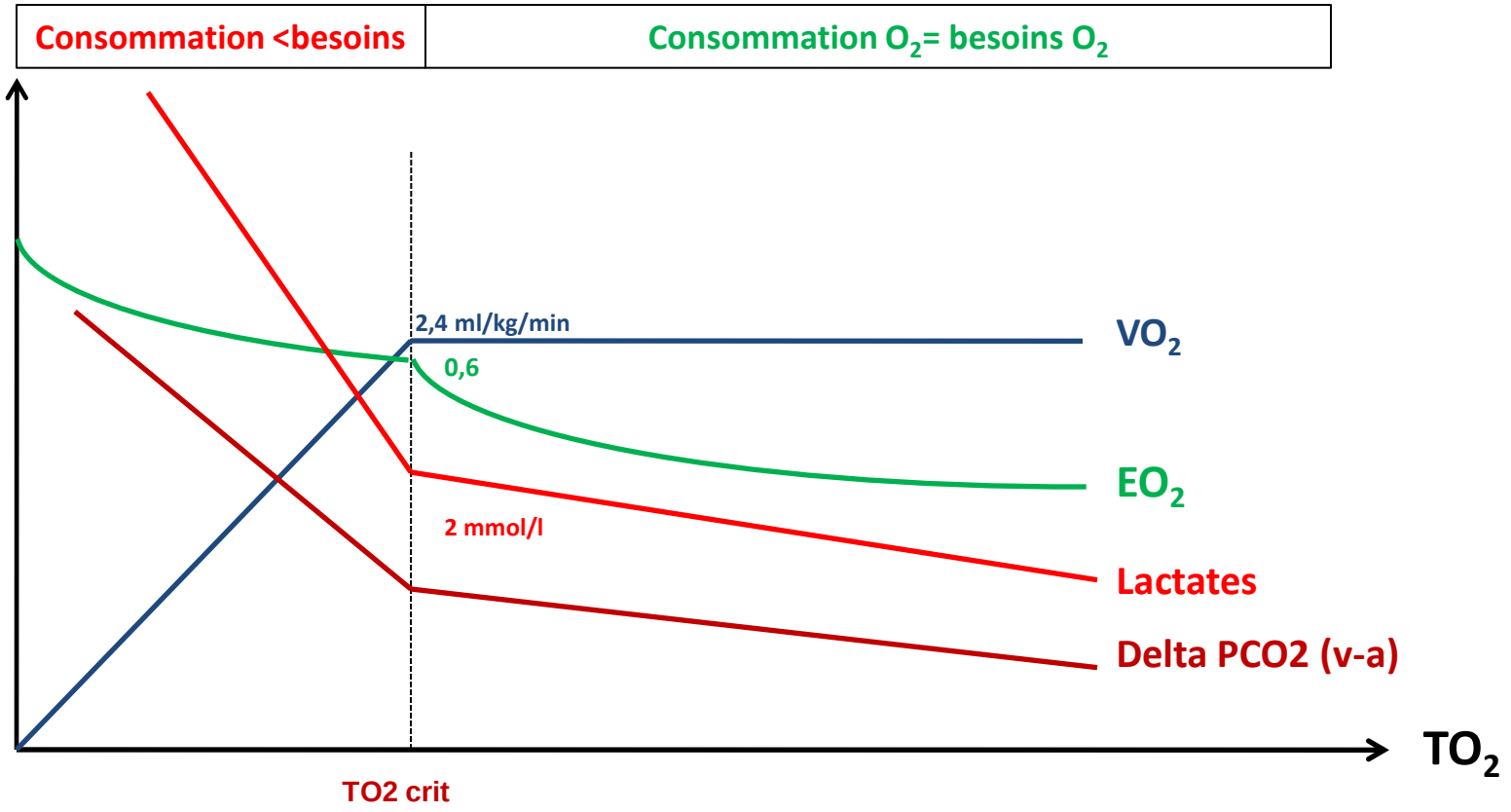
Hémodynamique-Oxygénation tissulaire



Hémodynamique: Transport de l'O2



Relations TO_2-VO_2-EO_2-Lactates



Ronco et al. JAMA 1993; 270: 1724-30.

Relation SvO_2-EO_2

- VO_2= DCxHbx1,34x(SaO_2-SvO_2)
- **TaO_2**=DCxHbx1,34xSaO_2

CaO_2

- **EO_2**= VO_2/TaO_2
- **EO_2**=(SaO_2-SvO_2)/SaO_2

Si SaO_2 est proche de 100%

↳**EO_2**=1-SvO_2

SvO_2=

marqueur de l'extraction

et de l'oxygénation tissulaire globale

Applications cliniques de monitorage de l'oxygénation tissulaire

Monitorage HD= utiliser les bons outils

- Bases physiologiques : ++
- Validité des outils : fiabilité de la mesure ?
- Validation des outils : intérêt clinique de l'outil ?

Marqueurs d'O_2 utilisés en clinique

- **SvO2 et ScvO2**
- **Lactates**
- **Delta PCO2**
- **Tonométrie gastrique**
- **StO2**

SvO2 et ScvO2

Définition SvO_2

- $\underline{SvO_2}$: proportion d'Hb transportant de l'O2 sur le sang veineux mêlé
- Reflet de la quantité d'O_2 non extraite par les tissus après satisfaction des besoins métaboliques de l'organisme
- Reflet global de l'oxygénation et de l'adéquation TaO_2/VO_2
- Recueil au niveau de l'artère pulmonaire
- Somme de tous les retours veineux de l'organisme (VCS, VCI, sinus coronaire)
- Disponible en continu

SvO2: Problématique

- Mesure de la **SvO_2** uniquement par cathétérisme artériel pulmonaire

↳ Rapport bénéfice/risque incertain et controversé (monitorage invasif)

- **$ScvO_2$:** saturation du sang veineux central

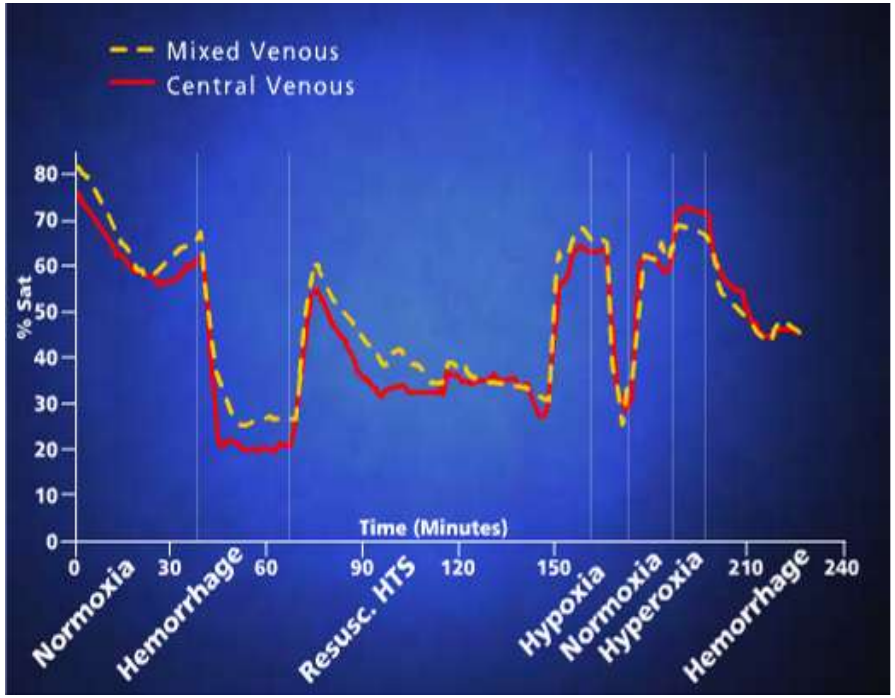
  - Recueil VCS ou OD, retour veineux de la partie supérieure de l'organisme, sur VVC avec adjonction fibre optique

