Oxygen Delivery (DO_2): An Oversimplified Concept?

Azriel Perel

Professor of Anesthesiology and Intensive Care

Sheba Medical Center, Tel Aviv University, Israel

Poland, 2016

Disclosure

Masimo (USA)

Pulsion/MAQUET (Germany)

The Oxygen Delivery (DO_2)

$$DO_2 = CaO_2 \times CO$$

CaO_2 = Arterial oxygen content (O_2 in 100 ml)

CO = Cardiac output

The Oxygen Delivery (DO_2)

$$DO_2 = CaO_2 \times CO$$

$$CaO_2 = Hgb \times 1.34 \times SaO_2 + (PaO_2 \times 0.0032)$$

$$CaO_2 = 15 \times 1.34 \times 1.0 + (100 \times 0.0032) \sim 20 \text{ ml/100 cc}$$

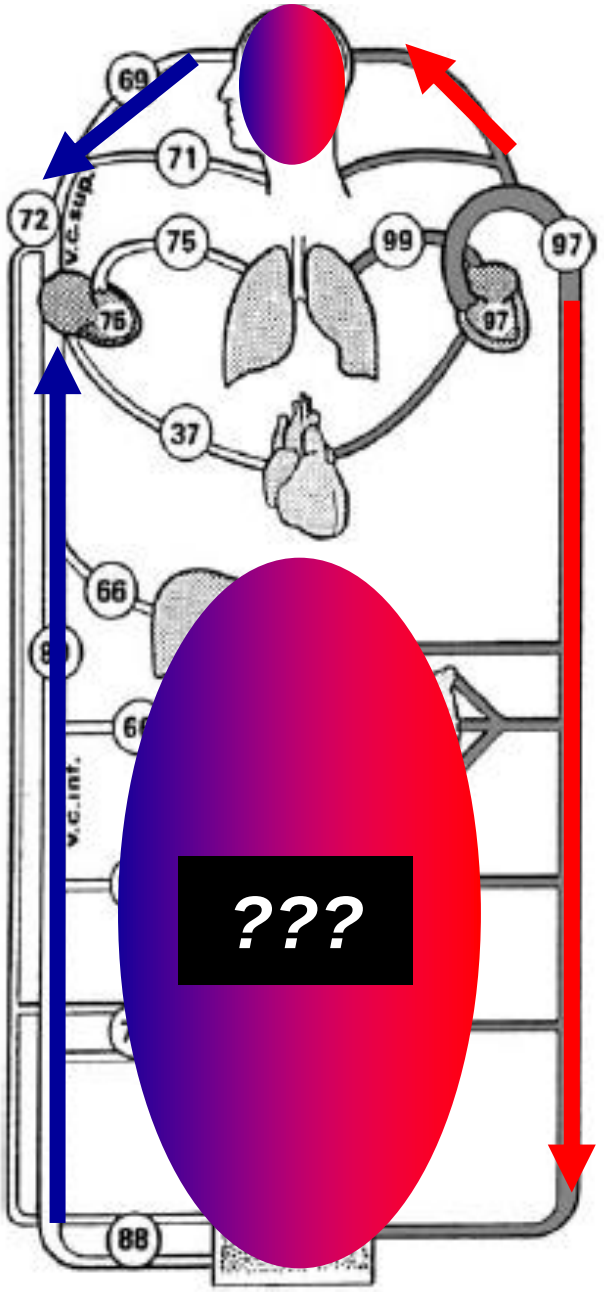
$$DO_2 = 20 \times 10 \times 5 = 1000 \text{ ml/min}$$

Venous oximetry.

Bloos, Reinhart.

Intensive Care Med

2005; 31:911-3

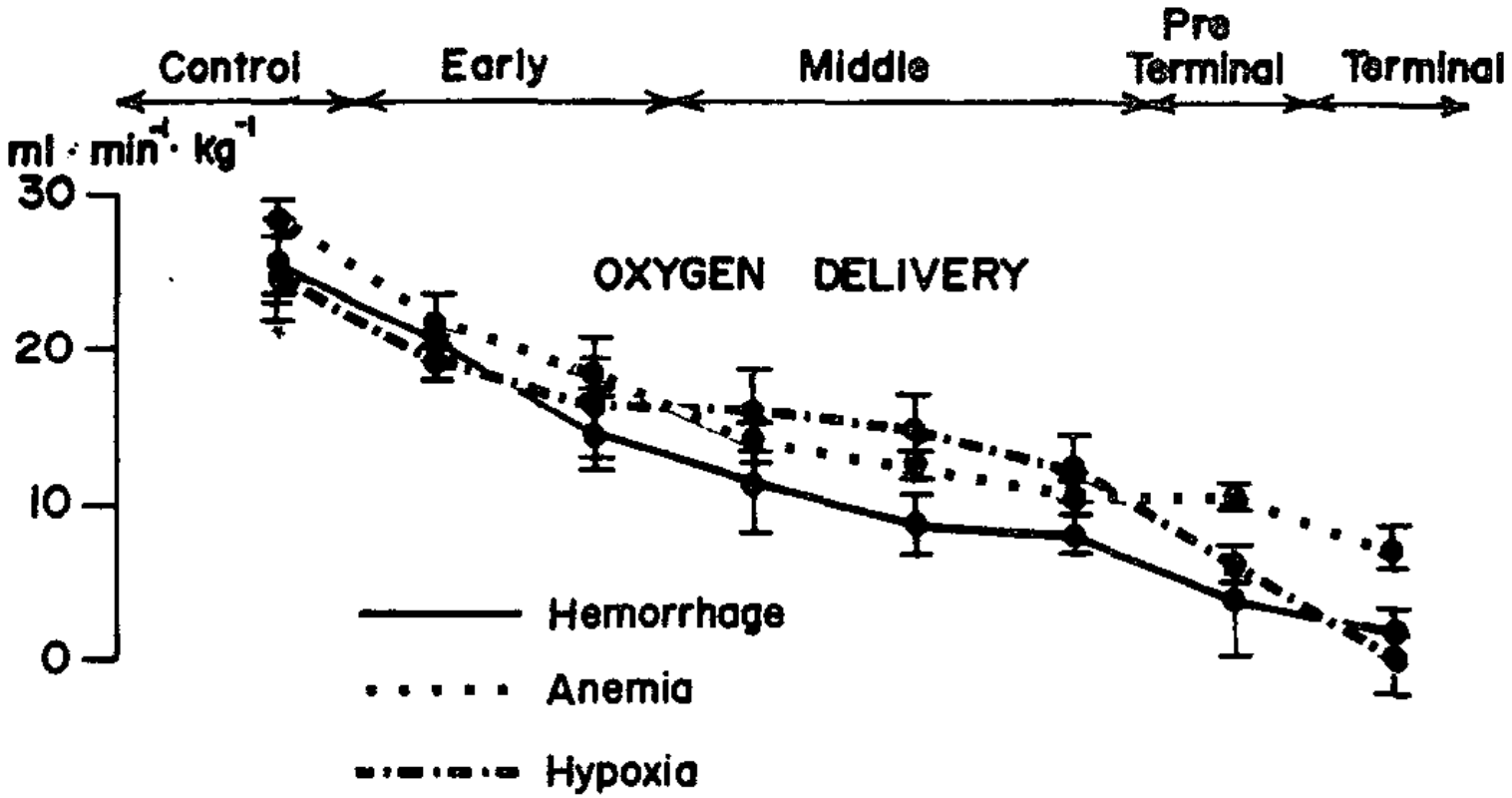


O_2 Delivery

Sequential hemodynamic and oxygen transport responses in hypovolemia, anemia, and hypoxia

SANDRA SCHWARTZ, ROBERT A. FRANTZ, AND WILLIAM C. SHOEMAKER

Am. J. Phys iol. 241 (Heart Circ. Physiol. 10): H864–H871, 1981.



$$DO_2 = CaO_2 \times CO$$

$$CaO_2 = Hgb \times 1.34 \times SaO_2 + (PaO_2 \times 0.0032)$$

Hypovolemia	Fluids
Anemia	Blood
Hypoxemia	Oxygen

How should we best titrate our therapeutic interventions, namely, Fluids, Blood and Oxygen, which are all potentially detrimental when given in excess?

$$DO_2 = CaO_2 \times CO$$

$$CaO_2 = Hgb \times 1.34 \times SaO_2 + (PaO_2 \times 0.0032)$$

SpHb	Hemoglobin
SpO_2	Oxygen Saturation
ORI	Oxygen Reserve Index
PVI	Pleth Variability Index

Patient blood management (PBM)

$$DO_2 = CaO_2 \times CO$$

$$CaO_2 = \mathbf{Hgb} \times 1.34 \times SaO_2 + (PaO_2 \times 0.0032)$$

The New England
Journal of Medicine

VOLUME 215 SEPTEMBER 3 1936 NUMBER 10

The Massachusetts Medical Society

SECTION OF MEDICINE

**Lower Section Room, Municipal Auditorium, Springfield,
Tuesday, June 9, 1936, 2 p. m.**

PRESIDING:
Dr. William D. Smith, Boston, Chairman.
Dr. Laurence B. Ellis, Boston, Secretary.

CHAIRMAN SMITH: Will the meeting please come to order.

The first duty of the Section is the selection of the Chairman and the Secretary for the coming year, and, in accordance with the usual custom, the Chair will appoint as the Nominating Committee to suggest names Dr. Dwight O'Hara, Chairman, Dr. George R. Minot and Dr. Chester M. Jones. They will report later and abide the pleasure of the Section.

I do not see Dr. Hamilton here. Apparently she is delayed, so we will pass on to the second paper. To those of us who have had our moments of indecision whether to transfuse or not to transfuse in some of our medical problems, Dr. Bock's paper should be of interest. His subject is "The Use and Abuse of Blood Transfusions."

THE USE AND ABUSE OF BLOOD TRANSFUSIONS*

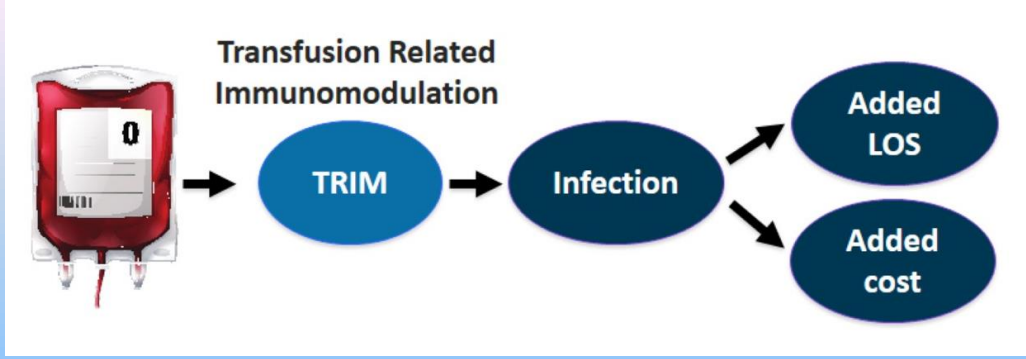
BY ARLIE V. BOCK, M.D.†

THE mass of literature on the subject of blood transfusions accumulated during the past twenty-five years is so great and most of

plish two things, restoration of diminished blood volume and elevation of low blood pressure.

Numerous studies have described the complications that may be associated with blood transfusions

- Increased risk of morbidity & mortality
- Multi-organ failure
- Infections, sepsis
- Myocardial infarction
- Immunomodulation
- Cancer
- TRALI
- Increased length of stay



Variability in Blood and Blood Component Utilization as Assessed by an Anesthesia Information Management System

Steven M. Frank, M.D.,* Will J. Savage, M.D.,† Jim A. Rothschild, M.D.,‡ Richard J. Rivers, M.D.,* Paul M. Ness, M.D.,§ Sharon L. Paul, B.S., M.S.,‖ John A. Ulatowski, M.D., Ph.D., M.B.A.#

Anesthesiology 2012; 117:99–106

- **Many transfusions are not preceded by a Hb measurement.**
- **Even a 10% reduction in RBC in our institution would result in more than $1,000,000 in blood acquisition cost savings.**

JAMA | Special Communication

Clinical Practice Guidelines From the AABB
Red Blood Cell Transfusion Thresholds and Storage

Jeffrey L. Carson, MD; Gordon Guyatt, MD; Nancy M. Heddle, MSc; Brenda J. Grossman, MD, MPH; Claudia S. Cohn, MD, PhD; Mark K. Fung, MD, PhD; Terry Gernsheimer, MD; John B. Holcomb, MD; Lewis J. Kaplan, MD; Louis M. Katz, MD; Nikki Peterson, BA; Glenn Ramsey, MD; Sunil V. Rao, MD; John D. Roback, MD, PhD; Aryeh Shander, MD; Aaron A. R. Tobian, MD, PhD

JAMA. doi:10.1001/jama.2016.9185
Published online October 12, 2016.

- **A restrictive RBC transfusion threshold (Hgb 7 g/dL) is recommended for hospitalized adult patients who are hemodynamically stable, including critically ill patients (strong recommendation, moderate quality evidence).**
- **A restrictive RBC transfusion threshold of 8 g/dL is recommended for patients undergoing orthopedic surgery, cardiac surgery, and those with preexisting cardiovascular disease (strong recommendation, moderate quality evidence).**

Patient blood management (PBM)

$DO_2 = CaO_2 \times CO$?

$CaO_2 = 7 \times 1.34 \times 1.0 + (0.3) \sim 10$ ml/100 cc

?

$DO_2 = 10 \times 10 \times 5 = 500$ ml/min

Annals of Internal Medicine | EDITORIAL

Indications for Blood Transfusions: Too Complex to Base on a Single Number?

Jean-Louis Vincent, MD, PhD

72 | 3 July 2012 | Annals of Internal Medicine | Volume 157 • Number 1

The decision to transfuse is too complex and important to be guided by a single number (of hemoglobin level) alone.