  - Plus facilement utilisable et mesurable

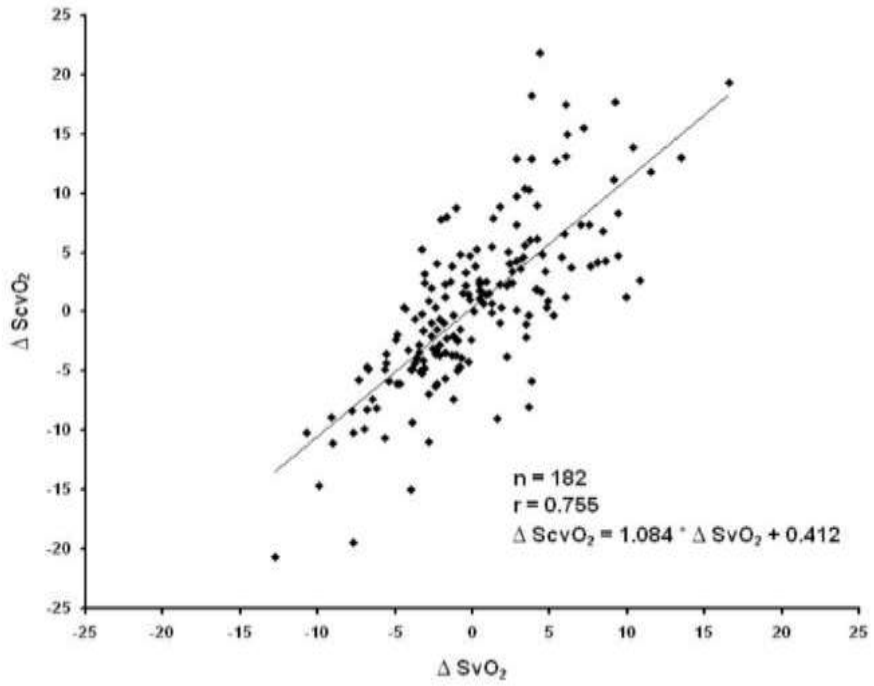
la ScvO2 peut-elle remplacer la SvO2 ?

Pas d'équivalence numérique stricte mais :

- Évolution parallèle
- Surestimation de la SvO2 par la ScvO2
- Même pathogénicité



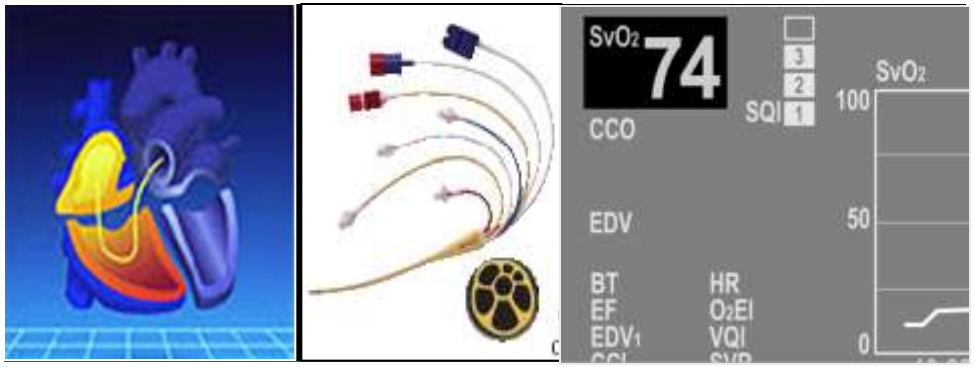
Reinhart et al. Chest 1989; 95: 1216-1221



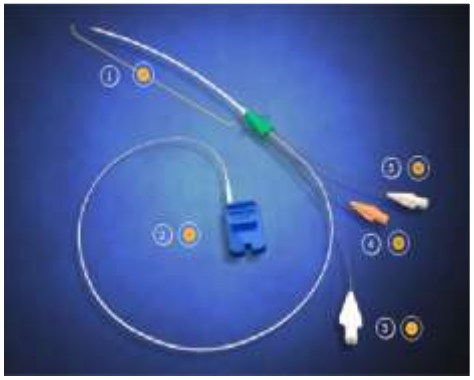
Reinhart et al. Intensive Care Med 2004

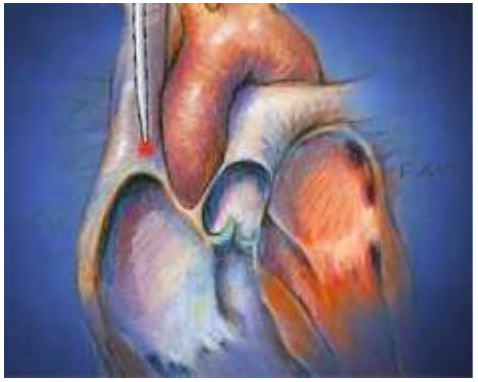
Surveillance continue de la SvO_2: deux sites de mesure