Red Blood Cell Transfusion
Precision vs Imprecision Medicine

JAMA October 20, 2015 Volume 314, Number 15 **1557**

- **It is unlikely that a single Hgb "transfusion trigger" is appropriate for all patients.**
- **Indiscriminate reliance on fixed targets and rigid protocols falls into the category of "imprecision medicine."**
- **Technical advances including noninvasive monitoring, imaging, and applied bioinformatics, facilitate more personalized and precise medical management.**

Intensive Care Med (2015) 41:1973–1976
DOI 10.1007/s00134-015-3950-7

EDITORIAL

Yasser Sakr
Jean-Louis Vincent

Should red cell transfusion be individualized? Yes

Intensive Care Med (2015) 41:1977–1979
DOI 10.1007/s00134-015-3948-1

EDITORIAL

Lars B. Holst
Jeffrey L. Carson
Anders Perner

Should red blood cell transfusion be individualized? No

Intensive Care Med (2015) 41:1980–1982
DOI 10.1007/s00134-015-4034-4

EDITORIAL

Annemarie Docherty
Timothy S. Walsh

Should blood transfusion be individualised? We are not sure

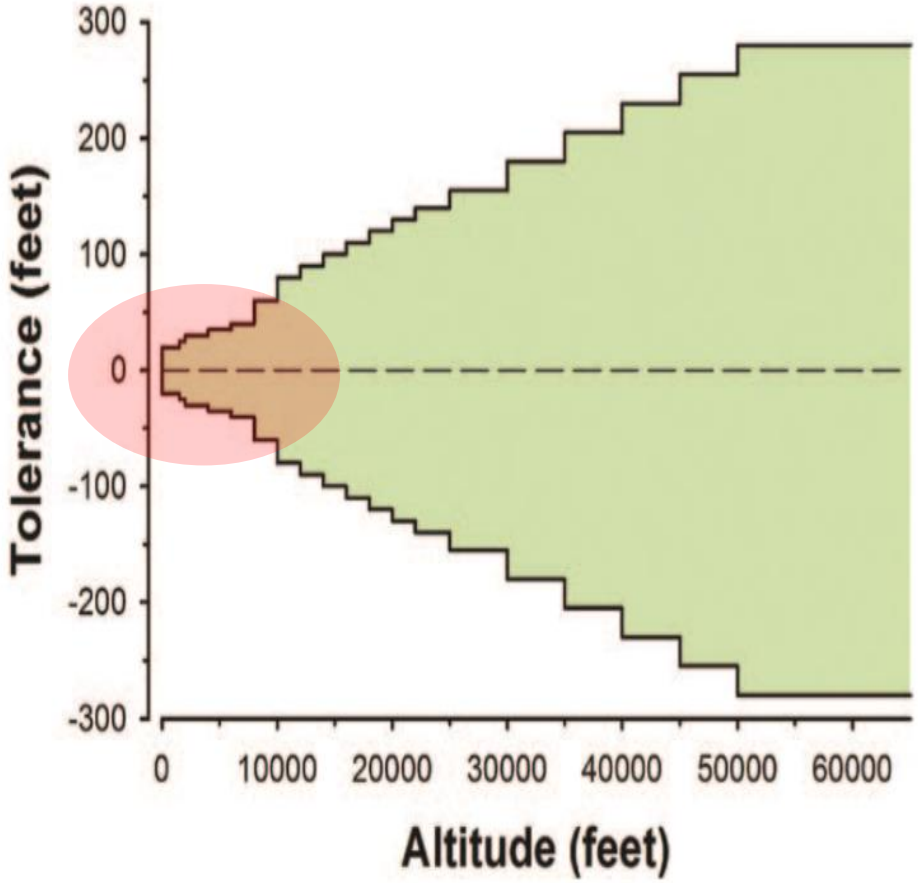


Figure 5. The magnitude of tolerance for an airplane altimeter as a function of altitude as mandated by the United States Federal Aviation Administration. The green shading indicates an area of acceptable performance of an aircraft altimeter. The dashed line indicates 0 ft of tolerance.

The lower you fly, the lesser is the tolerance for an error!

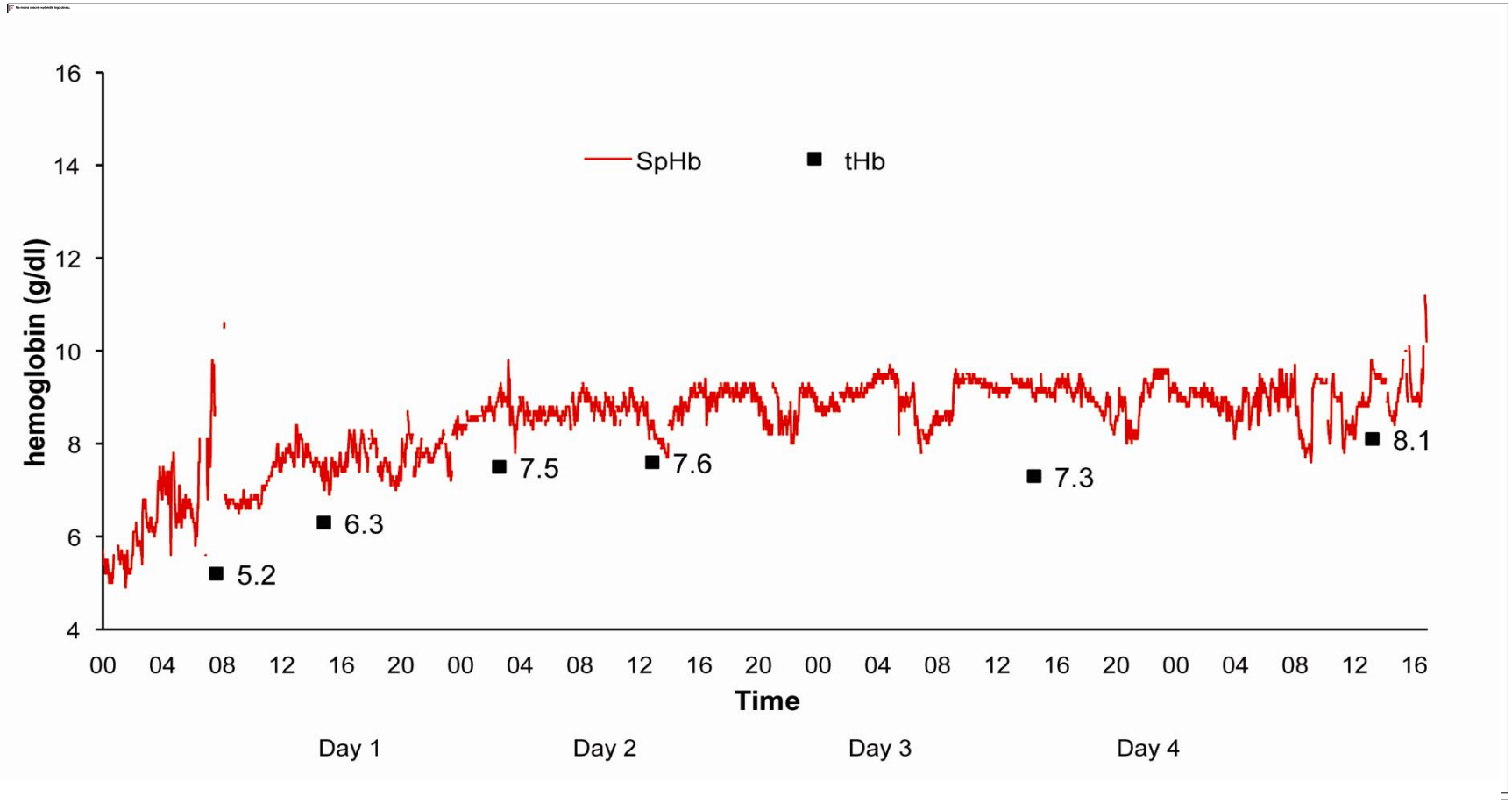
Patient blood management (PBM)

$$DO_2 = CaO_2 \times CO$$

$$CaO_2 = \mathbf{Hgb} \times 1.34 \times SaO_2 + (PaO_2 \times 0.0032)$$

SpHb

SpHb and tHb measurements over 4 days in a 84 y/o female patient being treated for pneumonia in the ICU



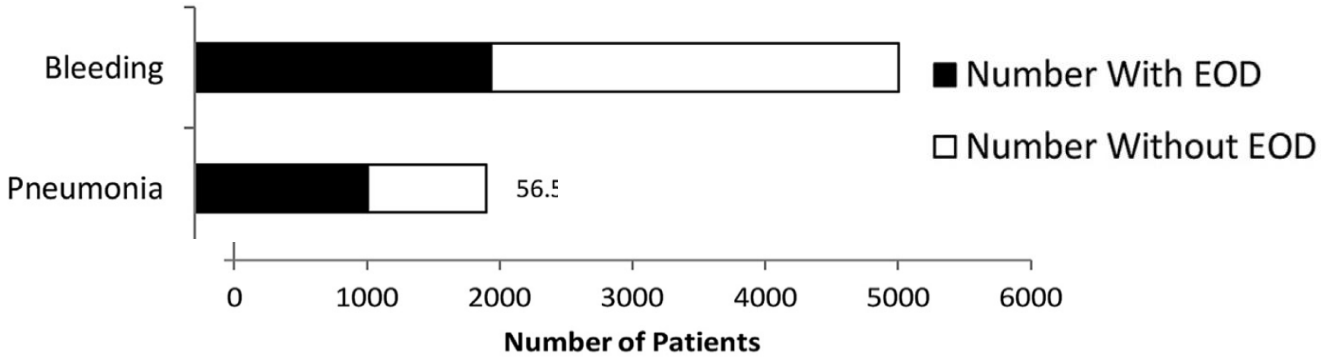
Shander A. et al. Presented at *Society for the Advancement of Blood Medicine* (SABM) *Annual Meeting 2010; San Juan, Puerto Rico*

Which Complications Matter Most? Prioritizing Quality Improvement in Emergency General Surgery

John E Scarborough, MD, FACS, Jessica Schumacher, PhD, Theodore N Pappas, MD, FACS, Christopher C McCoy, MD, Brian R Englum, MD, Suresh K Agarwal Jr, MD, FACS, Caprice C Greenberg, MD, MPH, FACS

J Am Coll Surg 2016;222:515–524.

- **The most common complication in these 79,183 patients was bleeding (6.2%).**
- **Bleeding was also the complication with the greatest overall impact on mortality and end-organ dysfunction.**



Intraoperative transfusion practices in Europe

J. Meier[1,*], D. Filipescu[2], S. Kozek-Langenecker[3], J. Llau Pitarch[4], S. Mallett[5], P. Martus[6] and I. Matot[7] and the ETPOS collaborators

British Journal of Anaesthesia, 116 (2): 255–61 (2016)

EJA

Eur J Anaesthesiol 2016; **33:**1–9

ORIGINAL ARTICLE

Implementation of patient blood management remains extremely variable in Europe and Canada

The NATA benchmark project

Philippe Van der Linden and Jean-François Hardy

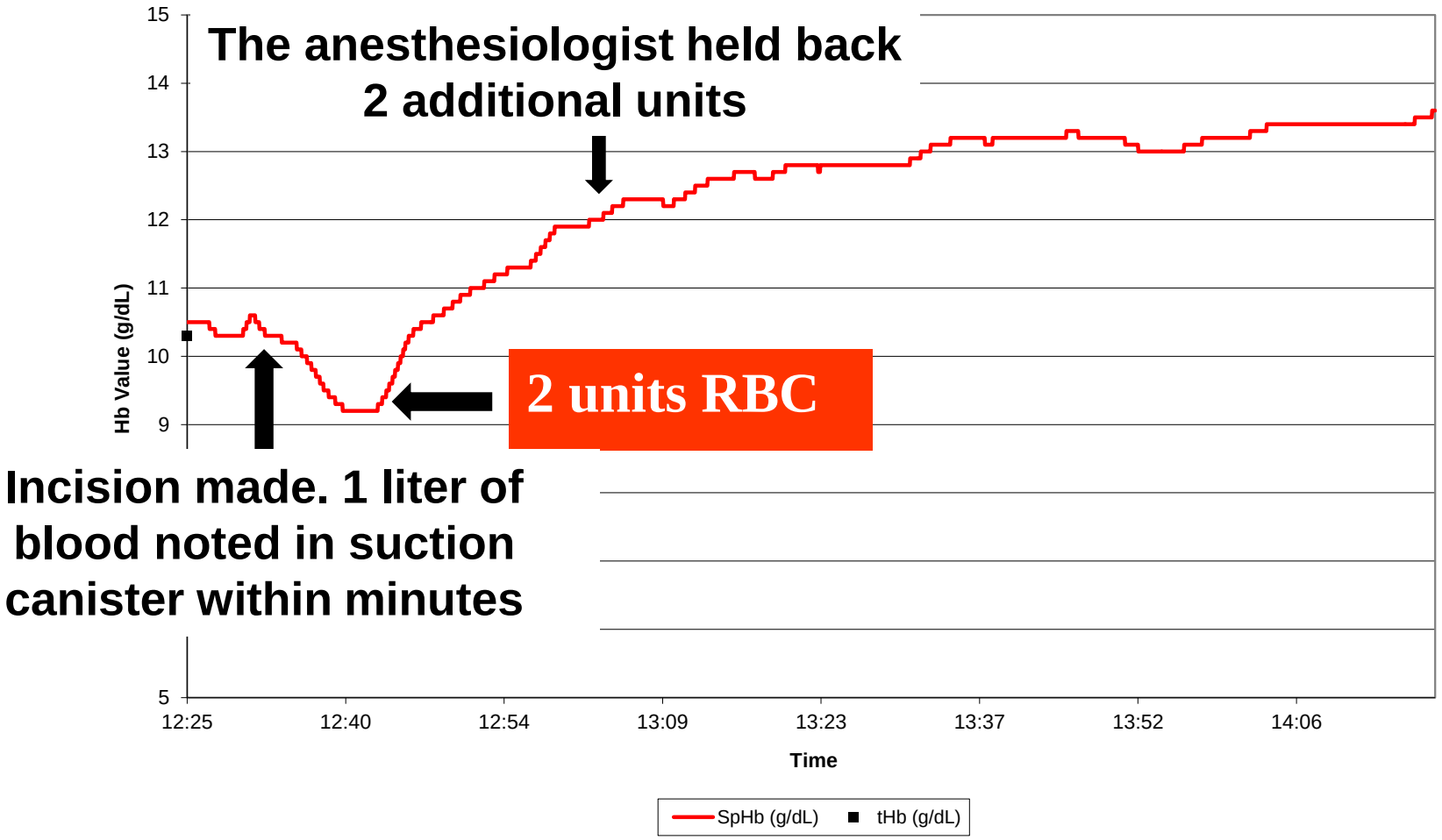
Intraoperative transfusion practices in Europe

J. Meier[1,*], D. Filipescu[2], S. Kozek-Langenecker[3], J. Llau Pitarch[4], S. Mallett[5], P. Martus[6] and I. Matot[7] and the ETPOS collaborators

British Journal of Anaesthesia, 116 (2): 255–61 (2016)

- **The post-transfusion Hb was unnecessarily high, suggesting that the decision to transfuse led to more than 1 pRBC unit at a time.**
- **Some hospitals that claimed to have a restrictive transfusion strategy transfused at rather high Hb concentrations.**

Continuous SpHb during exploratory laparotomy



The European guideline on management of major bleeding and coagulopathy following trauma: fourth edition

Rolf Rossaint[1], Bertil Bouillon[2], Vladimir Cerny[3,4,5,6], Timothy J. Coats[7], Jacques Duranteau[8], Enrique Fernández-Mondéjar[9], Daniela Filipescu[10], Beverley J. Hunt[11], Radko Komadina[12], Giuseppe Nardi[13], Edmund A. M. Neugebauer[14], Yves Ozier[15], Louis Riddez[16], Arthur Schultz[17], Jean-Louis Vincent[18] and Donat R. Spahn[19*]

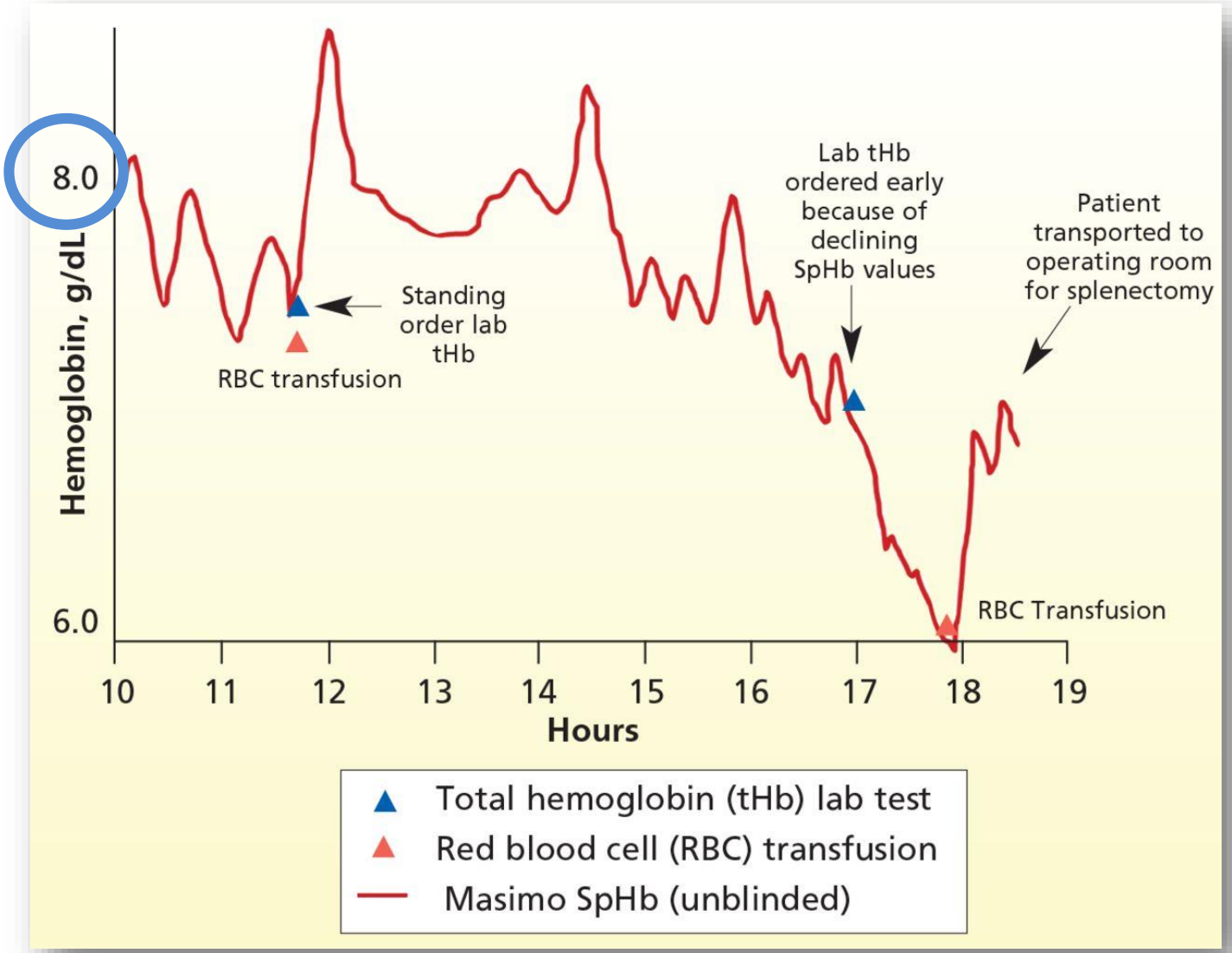
Critical Care (2016) 20:100

Haemoglobin

Recommendation 10 **We recommend that a low initial Hb be considered an indicator for severe bleeding associated with coagulopathy. (Grade 1B)**

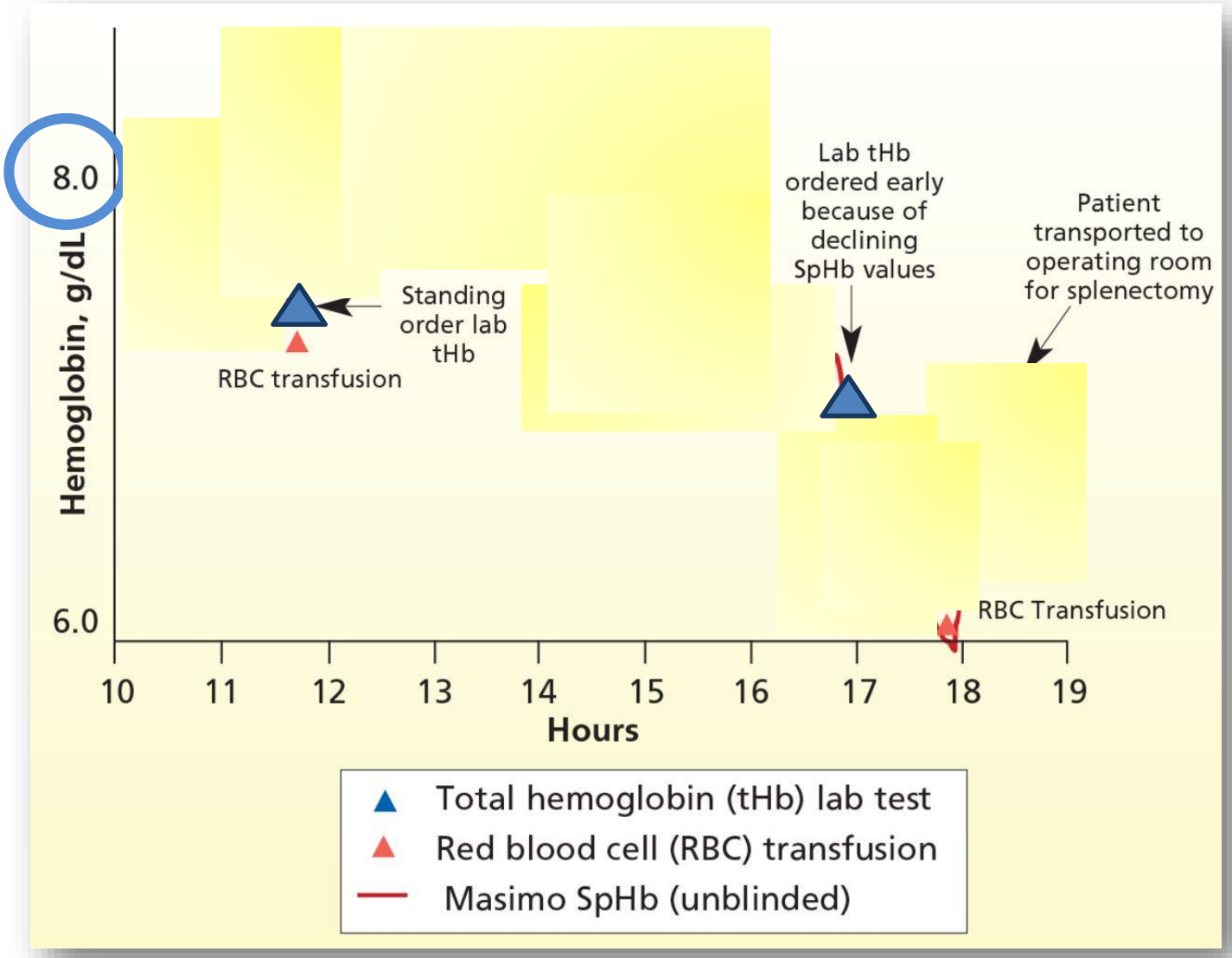
We recommend the use of repeated Hb measurements as a laboratory marker for bleeding, as an initial Hb value in the normal range may mask bleeding. (Grade 1B)

SpHb monitoring in a patient after multiple trauma



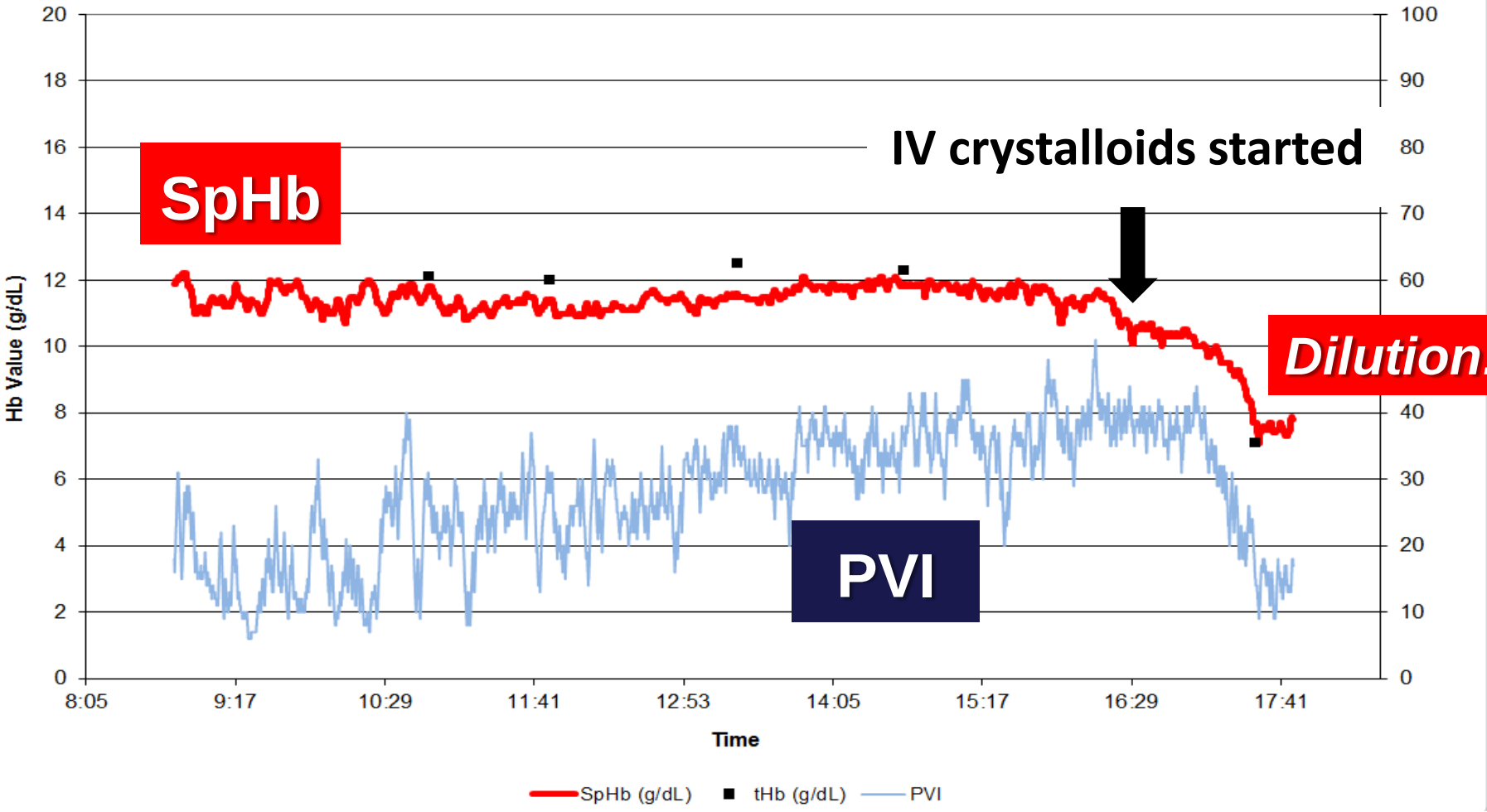
McEvoy MT. *Am J Crit Care*. 2013 Nov;22(6 Suppl):eS1-13.

SpHb monitoring in a patient after multiple trauma



McEvoy MT. *Am J Crit Care*. 2013 Nov;22(6 Suppl):eS1-13.

SpHb + PVI monitoring during partial hepatectomy

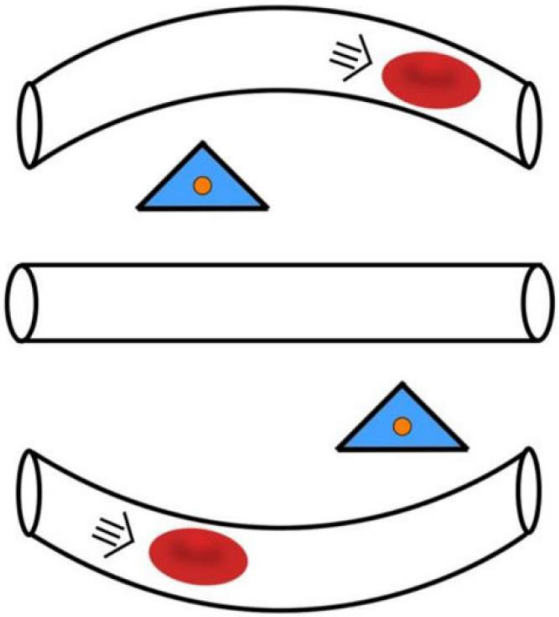


Hemodynamic coherence and the rationale for monitoring the microcirculation

Can Ince

Critical Care 2015, **19**:S8

- **Hemodilution results in a loss of RBC-filled capillaries, leading to a iatrogenic reduction in oxygen-carrying capacity and the development of organ dysfunction.**

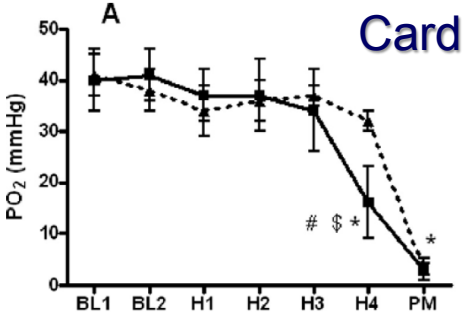


Type 2: Hemodilution

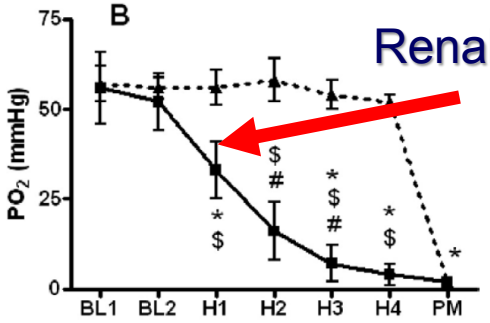
Heart, kidney, and intestine have different tolerances for anemia

(Translational Research 2008;151:110-117)

JASPER VAN BOMMEL, MARTIN SIEGEMUND, CH. PIETER HENNY, and CAN INCE

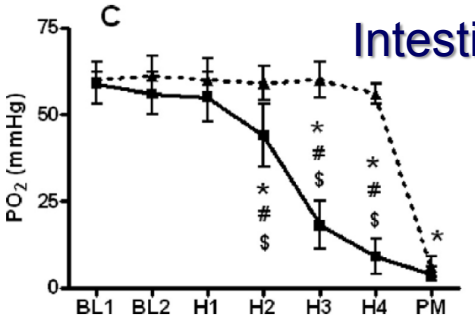


Cardiac μPO_2



Renal μPO_2

Renal μPO_2 started to decrease at a Hct of 38%!