- La SvO_2 du sang veineux mêlé : CAP + fibres optiques



- La SvO2 centrale ou ScvO2 : cathéter VCS + fibres optiques

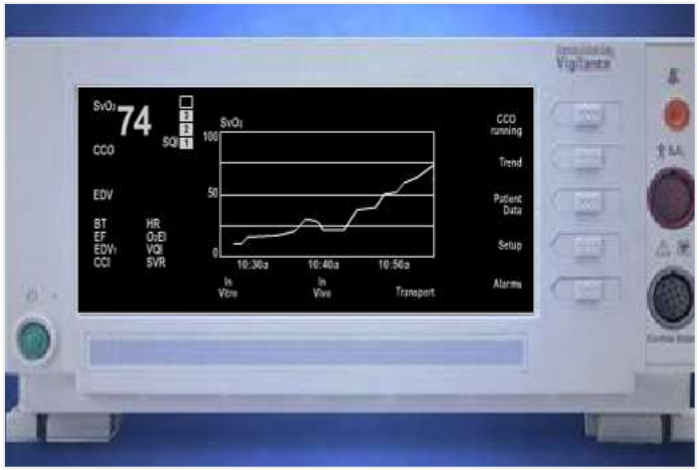




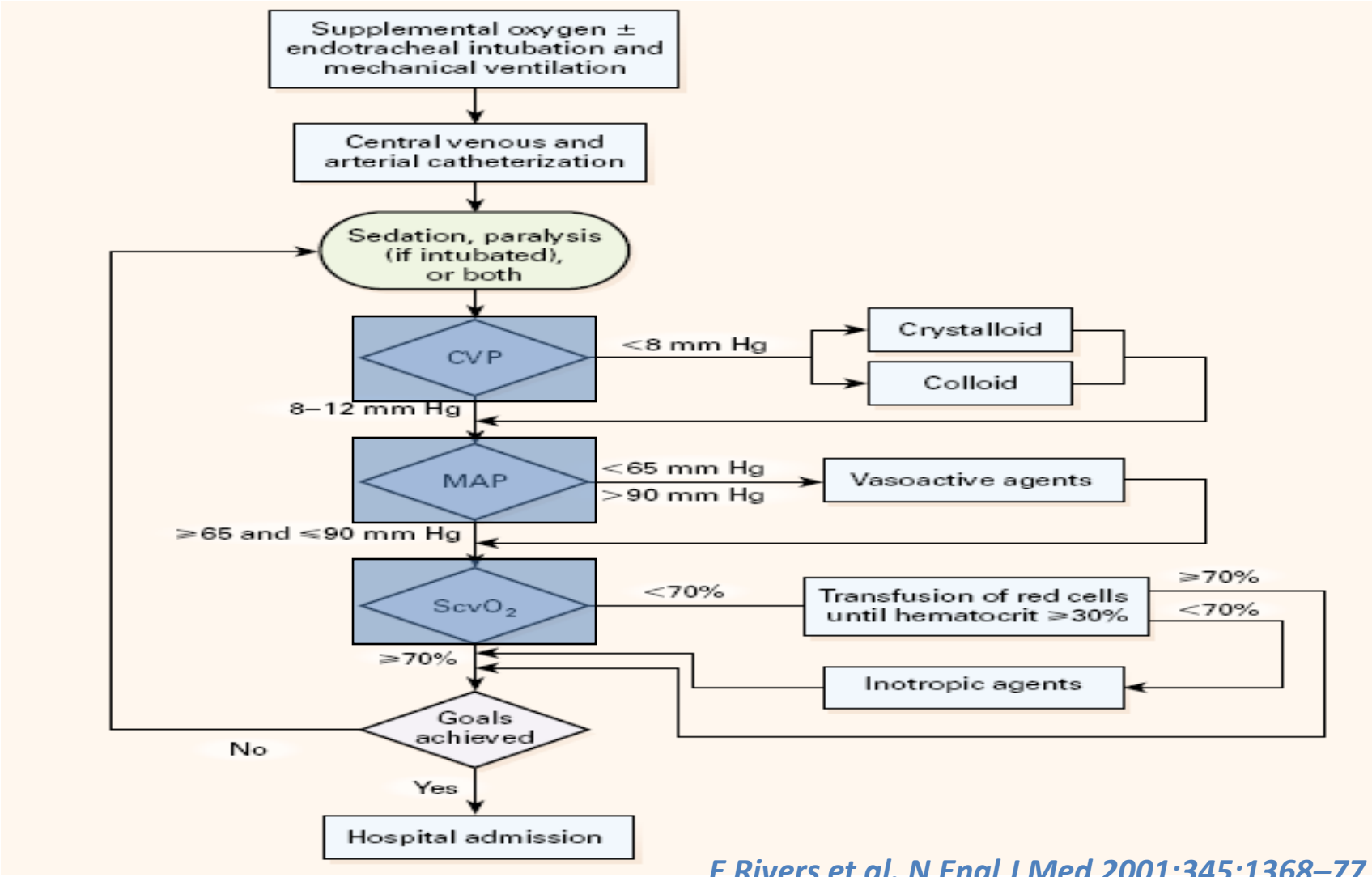
SvO2: Principes de mesure

Spectrophotométrie

- Source de lumière rouge et infra rouge envoie des longueurs d'onde différentes, illumine le sang
- Réflexion lumière par GR (= selon le type Hb) par une fibre optique vers un photodétecteur ;
- Un logiciel calcule la SvO2

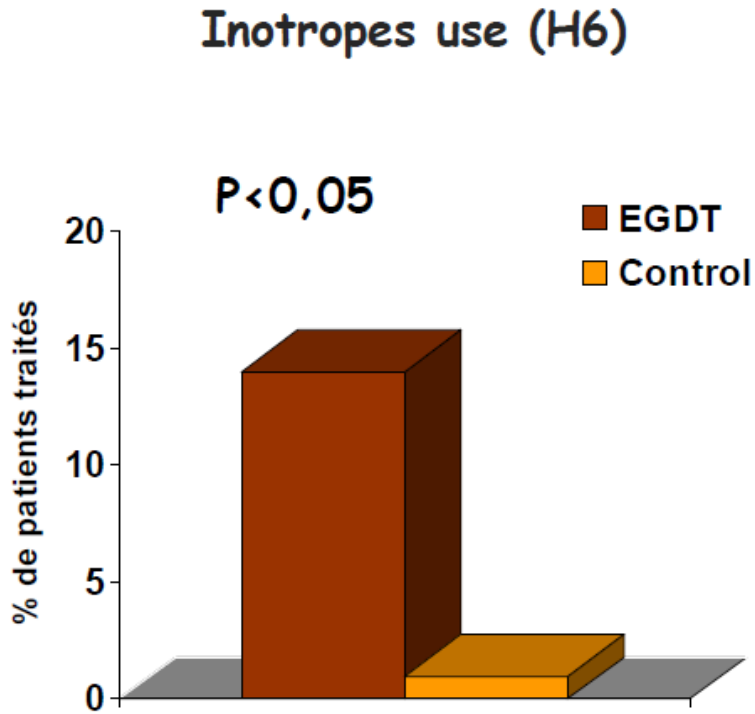


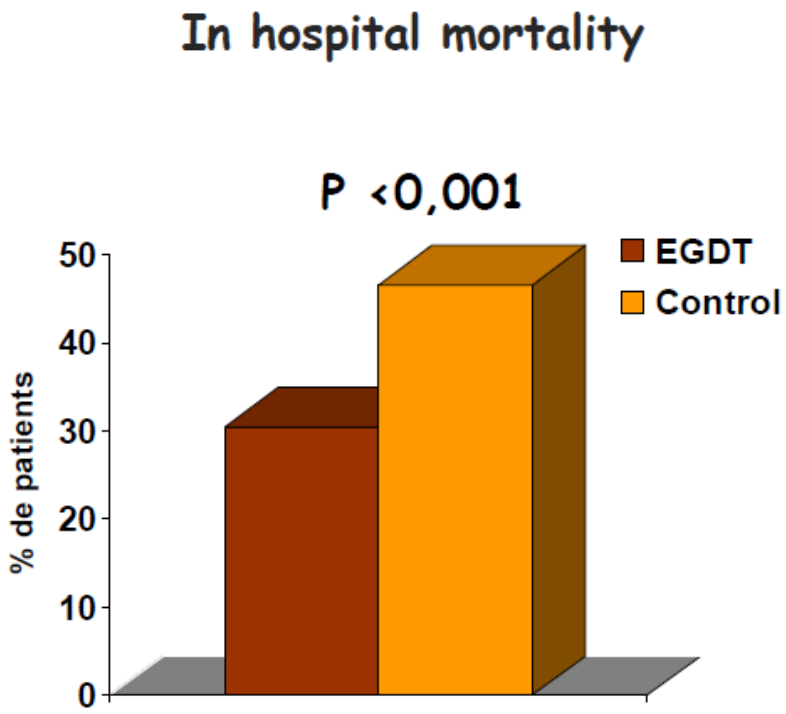
Place de la SvO_2 en pratique clinique
Early Goal directed therapy