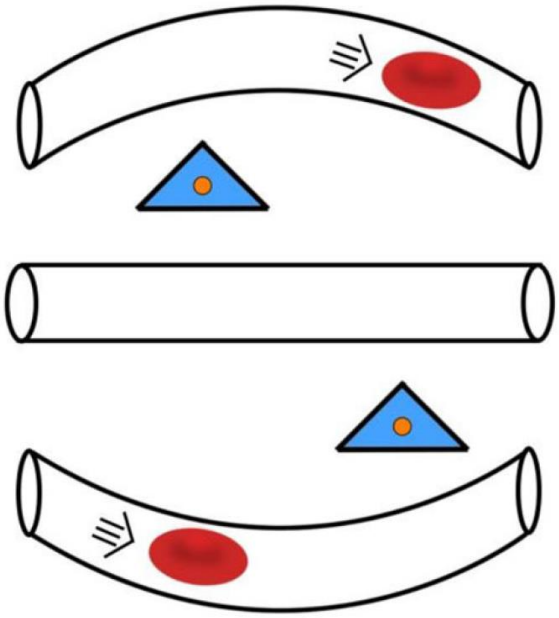
Intestinal μPO_2

Hemodynamic coherence and the rationale for monitoring the microcirculation

Can Ince

Critical Care 2015, **19**:S8

- Hemodilution results in a loss of RBC-filled capillaries, leading to a iatrogenic reduction in oxygen-carrying capacity and the development of organ dysfunction.
- **Such a hemodilutional loss of coherence can be corrected by maintaining an adequate Hct and by the appropriate administration of quality blood.**



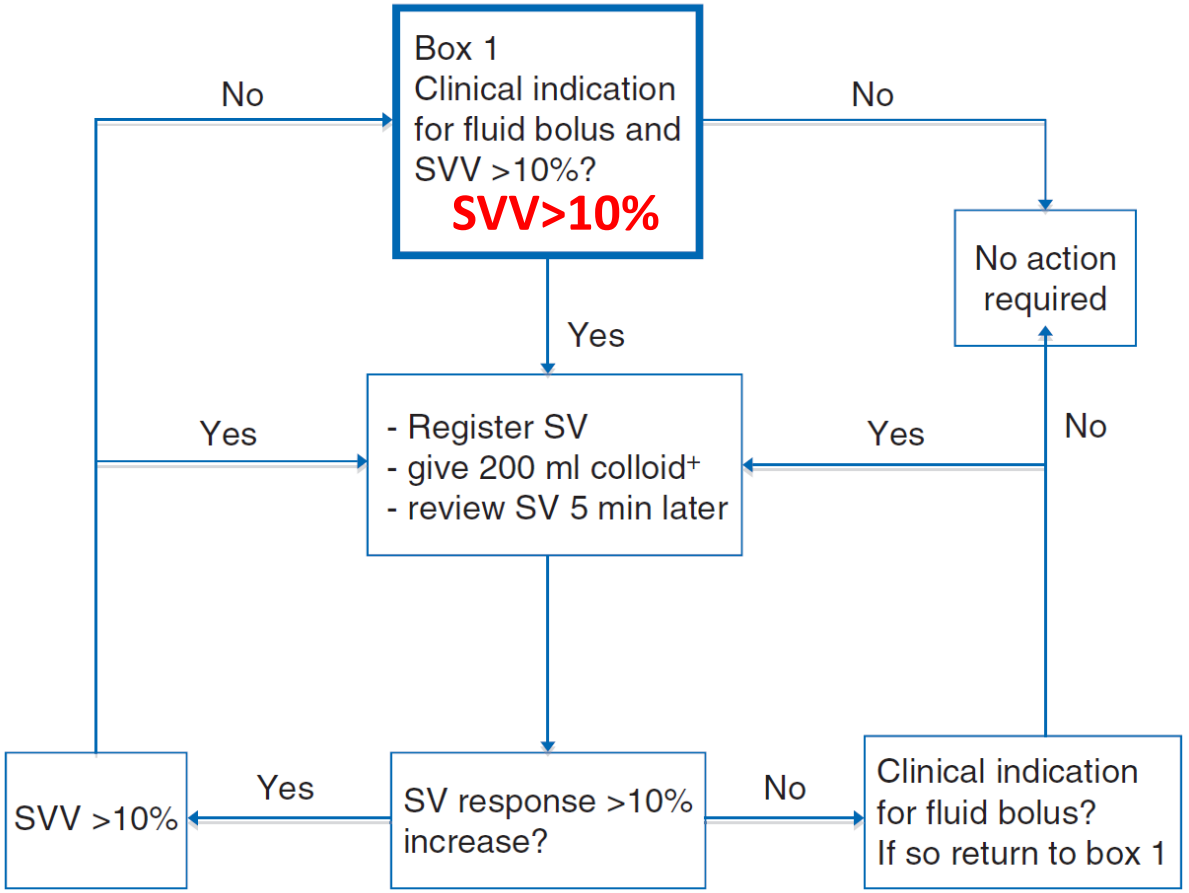
Type 2: Hemodilution

Randomized controlled trial of stroke volume optimization during elective major abdominal surgery in patients stratified by aerobic fitness

C. W. Lai[1,3], T. Starkie[2], S. Creanor[3], R. A. Struthers[2,3], D. Portch[4], P. D. Erasmus[2], N. Mellor[1], K. B. Hosie[1], J. R. Sneyd[2,3] and G. Minto[2,3,*]

British Journal of Anaesthesia, 115 (4): 578–89 (2015)

RCT; 220 patients having major surgery using enhanced recovery pathway with or without supplementary blinded intra-operative SV optimization.



The GDT group received additional 956 ml colloids during surgery

Parameter	Control (n=111)	GDT (n=109)
Stroke volume variation (%)		
Before incision	10.1 (10.5)	7.4 (6.6)
End	9.0 (6.6)	7.9 (6.8)
Cardiac index (litres min^{-1})		
Awake	3.7 (1.0)	3.7 (1.3)
Before incision	2.4 (0.8)	2.5 (0.8)
End	2.8 (1.0)	2.8 (1.0)
D_{O_2} (ml O_2 min^{-1} m^{-2})		
Start	343.0 (174.0)	332.0 (179.0)
End	411.1 (149.6)	387.5 (154.2)
Lactate (mmol $litre^{-1}$)		
Start	1.6 (0.6)	1.5 (0.5)
End	1.8 (0.8)	1.7 (0.9)
Hb (g $litre^{-1}$)		
Start	120 (18)	120 (17)
End	112 (18)	103 (17)

British Journal of Anaesthesia, 115 (4): 578–89 (2015)

Changing trends in transfusion practice in liver transplantation

Yves Ozier[a] and Mei-Yung Tsou[b]

Current Opinion in Organ Transplantation 2008, 13:304–309

- **Blood volume expansion with crystalloids and colloid solutions will result in dilution, a decrease in plasma levels of coagulation factors, and worsening coagulopathy.**
- **As a consequence, differences in volume loading can markedly influence blood product requirements.**

Oxygenation (SpO_2)

$$DO_2 = CaO_2 \times CO$$

$$CaO_2 = Hgb \times 1.34 \times SaO_2 + (PaO_2 \times 0.0032)$$

SpO_2

Is pulse oximetry an essential tool or just another distraction? The role of the pulse oximeter in modern anesthesia care

Amit Shah · Kirk H. Shelley

J Clin Monit Comput (2013) 27:235–242

"The role of pulse oximetry in clinical anesthesia and intensive care has evolved to the point where it is unlikely that we will ever be able to do without it".

THE COCHRANE COLLABORATION®

Pulse oximetry for perioperative monitoring (Review)

Pedersen T, Hovhannisyan K, Møller AM

Cochrane Database of Systematic Reviews 2009

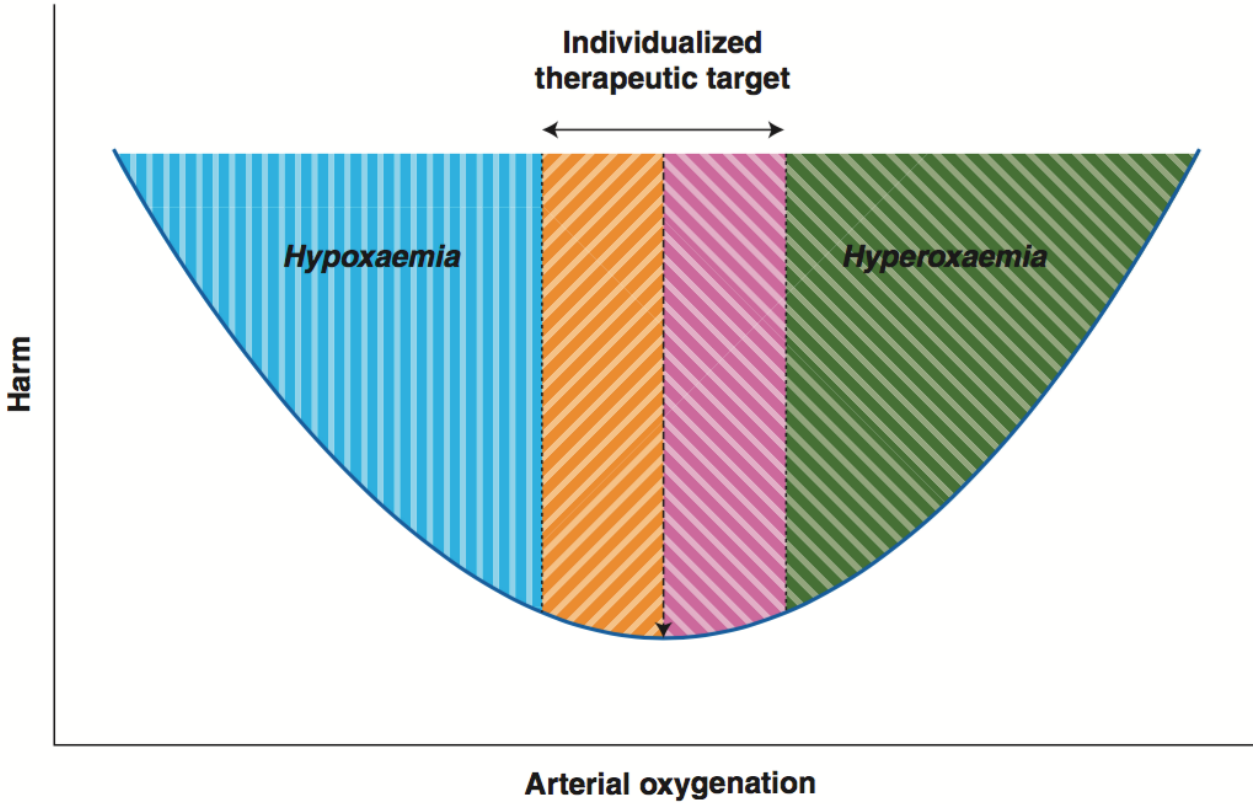
"The use of pulse oximetry as an early warning of moderate hypoxemia does not seem to be beneficial…."

British Journal of Anaesthesia **111** (6): 867–71 (2013)
doi:10.1093/bja/aet291

EDITORIAL III

Oxygen therapy in anaesthesia: the yin and yang of O_2

D. S. Martin[1] and M. P. W. Grocott[2,3,4*]



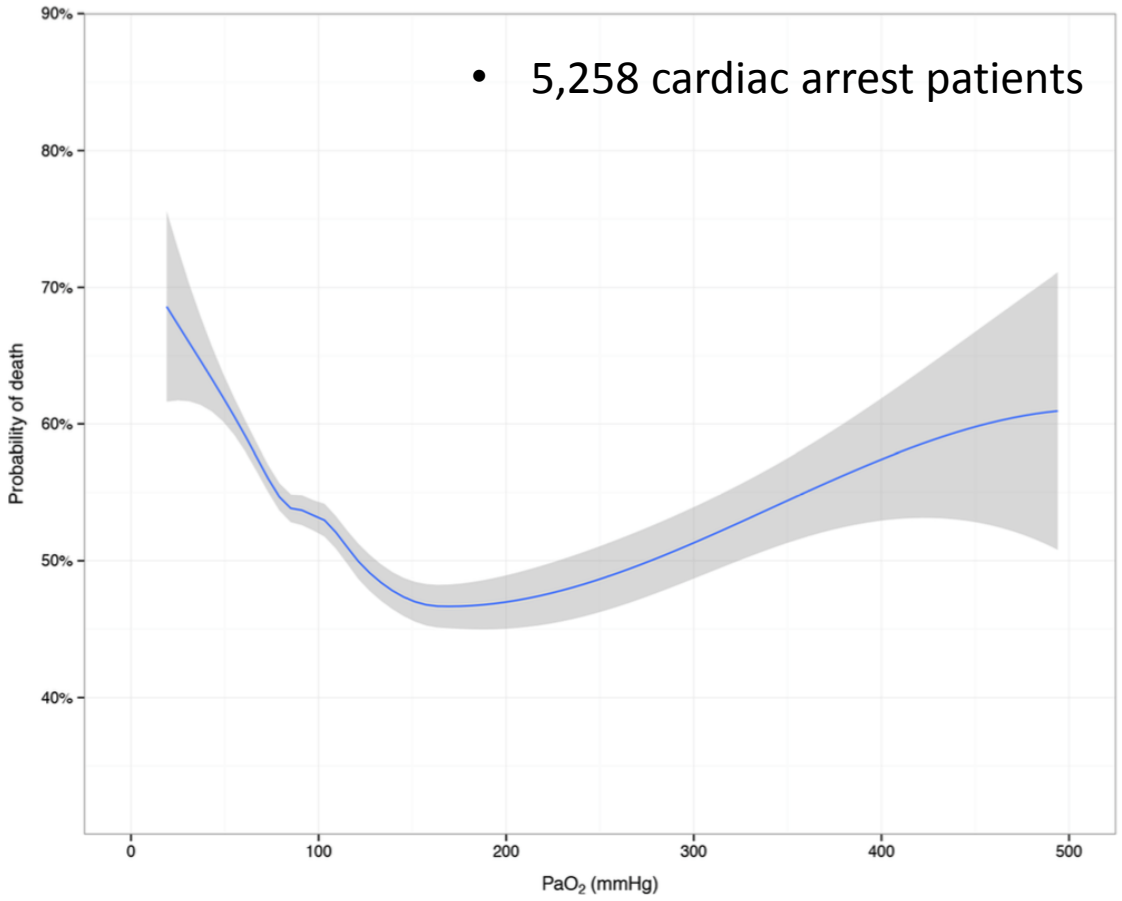
RESEARCH Open Access

Associations of arterial carbon dioxide and arterial oxygen concentrations with hospital mortality after resuscitation from cardiac arrest

Hendrik J. F. Helmerhorst[1,2*], Marie-José Roos-Blom[3,4], David J. van Westerloo[1], Ameen Abu-Hanna[3], Nicolette F. de Keizer[3,4] and Evert de Jonge[1,4]

Critical Care (2015) 19:348

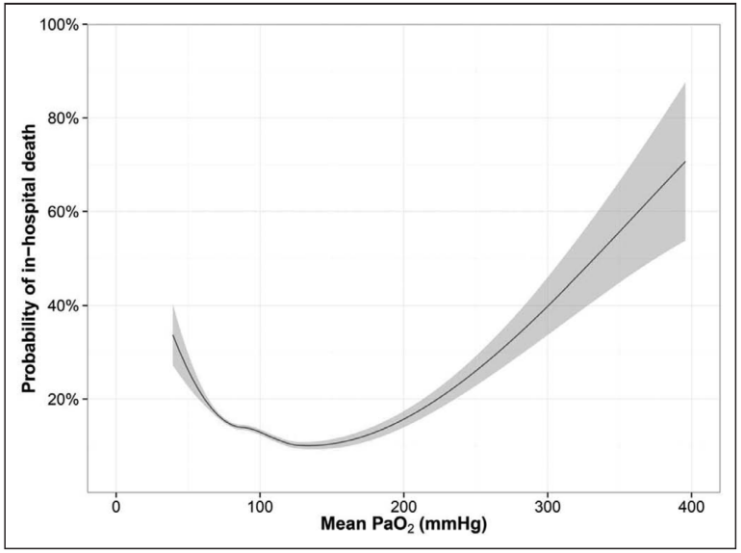
- 5,258 cardiac arrest patients

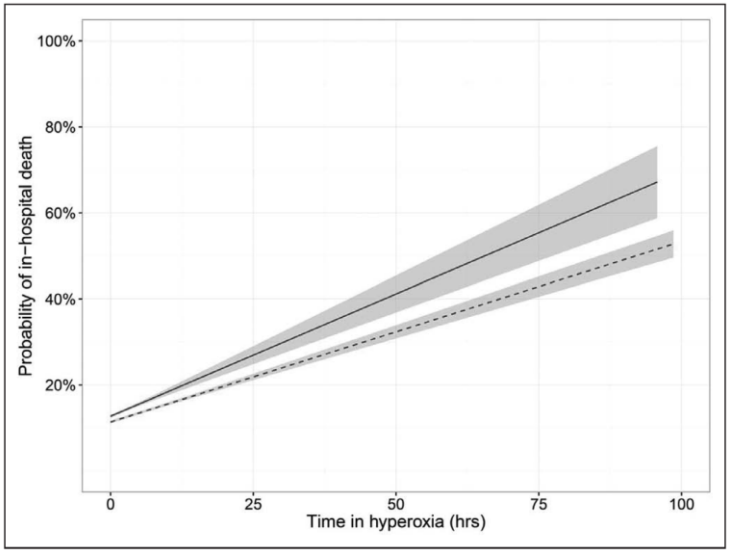


Metrics of Arterial Hyperoxia and Associated Outcomes in Critical Care (*Crit Care Med* 2016;

Hendrik J. F. Helmerhorst, MD[1,2]; Derk L. Arts, MD[3]; Marcus J. Schultz, MD, PhD[2,4]; Peter H. J. van der Voort, MD, PhD[5]; Ameen Abu-Hanna, PhD[3]; Evert de Jonge, MD, PhD[1]; David J. van Westerloo, MD, PhD[1]

295,079 ABG's from 14,441 ICU patients





"We should limit the PaO_2 levels of critically ill patients within a safe range, as we do with other physiologic variables".

Association between administered oxygen, arterial partial oxygen pressure and mortality in mechanically ventilated intensive care unit patients

Evert de Jonge[1], Linda Peelen[2,3], Peter J Keijzers[4], Hans Joore[4], Dylan de Lange[4], Peter HJ van der Voort[5], Robert J Bosman[5], Ruud AL de Waal[6], Ronald Wesselink[7] and Nicolette F de Keizer[2]

Critical Care 2008, **12**:R156

Conclusions Actually achieved PaO_2 values in ICU patients in The Netherlands are higher than generally recommended in the literature.

Targeting Normoxemia in Acute Respiratory Distress Syndrome May Cause Worse Short-Term Outcomes because of Oxygen Toxicity

Neil R. Aggarwal and Roy G. Brower

AnnalsATS Volume 11 Number 9 | November 2014

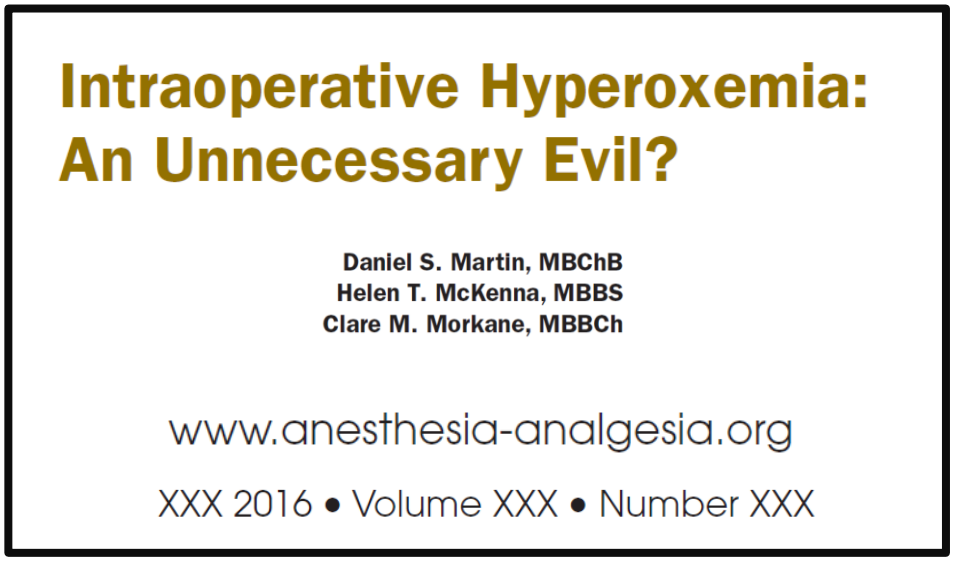
Physicians frequently prescribe higher FIO_2 levels than are necessary to achieve their arterial oxygenation goal, further increasing the risk of oxygen toxicity.

Liberal oxygenation in paediatric intensive care: retrospective analysis of high-resolution SpO_2 data

Samiran Ray[1*], L. Rogers[2], S. Raman[1], M. J. Peters[1] and On behalf of the Oxy-PICU investigators

Intensive Care Med Published online: 28 October 2016

- **Current practice is for very liberal oxygenation above the recommended targets even in children with low PF ratios.**
- **PICU practice does not follow what clinicians report, recent evidence or existing guidelines.**



- **The intraoperative PaO_2 appeared to be rather high in this cohort of patients.**
- **The mean PaO_2 was 206 mm Hg, which is comparable with UK data, demonstrating the pervasiveness of intraoperative hyperoxemia.**

Oxygen therapy and anaesthesia: too much of a good thing?

Martin DS, Grocott MPW Anaesthesia 2015, 70, 511–527

- **There is an often unrecognized trend towards maintaining significantly higher than normal PaO_2 during major surgery.**
- **Is this state of supernormal oxygenation maintained 'just in case' there is an unanticipated crisis, or does this represent indifference based on an assumption that there is no risk of harm from hyperoxia?**

JAMA | Preliminary Communication | CARING FOR THE CRITICALLY ILL PATIENT

Effect of Conservative vs Conventional Oxygen Therapy on Mortality Among Patients in an Intensive Care Unit

The Oxygen-ICU Randomized Clinical Trial

Massimo Girardis, MD; Stefano Busani, MD; Elisa Damiani, MD; Abele Donati, MD; Laura Rinaldi, MD; Andrea Marudi, MD; Andrea Morelli, MD; Massimo Antonelli, MD; Mervyn Singer, MD, FRCA

JAMA. doi:10.1001/jama.2016.11993
Published online October 5, 2016.

- **Control group: Each patient received an FiO_2 of at least 0.4, allowing PaO_2 values up to 150 mmHg and an SpO_2 97% - 100%. If the SpO_2 decreased below 95% - 97%, the FiO_2 was increased to reach the target value of SpO_2.**
- **Protocol group: Oxygen therapy was administered at the lowest possible FiO_2 to maintain the PaO_2 70 - 100 mmHg or SpO_2 values of 94% - 98%.**

JAMA | Preliminary Communication | CARING FOR THE CRITICALLY ILL PATIENT

Effect of Conservative vs Conventional Oxygen Therapy on Mortality Among Patients in an Intensive Care Unit

The Oxygen-ICU Randomized Clinical Trial

Massimo Girardis, MD; Stefano Busani, MD; Elisa Damiani, MD; Abele Donati, MD; Laura Rinaldi, MD; Andrea Marudi, MD; Andrea Morelli, MD; Massimo Antonelli, MD; Mervyn Singer, MD, FRCA

JAMA. doi:10.1001/jama.2016.11993
Published online October 5, 2016.

CONCLUSIONS AND RELEVANCE

Among critically ill patients with an ICU length of stay of ≥72H, a conservative protocol for oxygen therapy vs conventional therapy resulted in lower ICU mortality.

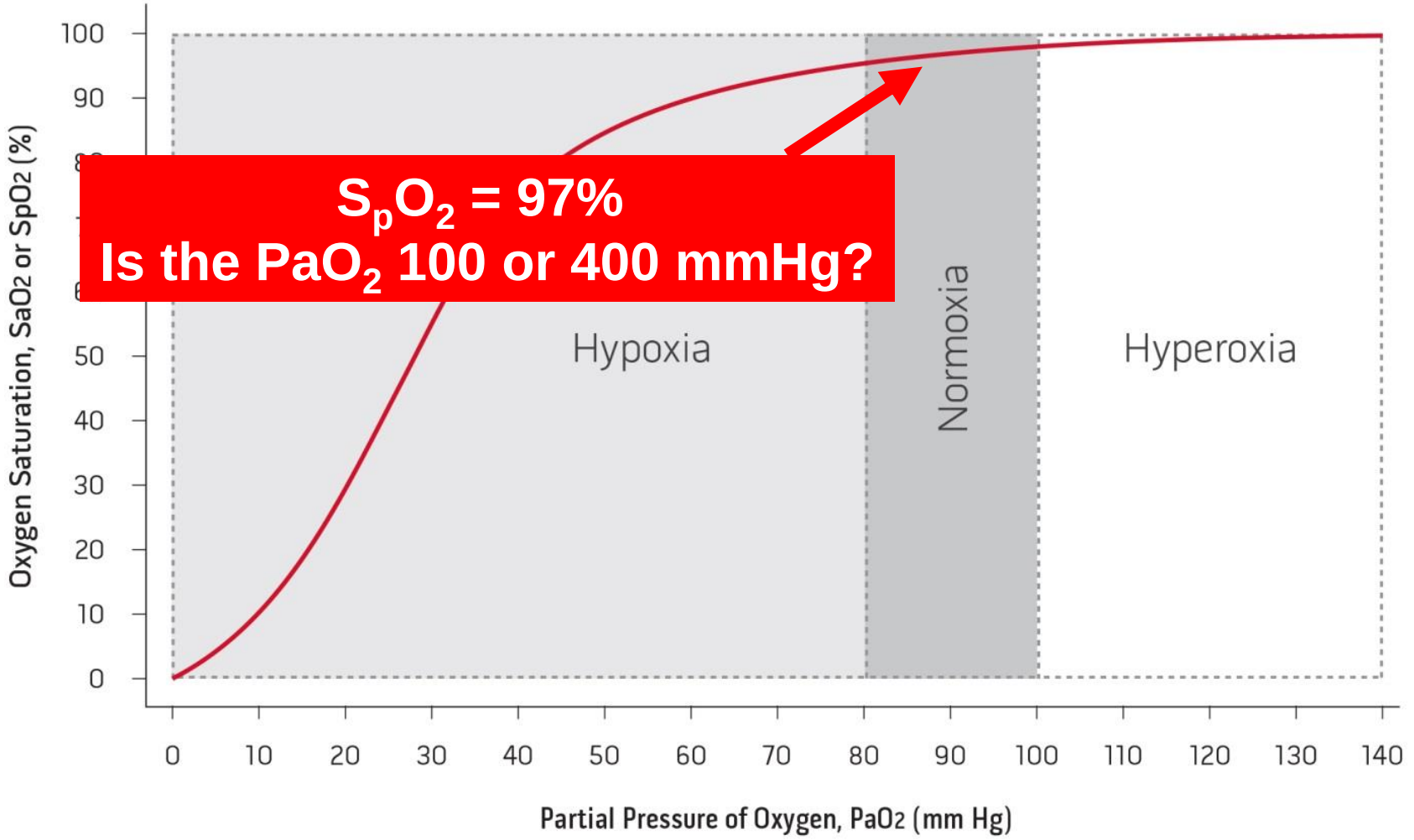
EDITORIAL

Oxygen in the ICU

Too Much of a Good Thing?

Niall D. Ferguson, MD, MSc

The limitations of pulse oximetry



Only the PaO_2 can be used to assess the hyperoxic range; however, measurements are both intermittent and delayed.

Oxygenation (PaO_2)