E Rivers et al. N Engl J Med 2001;345:1368–77

Place de la SvO_2 en pratique clinique





En résumé, la SvO_2 …

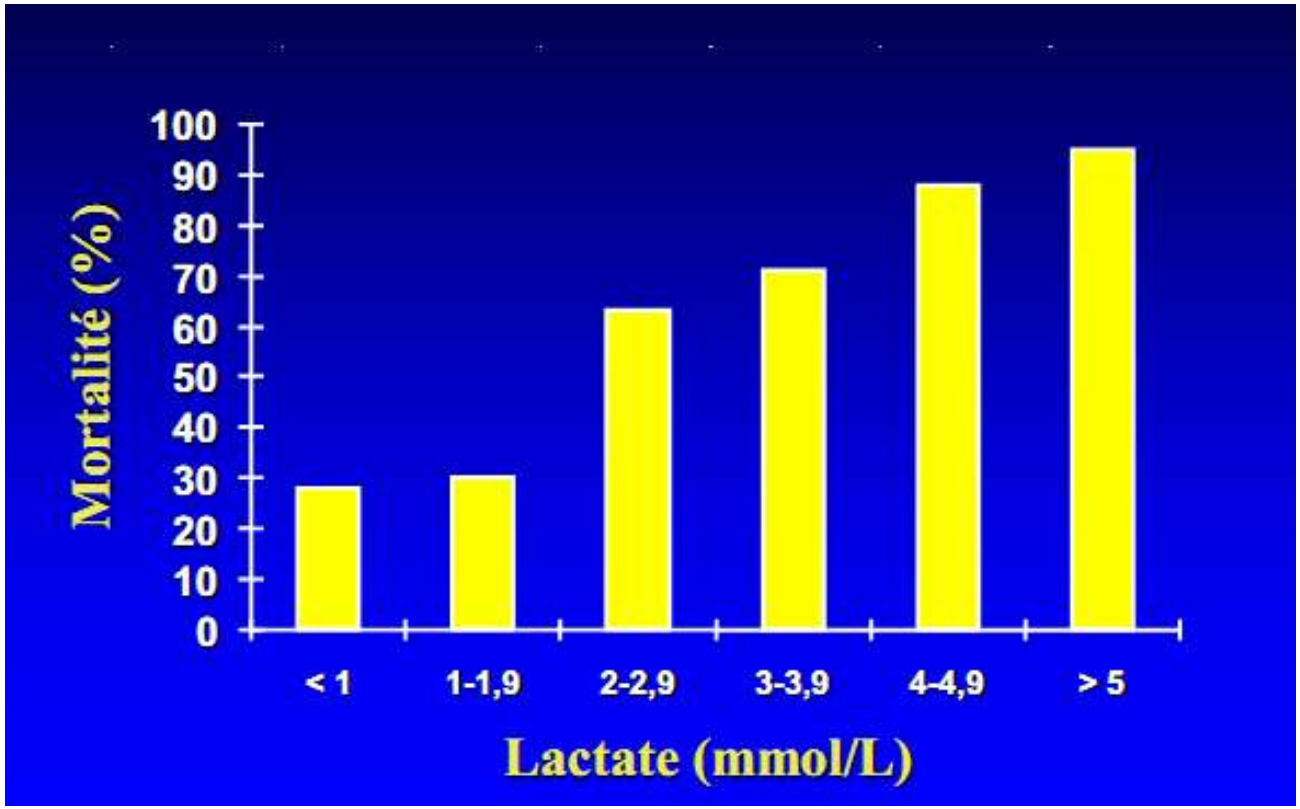
- N'est pas physiologiquement régulée: pas de valeur « normale » (conséquence).
- Permet d'apprécier l'équilibre entre les besoins et les apports en O_2.
- Méthode permettant d'évaluer en continu la finalité principale du DC: la délivrance d'O_2 aux tissus.
- Limite: mesure globale, ne prend pas en compte une souffrance tissulaire localisée.

Circulations régionales

	Q (%)	VO_2 (%)	EO_2 (%)	$ScvO_2$ (%)
Peau	15	5	10	90
Reins	25	10	11	89
Viscères	25	25	29	71
Muscles	20	37	53	47
SNC	12	15	36	64
Myocarde	3	8	77	23

Lactates et Pyruvates

Relation entre Lactatémie et Mortalité Hospitalière chez les Patients en Etat Critique



Kruse JA. Intensive Care World 1987;4:121-5

Lactates et Pronostic

Feature Articles

Early lactate clearance is associated with improved outcome in severe sepsis and septic shock*

H. Bryant Nguyen, MD, MS; Emanuel P. Rivers, MD, MPH; Bernhard P. Knoblich, MD; Gordon Jacobsen, MS; Alexandria Muzzin, BS; Julie A. Ressler, BS; Michael C. Tomlanovich, MD

Critical Care Medicine
OFFICIAL JOURNAL OF THE SOCIETY OF CRITICAL CARE MEDICINE

Table 3. Multivariate logistic regression modeling using statistically significant univariate variables associated with mortality

Variable	OR (95% CI)	*p* Value
Septic shock	2.473 (0.927–6.600)	.07
Platelet	0.999 (0.994–1.004)	.69
Prothrombin time	1.140 (0.988–1.315)	.07
Albumin	0.569 (0.267–1.212)	.14
Total bilirubin	1.045 (0.855–1.276)	.67
Lactate	1.057 (0.945–1.182)	.34
Lactate clearance	0.989 (0.978–0.999)	.04[a]

OR, odds ratio; CI, confidence interval.
[a]Statistically significant, $p < .05$.

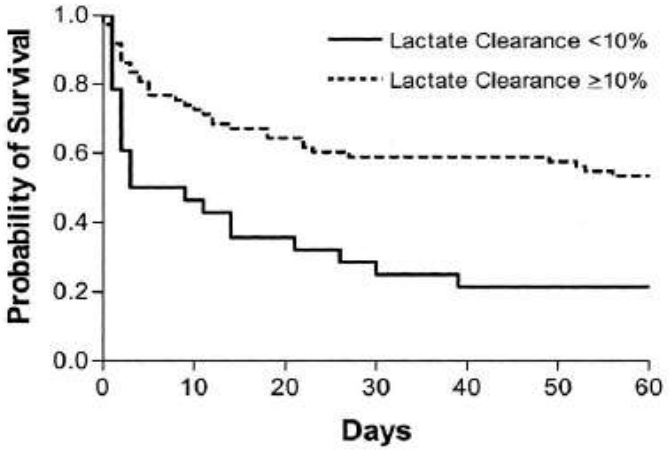


Figure 1. Kaplan-Meier survival analysis between patients with lactate clearance <10 vs. ≥10% at 6 hrs after emergency department presentation.