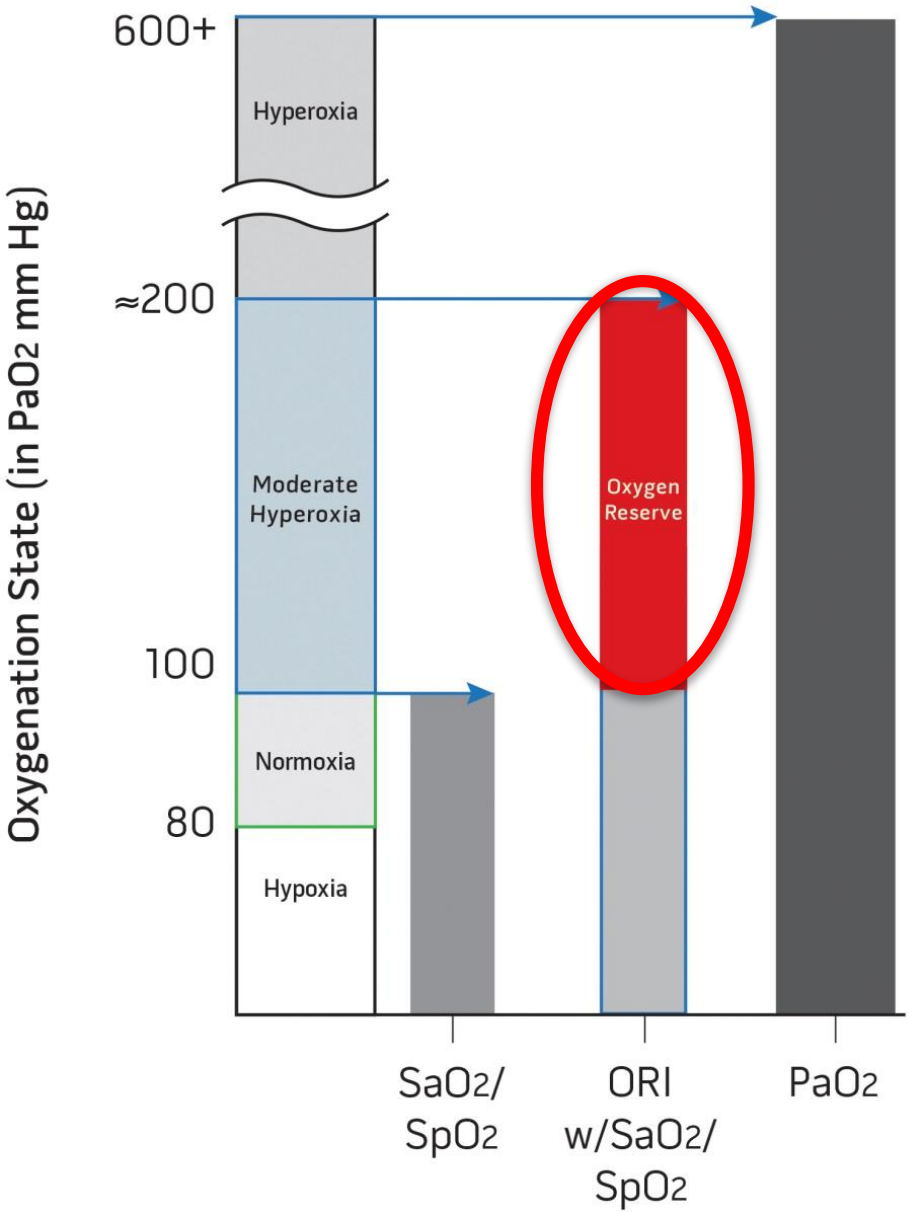
$$DO_2 = CaO_2 \times CO$$

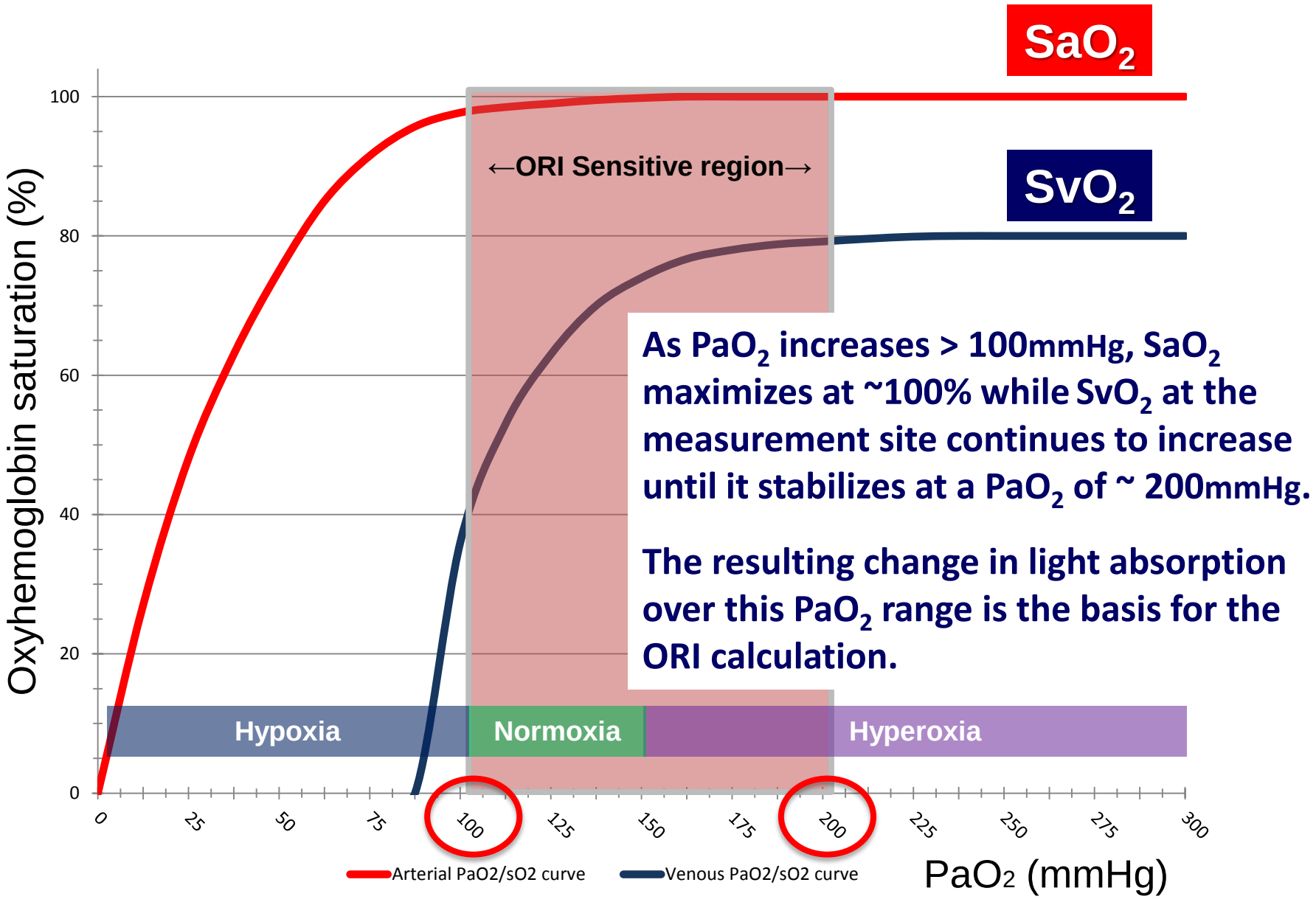
$$CaO_2 = Hgb \times 1.34 \times SaO_2 + (PaO_2 \times 0.0032)$$

ORI – Oxygen Reserve Index

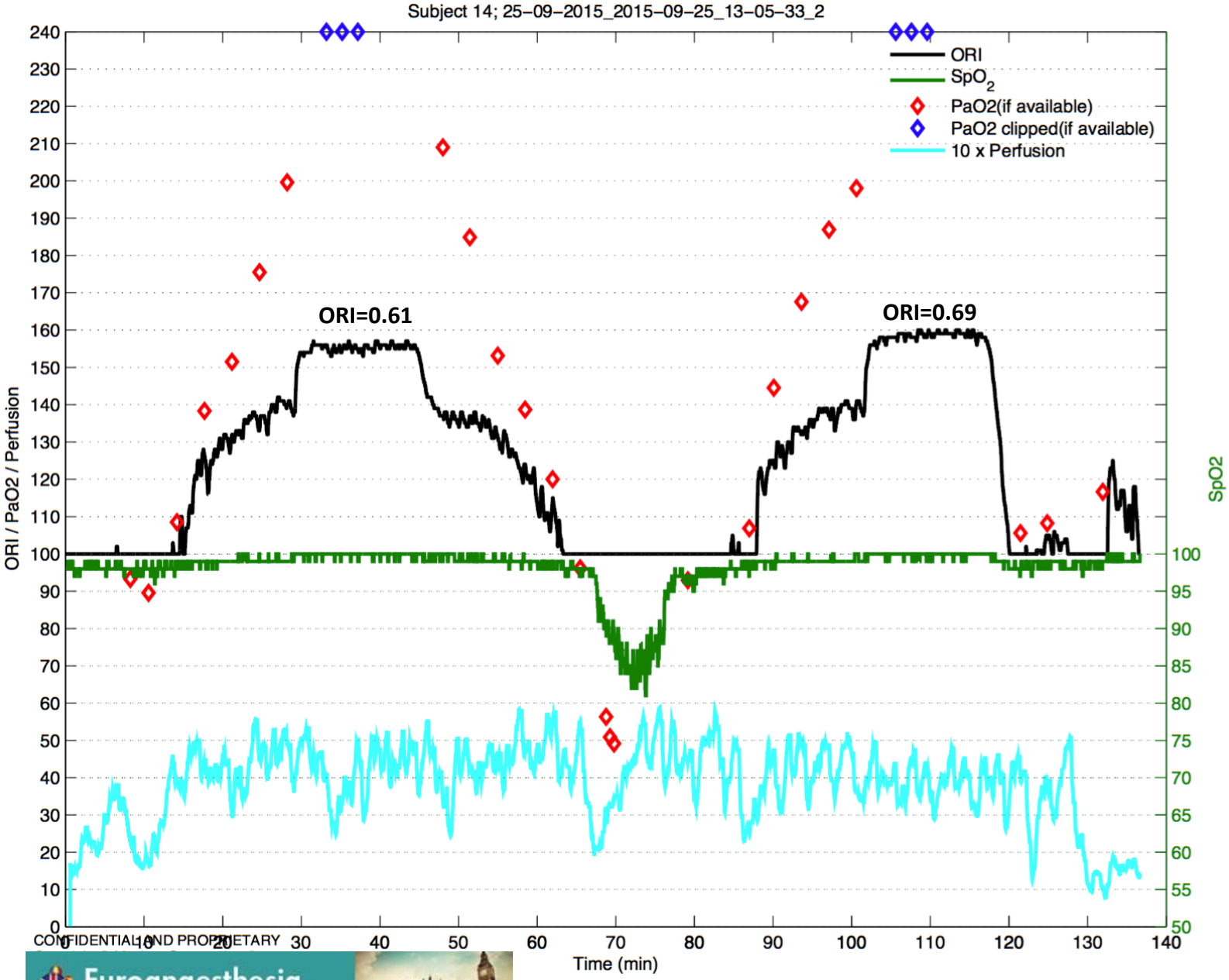
The Oxygen Reserve Index (ORI)

- ORI is a non-invasive continuous parameter that provides information about the oxygenation in the moderate hyperoxic range (**PaO_2 >100 and <≈200 mmHg**) in patients receiving supplemental oxygen.
- ORI is an "index" with a unit-less scale between 0 and 1.




SaO2
SvO2
←ORI Sensitive region→
As PaO2 increases > 100mmHg, SaO2 maximizes at ~100% while SvO2 at the measurement site continues to increase until it stabilizes at a PaO2 of ~ 200mmHg.
The resulting change in light absorption over this PaO2 range is the basis for the ORI calculation.
Hypoxia
Normoxia
Hyperoxia
Oxyhemoglobin saturation (%)
100
80
60
40
20
0
0
25
50
75
100
125
150
175
200
225
250
275
300
Arterial PaO2/sO2 curve
Venous PaO2/sO2 curve
PaO2 (mmHg)

ORI validation study: preliminary results



Scheeren TWL et al., Euroanaesthesia 2016: 01AP04-9

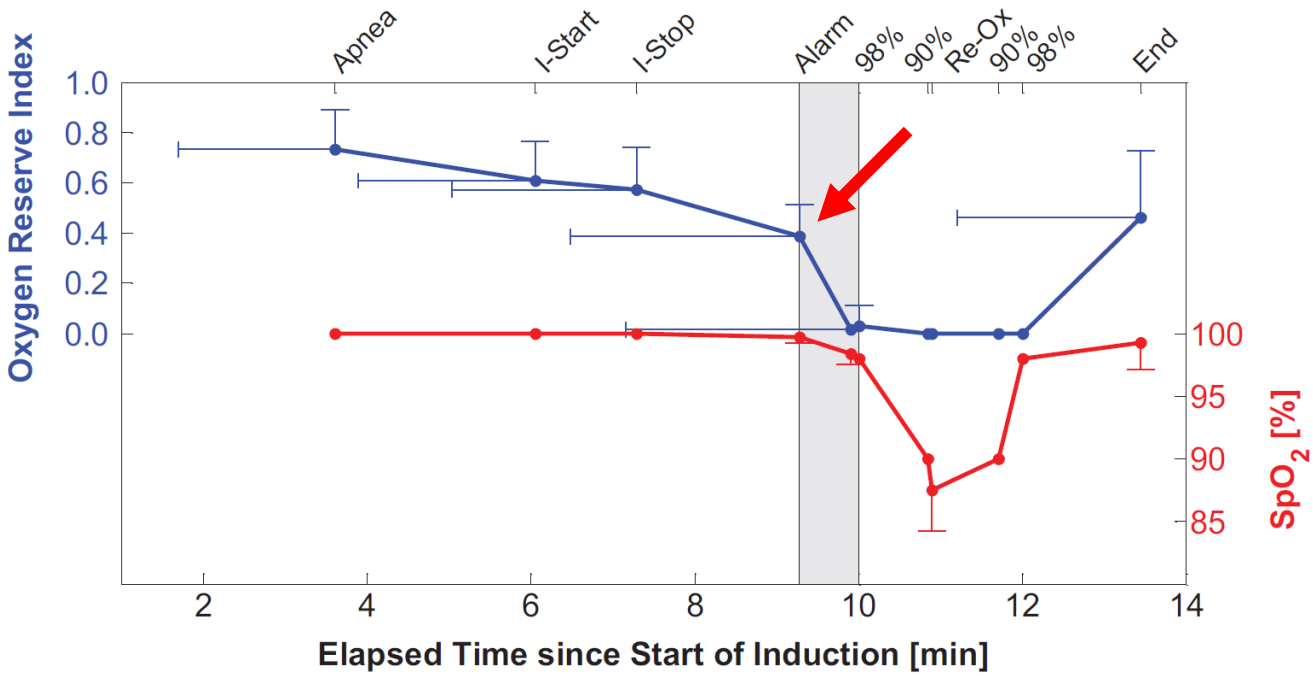
PERIOPERATIVE MEDICINE

(ANESTHESIOLOGY 2016; 124:00-00)

Oxygen Reserve Index

A Novel Noninvasive Measure of Oxygen Reserve—A Pilot Study

Peter Szmuk, M.D., Jeffrey W. Steiner, D.O., Patrick N. Olomu, M.D., Roxana P. Ploski, B.S., Daniel I. Sessler, M.D., Tiberiu Ezri, M.D.



When Seconds Count, Buy More Time

The Oxygen Reserve Index and Its Promising Role in Patient Monitoring and Safety

Allan F. Simpao, M.D., M.B.I., Jorge A. Gálvez, M.D.

Anesthesiology. 2016;124(4):750-1

Use of deep laryngeal oxygen insufflation during laryngoscopy in children: a randomized clinical trial

J. W. Steiner[1,2,*], D. I. Sessler[2,3], N. Makarova[2,3,4], E. J. Mascha[2,3,4], P. N. Olomu[1], J. W. Zhong[1], C. T. Setiawan[1], A. E. Handy[1], B. N. Kravitz[5] and P. Szmuk[1,2]

British Journal of Anaesthesia, 117 (3): 350–7 (2016)

Editor's key points

- Haemoglobin oxygen desaturation is common and rapid in children during laryngoscopy for tracheal intubation.
- The effect of oxygen insufflation on pulse oximetry measurements during laryngoscopy was studied in 457 children undergoing nasotracheal intubation.
- Deep insufflation of oxygen slowed desaturation when used with either direct or video-assisted laryngoscopy compared to direct laryngoscopy alone.

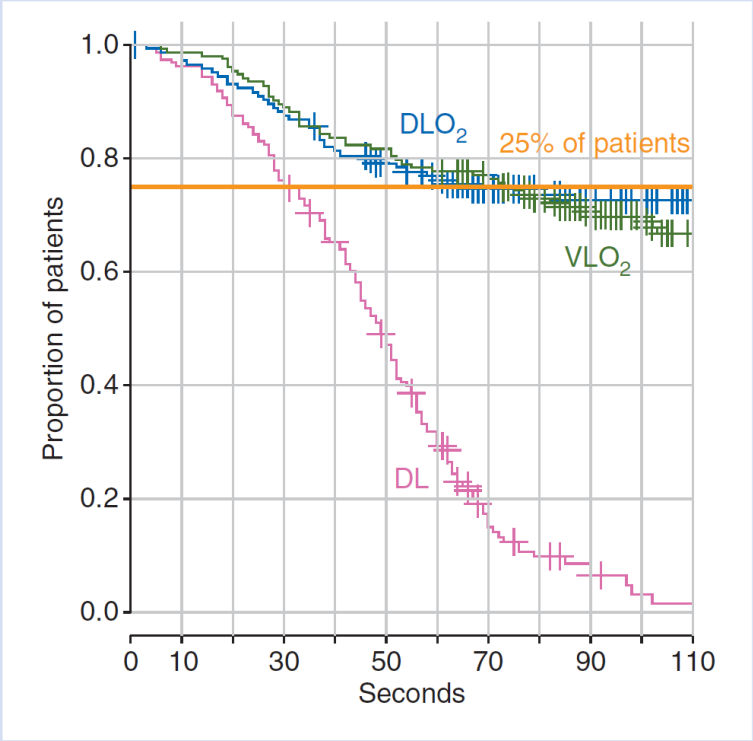
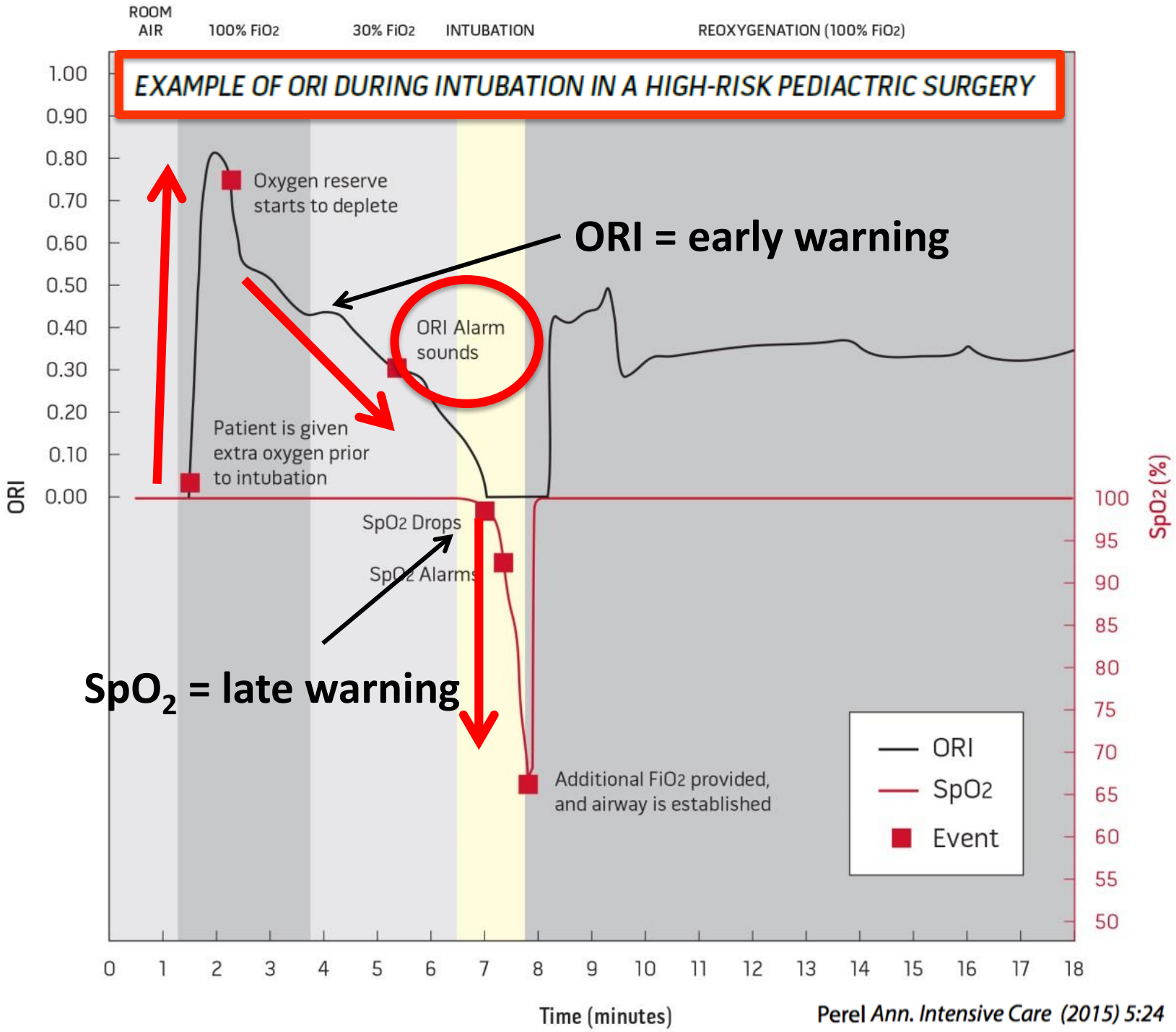


Fig 4 Kaplan–Meier curves of time to 1% reduction in saturation from the baseline. Time to 1% reduction in saturation was censored at the end of intubation.

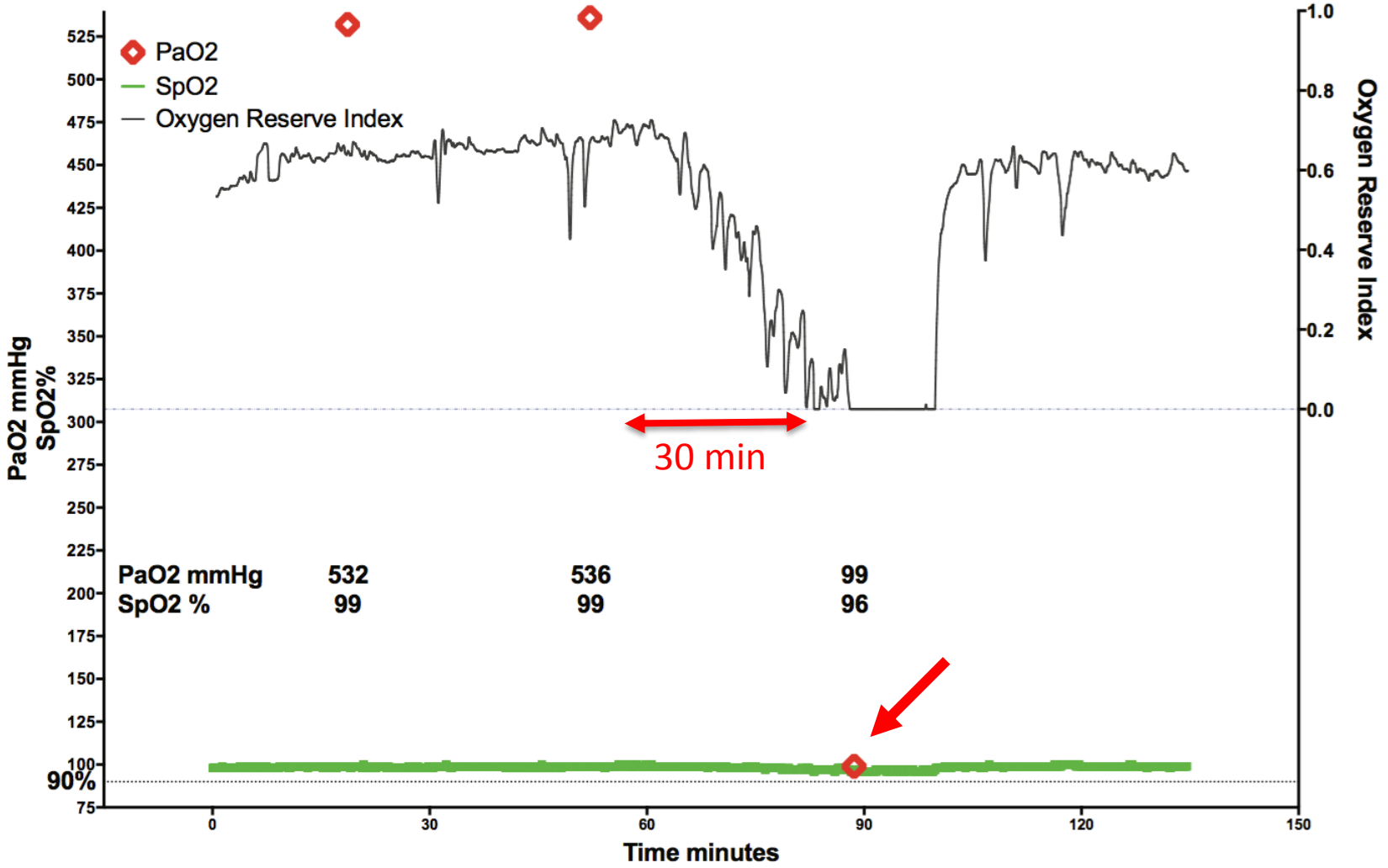


Perel *Ann. Intensive Care* (2015) 5:24

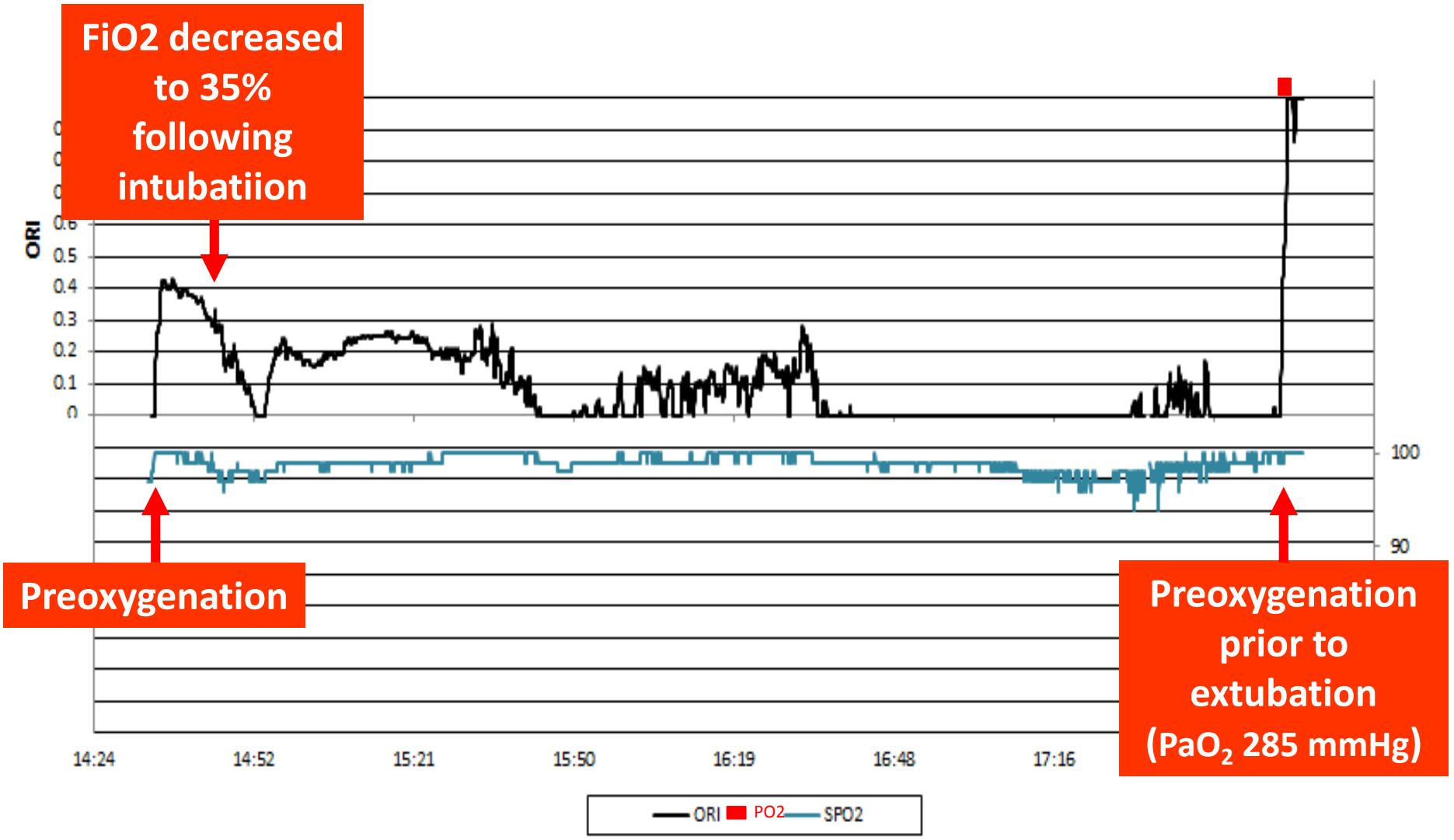
The Relationship Between Oxygen Reserve Index and Arterial Partial Pressure of Oxygen During Surgery

Richard L. Applegate II, MD,* Ihab L. Dorotta, MD,* Briana Wells, MS,† David Juma, MPH,† and Patricia M. Applegate, MD‡

(Anesth Analg 2016;123:626–33)



ORI response to preoxygenation before intubation and extubation



Pre-oxygenation and general anesthesia: a review

Gaelle BOUROCHE, Jean Louis BOURGAIN

Minerva Anestesiol 2015 Jun 05 [Epub ahead of print]

- **Pre-oxygenation should be routine, as oxygen reserves are not always sufficient to cover the duration of intubation.**
- **Predictive risk factors for inadequate pre-oxygenation are similar to those of difficult mask ventilation.**

Prevention and care of respiratory failure in obese patients

Jean Louis Pépin, Jean François Timsit, Renaud Tamisier, Jean Christian Borel, Patrick Lévy, Samir Jaber