111 patients

$$\text{Lactate clearance} = \frac{(\text{Lactate}^{\text{ED Presentation}} - \text{Lactate}^{\text{Hour 6}}) \times 100}{\text{Lactate}^{\text{ED Presentation}}}$$

Lactate clearance in the most proximal presentation of severe sepsis and septic shock is associated with improved morbidity and mortality rates.

Serum lactate is associated with mortality in severe sepsis independent of organ failure and shock*

Mark E. Mikkelsen, MD, MS; Andrea N. Miltiades, BA; David F. Gaieski, MD; Munish Goyal, MD; Barry D. Fuchs, MD; Chirag V. Shah, MD, MS; Scarlett L. Bellamy, ScD; Jason D. Christie, MD, MS

Crit Care Med 2009 Vol. 37, No. 5

Lactates:
Low (<2), Intermediate (2–3.9), High (>4)

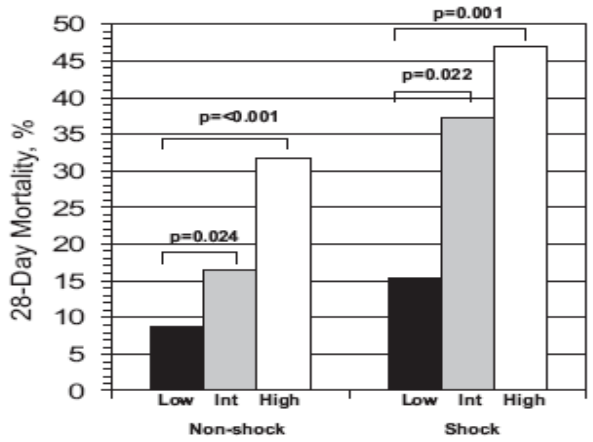


Figure 3. Association between serum lactate level and 28-day mortality, stratified by the presence of shock. Serum lactate categorized as follows: low = 0–1.9 mmol/L, intermediate (*Int*) = 2–3.9 mmol/L, and high = ≥4 mmol/L.

Table 4. Multivariable logistic regression demonstrating odds ratio of 28-day mortality by serum lactate strata in nonshock subgroup

Nonshock Model (n = 634)	Adjusted Odds Ratio (95% Confidence Interval)	*p*
Lactate stratum		
Low	Reference	Reference
Intermediate	2.05 (1.1–3.82)	0.024
High	4.87 (2.56–9.27)	<0.001

Table 5. Multivariable logistic regression demonstrating odds ratio of 28-day mortality by serum lactate strata in overt shock

Shock model (n = 196)	Adjusted Odds Ratio (95% Confidence Interval)	*p*
Lactate strata		
Low	Reference	Reference
Intermediate	3.27 (1.18–9.05)	0.022
High	4.87 (1.87–12.66)	0.001

Lactates/pyruvates

- Le ratio Lactates/pyruvates pourrait orienter vers le mécanisme de l'hyperlactatémie:
- Hyperlactatémies dues à un déséquilibre TO_2-VO_2: **L/P élevé** (>18)
- Hyperlactatémies d'autres mécanismes : **L/P normal ou peu élevé**

Glycolyse aérobie, catécholamines (adrénaline), retard d'élimination…

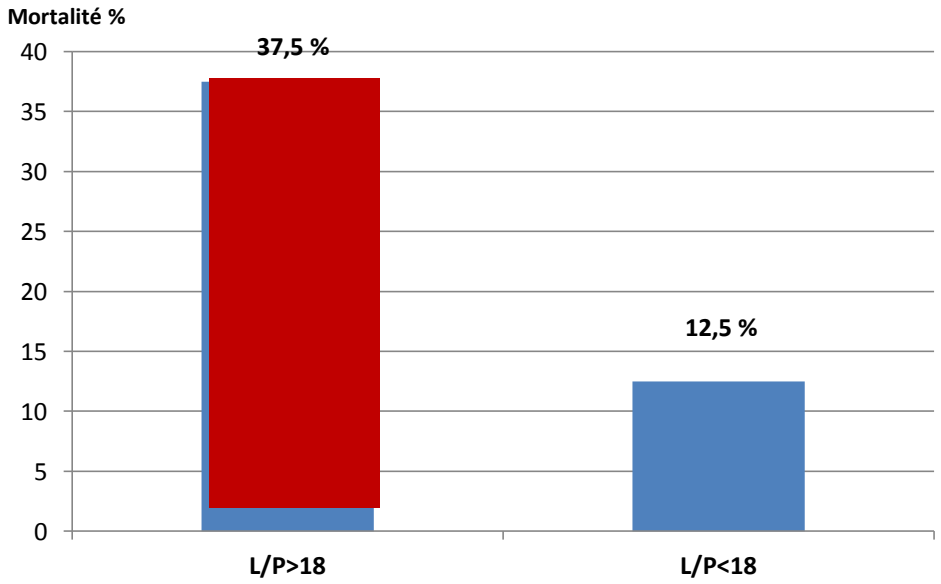
Lactates/pyruvates

SHOCK, Vol. 14, No. 1, pp. 8–12, 2000

TIME-PATTERN OF LACTATE AND LACTATE TO PYRUVATE RATIO IN THE FIRST 24 HOURS OF INTENSIVE CARE EMERGENCY ADMISSIONS

Matti Suistomaa, Esko Ruokonen, Aarno Kari, and Jukka Takala

Department of Intensive Care, Critical Care Research Program, Kuopio University Hospital, Kuopio, Finland



En résumé: que faire des lactates en pratique clinique?

- Un bon signe d'**alerte** et de **suivi**
- un marqueur **pronostique**
- Un **déséquilibre:** production/élimination

Lactate Clearance vs Central Venous Oxygen Saturation as Goals of Early Sepsis Therapy

A Randomized Clinical Trial

JAMA. 2010;303(8):739-746

Alan E. Jones, MD
Nathan I. Shapiro, MD, MPH
Stephen Trzeciak, MD, MPH
Ryan C. Arnold, MD
Heather A. Claremont, BFA
Jeffrey A. Kline, MD
for the Emergency Medicine Shock Research Network (EMShockNet) Investigators

Objectifs:

- SvO2>70%
- Lactate clearance >10%

Noninferiority margin (Δ) at –10%.

Lactate clearance=
[(lactate $_{initial}$ –lactate $_{delayed}$)/lactate $_{initial}$]x100%,

Table 5. Hospital Mortality and Length of Stay

Variable	Lactate Clearance Group (n = 150)	$ScvO_2$ Group (n = 150)	Proportion Difference (95% Confidence Interval)	*P* Value[b]
In-hospital mortality, No. (%)[a]				
Intent to treat	25 (17)	34 (23)	6 (–3 to 15)	
Per protocol	25 (17)	33 (22)	5 (–3 to 14)	
Length of stay, mean (SD), d				
ICU	5.9 (8.46)	5.6 (7.39)		.75
Hospital	11.4 (10.89)	12.1 (11.68)		.60
Hospital complications				
Ventilator-free days, mean (SD)	9.3 (10.31)	9.9 (11.09)		.67
Multiple organ failure, No. (%)	37 (25)	33 (22)		.68
Care withdrawn, No. (%)	14 (9)	23 (15)		.15

Delta PCO2

Delta PCO_2

- **$\Delta PCO_2 = PvCO_2 - PaCO_2$** ($PvCO_2$ du sang veineux mêlé ou veineux central).
- Reflète la balance entre le TO_2 et les besoins métaboliques.
- **La production du CO_2**: $VCO_2 = VO_2 \times R$

  R: Quotient respiratoire (1 ou 0,7 selon source d'énergie: glucides ou lipides).
- **En cas d'hypoxie** le CO2 est produit par le tamponnement de H+:

  Acidose lactique: $\mathbf{H^+} + HCO_3^- \rightarrow H_2O + \mathbf{CO_2}$

↳ Majoration de l'affinité de l'Hb au CO_2 au détriment de l'O_2: Effet Haldane.

$\Delta PCO_{2=}$ (Kx VCO2)/Débit cardiaque

Dres, M; J Clin Monit Comput (2012) 26:367–374

Delta PCO_2

Intensive Care Med (2005) 31:818–822
DOI 10.1007/s00134-005-2602-8

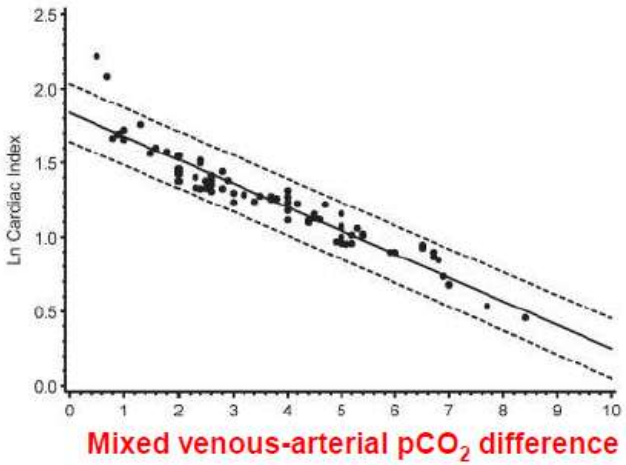
ORIGINAL

Joseph Cuschieri
Emanuel P. Rivers
Michael W. Donnino
Marius Katilius
Gordon Jacobsen
H. Bryant Nguyen
Nikolai Pamukov
H. Mathilda Horst

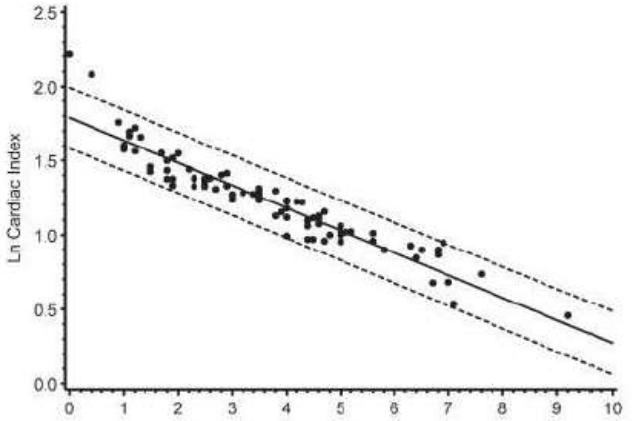
Central venous-arterial carbon dioxide difference as an indicator of cardiac index

Patients and participants: 83 consecutive ICU patients

Measurements: Simultaneous blood gases from the arterial, pulmonary artery (PA), and central venous (CV) catheters were obtained



Mixed venous-arterial pCO_2 difference



Central venous-arterial pCO_2 difference

Delta PCO_2

Intensive Care Med (2002) 28:272–277
DOI 10.1007/s00134-002-1215-8

ORIGINAL

Armand Mekontso-Dessap
Vincent Castelain
Nadia Anguel
Mabrouk Bahloul
Franck Schauvliege
Christian Richard
Jean-Louis Teboul

Combination of venoarterial PCO_2 difference with arteriovenous O_2 content difference to detect anaerobic metabolism in patients

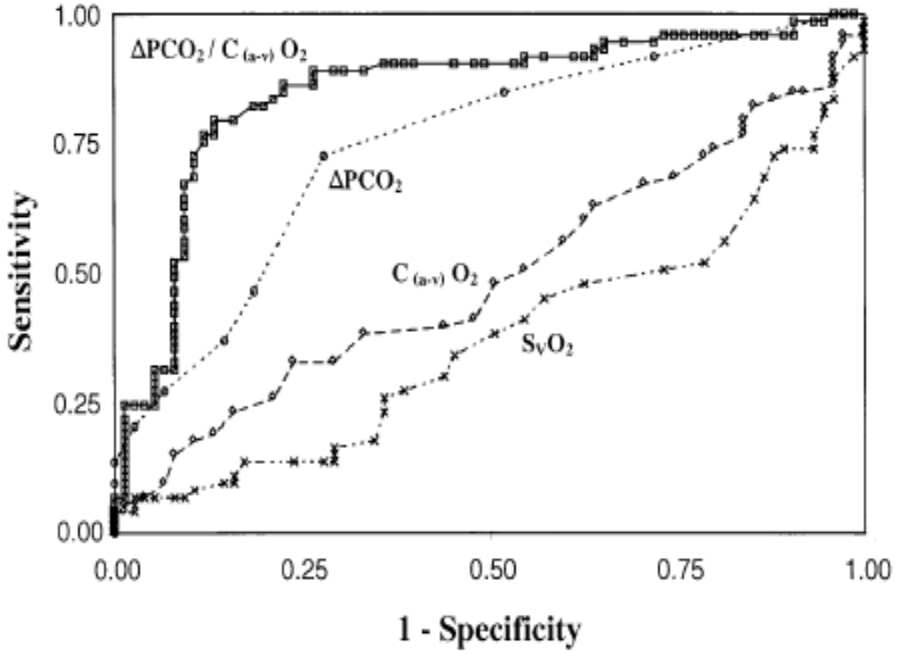


Fig. 1 Receiver operating characteristic curves of the studied O_2- and CO_2-derived parameters for the prediction of hyperlactatemia (arterial lactate level ≥2 mmol/l)

Tonométrie gastrique

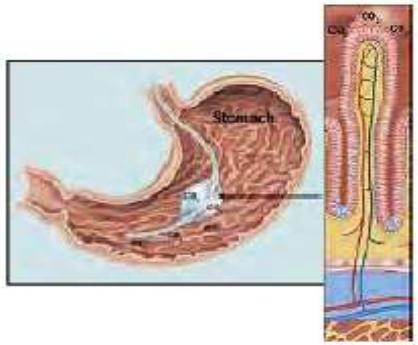
Tonométrie gastrique

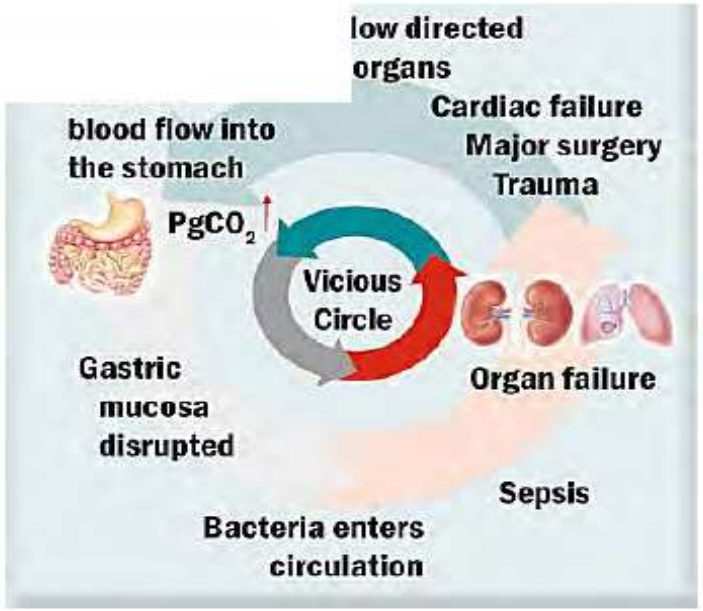
Intensive Care Med (2001) 27: 317–319
DOI 10.1007/s001340000866

CURRENT TOPICS

G. Lebuffe
E. Robin
B. Vallet

Gastric tonometry





$$PCO2_{gap} = P_gCO_2 - P_aCO_2 < 10\ mmHg$$

Tonométrie gastrique

Gastric capnometry with air-automated tonometry predicts outcome in critically ill patients

Crit Care Med 2003; 31:474-80

Bruno Levy, MD, PhD; Pascale Gawalkiewicz, MD; Benoit Vallet, MD, PhD; Serge Briancon, MD, PhD; Lionel Nace, MD; Pierre-Edouard Bollaert, MD, PhD

Observational cohort study (n=95)

Relationship between PCO_2 gap and mortality

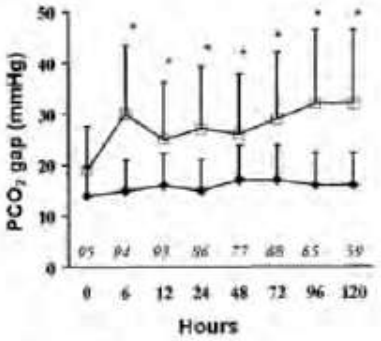


Figure 1. Pco_2 gap (mm Hg) in survivors (*diamonds*) and nonsurvivors (*squares*) during the study. *$p < .05$ survivors vs. nonsurvivors. The *numbers* in *italics* indicate the actual number of patients who were monitored during that day.

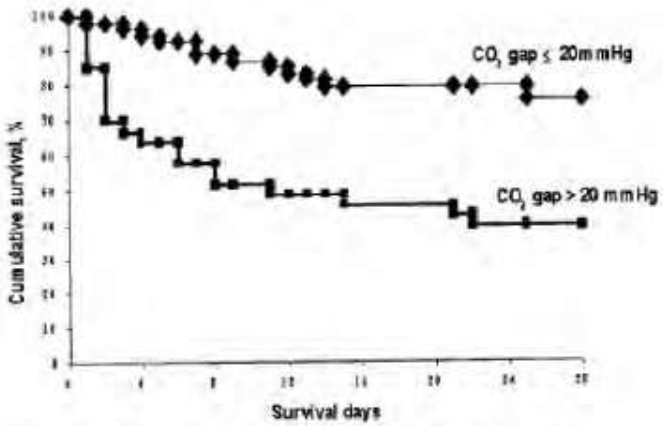
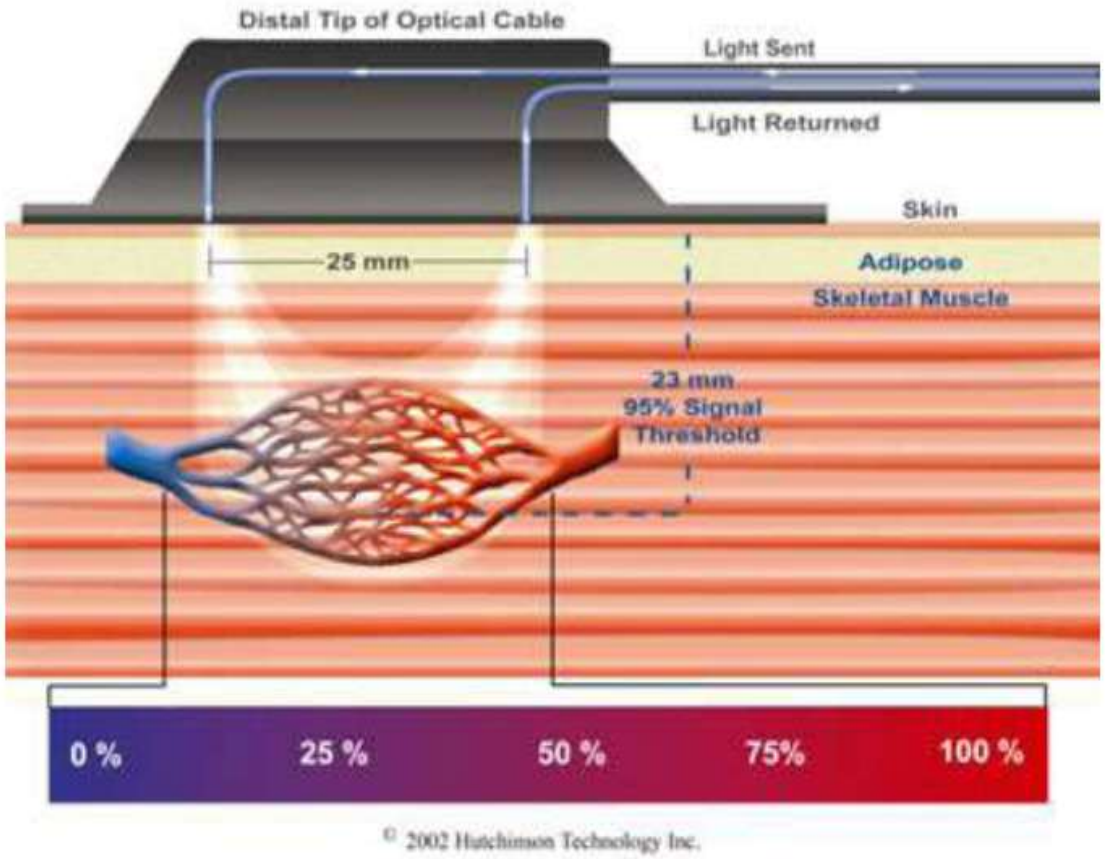


Figure 4. Kaplan-Meier 28-day survival curves according to the Pco_2 gap at hour 24.

Saturation tissulaire en oxygène (StO2)

StO2



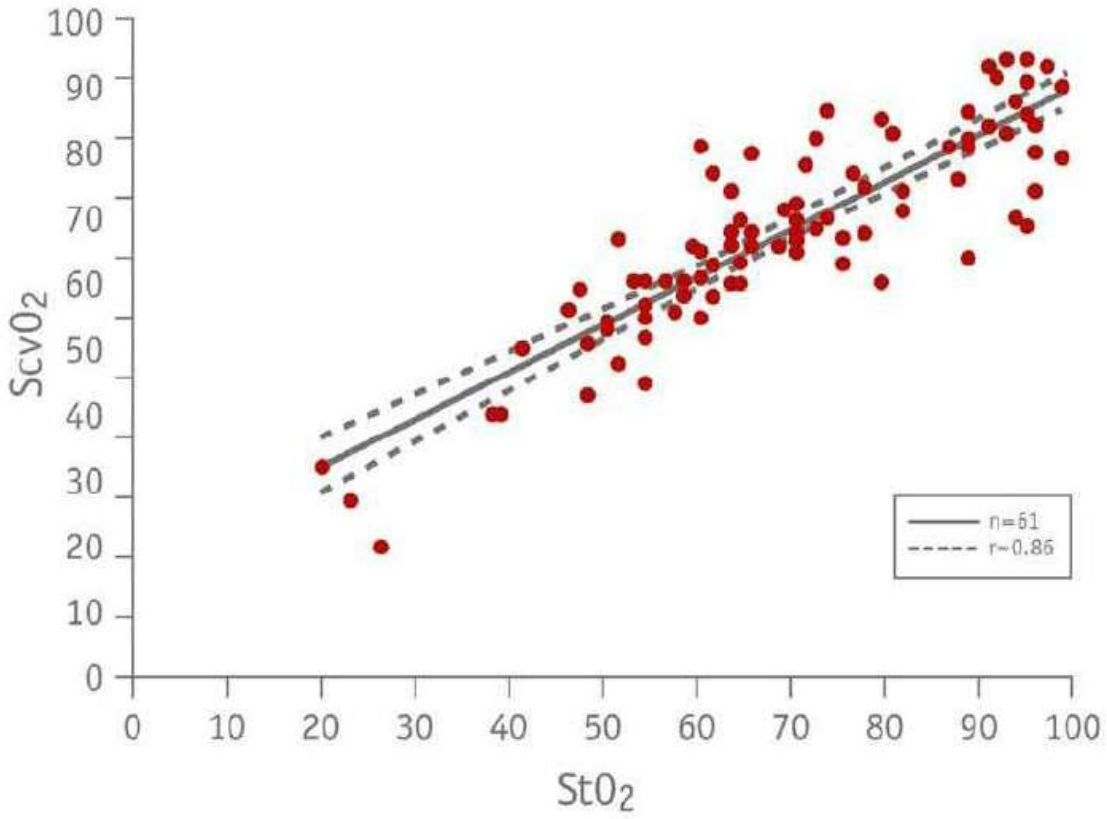
PROCÉDÉ DE MESURE : *Near Infra Red Spectroscopy (*N.I.R.S.)

StO2

Near infrared spectroscopy to assess systemic perfusion in the critically ill

Crawford J, Otero R, Goyal N, Sankey S, Rivers E. Crit Care Med. 2007;35(12, Abstract Supplement):A254.

StO_2–$ScvO_2$ Scatter Plot at a Single Point in Time Measurement

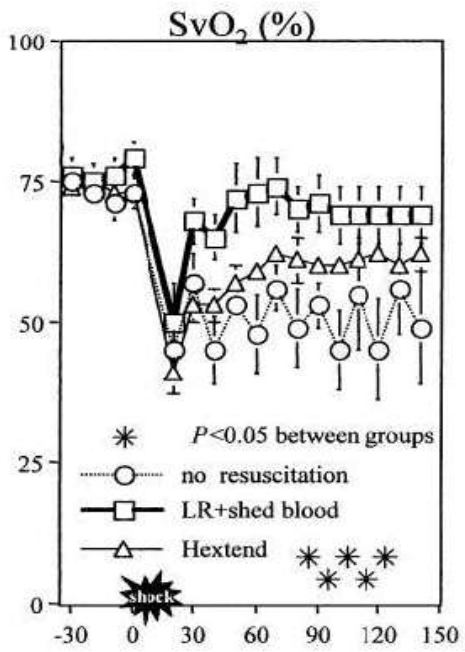


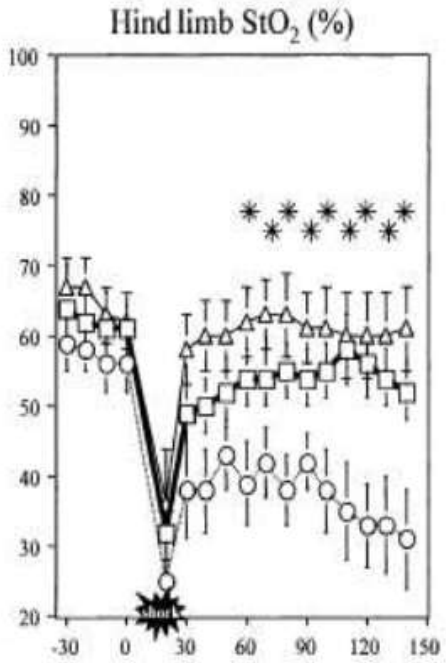
StO2

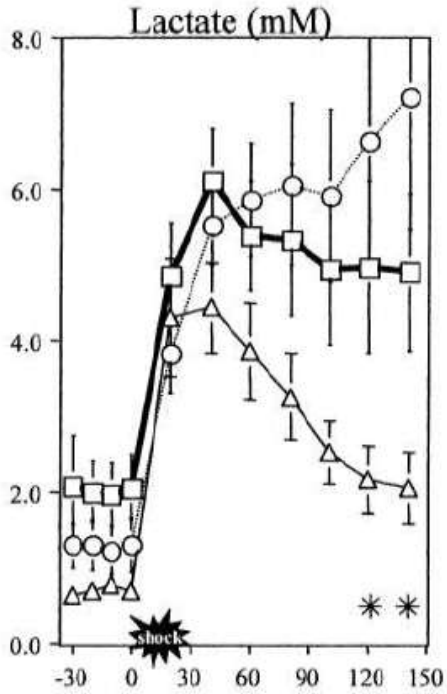
Noninvasive muscle oxygenation to guide fluid resuscitation after traumatic shock

Crookes BA, Cohn SM, Burton EA, Nelson J, Proctor KG

Surgery. 2004;135:662-70







Autres indicateurs de la microcirculation

- Capnographie sub-linguale (CO_2 tissulaire)

- Microscopie spectrale polarisée orthogonale (MSPO)

Conclusion

Marqueurs de l'oxygénation tissulaire:

- Progrès technologique.
- Moyens non invasifs (au lit de malade).
- Mise en évidence de mécanismes physiopathologiques et de « nouveaux » concepts thérapeutiques (microcirculation).
- Objectifs thérapeutiques et marqueurs pronostique
- Etudes cliniques à large effectif.
- Réduction morbi-mortalité?