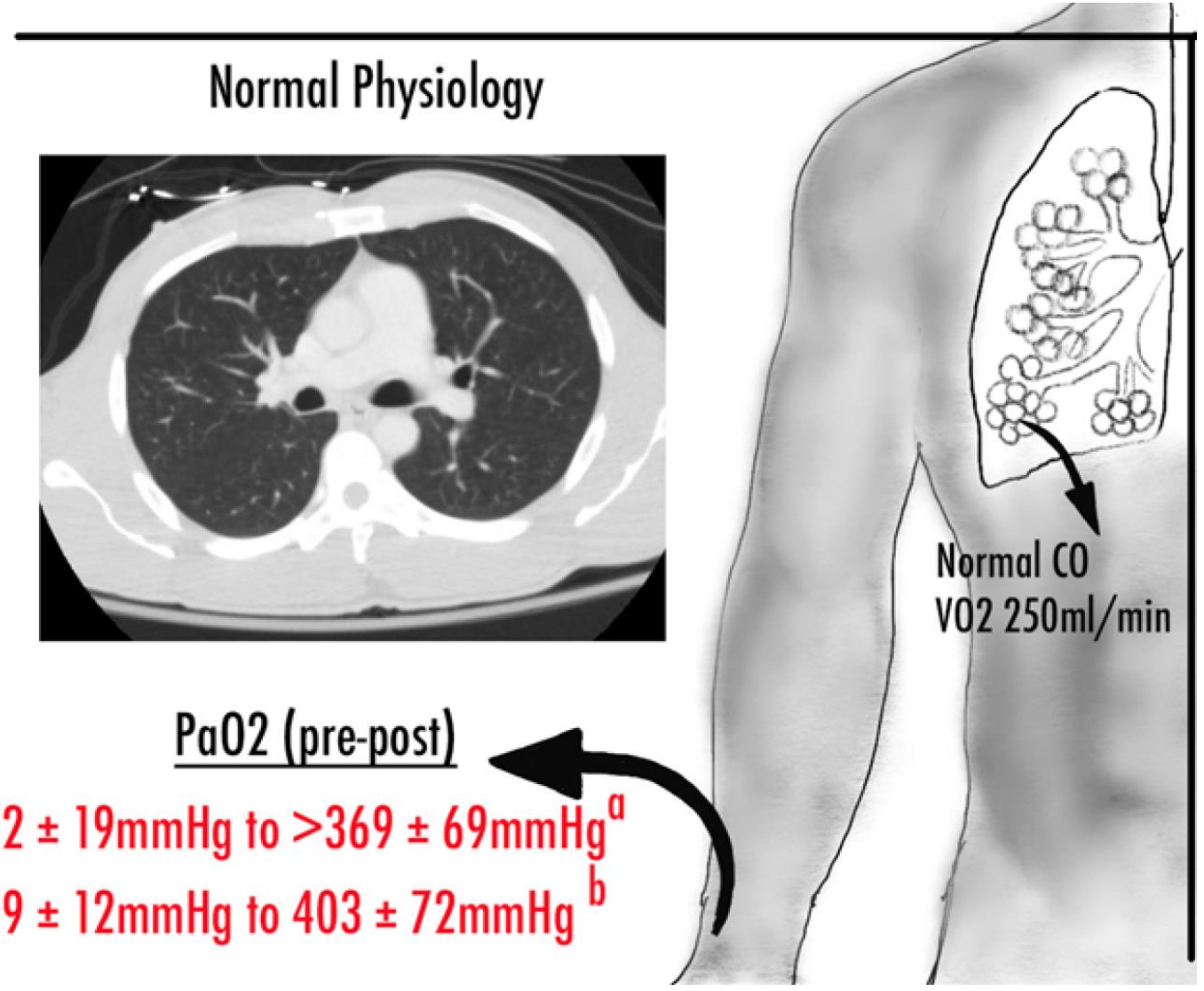
Lancet Respir Med 2016; 4: 407–18

- **Obesity presents a risk factor for difficult mask ventilation and difficult intubation.**
- **In morbidly obese patients, the non-hypoxic apnea time (length of apnea after the induction of anesthesia when the patient has no oxygen desaturation) decreases from 3 min to 1 min.**
- **Preoxygenation for 5 min with NIV and PEEP in a head-up position is recommended.**

Understanding preoxygenation and apneic oxygenation during intubation in the critically ill

Intensive Care Med **2016**

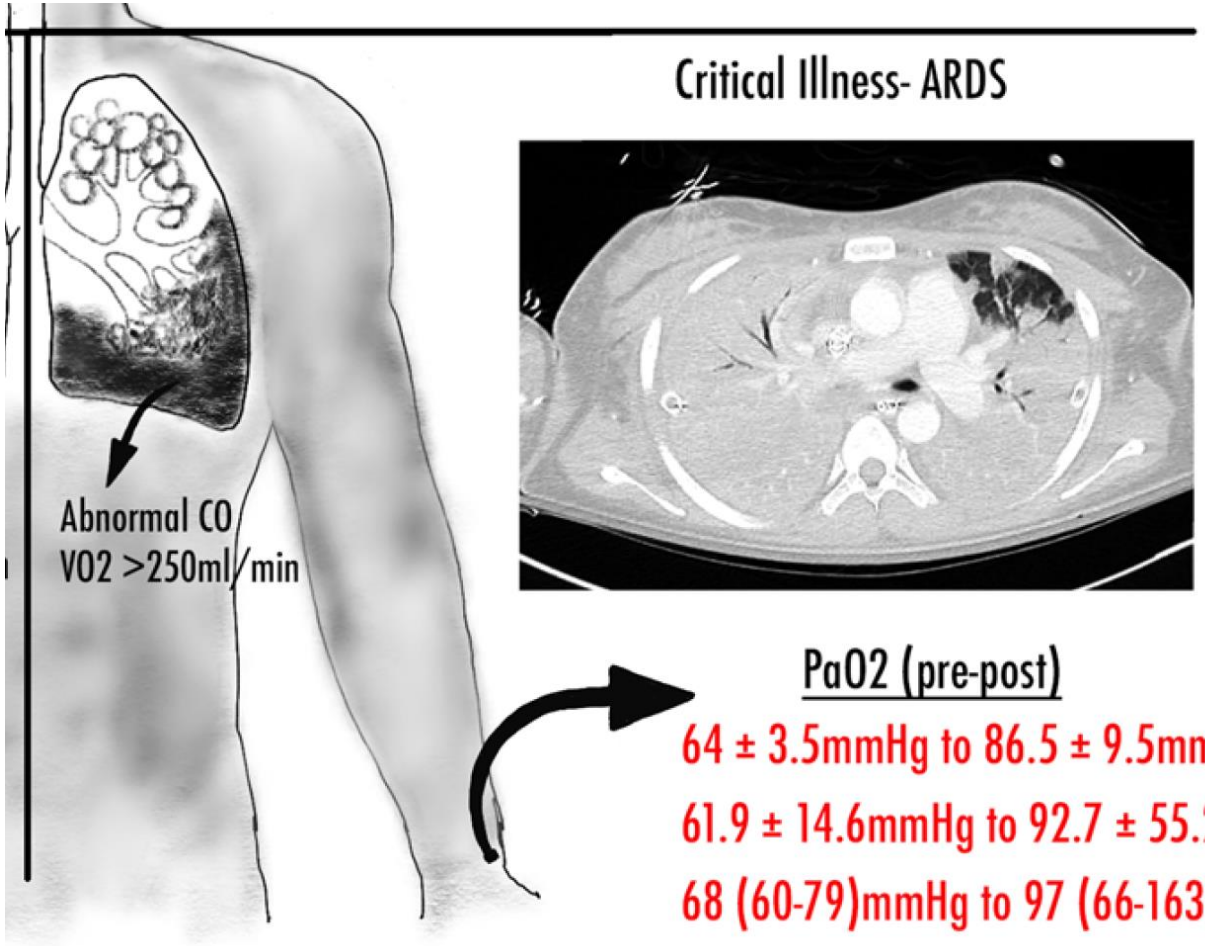
Jarrod M. Mosier[1,2*], Cameron D. Hypes[1,2] and John C. Sakles[2]



Understanding preoxygenation and apneic oxygenation during intubation in the critically ill

Intensive Care Med **2016**

Jarrod M. Mosier[1,2*], Cameron D. Hypes[1,2] and John C. Sakles[2]



Crit Care Med
2015; 43:574–583

Use of High-Flow Nasal Cannula Oxygen Therapy to Prevent Desaturation During Tracheal Intubation of Intensive Care Patients With Mild-to-Moderate Hypoxemia*

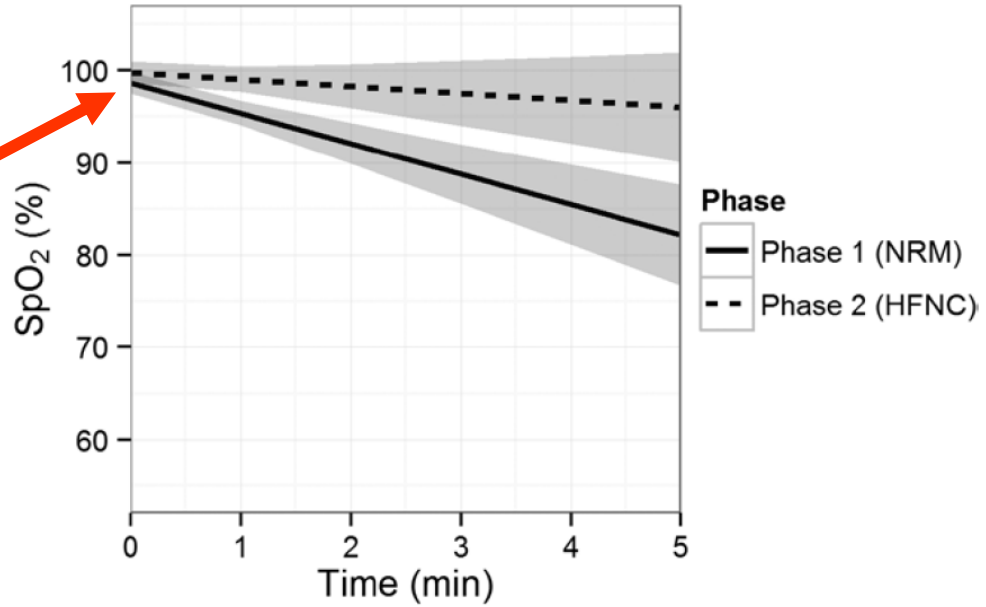
Romain Miguel-Montanes, MD[1]; David Hajage, MD[2]; Jonathan Messika, MD[1,3,4]; Fabrice Bertrand, MD[1]; Stéphane Gaudry, MD[1,3,4]; Cédric Rafat, MD[1]; Vincent Labbé, MD[1]; Nicolas Dufour, MD[1,3,4]; Sylvain Jean-Baptiste, MD[1]; Alexandre Bedet, MD[1]; Didier Dreyfuss, MD[1,3,4]; Jean-Damien Ricard, MD, PhD[1,3,4]

Am J Respir Crit Care Med
2016; 193: 273-80

Randomized Trial of Apneic Oxygenation during Endotracheal Intubation of the Critically Ill

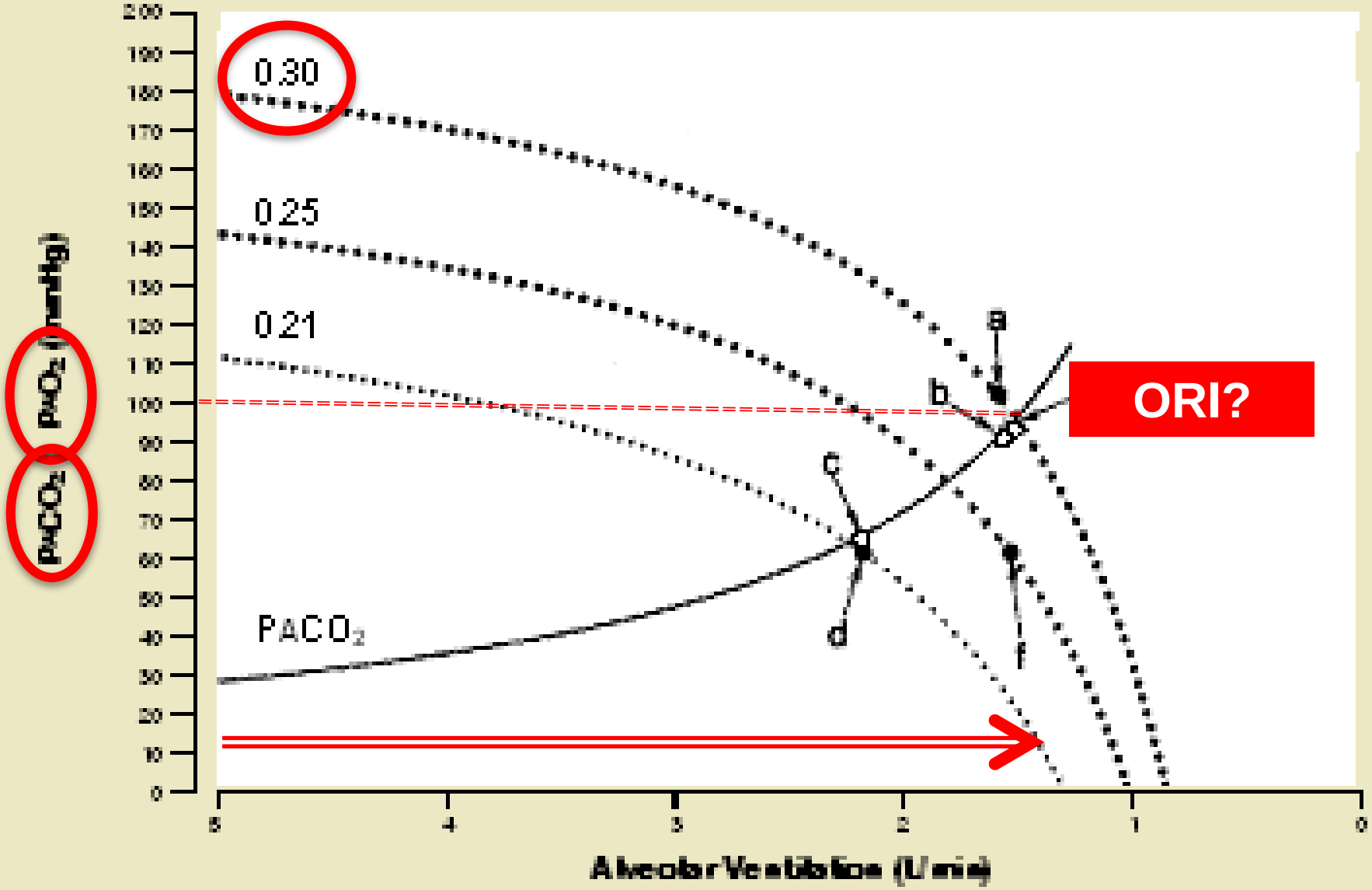
Matthew W. Semler[1], David R. Janz[2], Robert J. Lentz[1], Daniel T. Matthews[1], Brett C. Norman[1], Tufik R. Assad[1], Raj D. Keriwala[1], Benjamin A. Ferrell[1], Michael J. Noto[1], Andrew C. McKown[1], Emily G. Kocurek[1], Melissa A. Warren[1], Luis E. Huerta[1], and Todd W. Rice[1]; for the FELLOW Investigators and the Pragmatic Critical Care Research Group

PaO_2?



Supplemental Oxygen Impairs Detection of Hypoventilation by Pulse Oximetry

Fu ES, *et al.* Chest 2004, 126: 1552



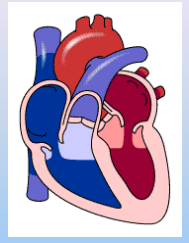
The Oxygen Reserve Index (ORI)

- May provide early alarm when oxygenation deteriorates.
- May make pre-oxygenation visible.
- May facilitate FiO_2 titration and prevent unintended hyperoxia.

The Cardiac Output (CO)

$$DO_2 = CaO_2 \times CO$$

$$CaO_2 = Hgb \times 1.34 \times SaO_2 + (PaO_2 \times 0.0032)$$



Fluids!
Inotropes!

Goal-Directed Therapy: Time to Move on?

Maurizio Cecconi, MD, FRCA, MD(UK), FICM, and Andrew Rhodes, FRCP, FRCA, FFICM, MD

ANESTHESIA & ANALGESIA September 2014 • Volume 119 • Number 3

"Goal-directed therapy (GDT) refers to the use of fluids and/or inotropes to target hemodynamic goals to improve oxygen delivery (DO_2) to the tissues."

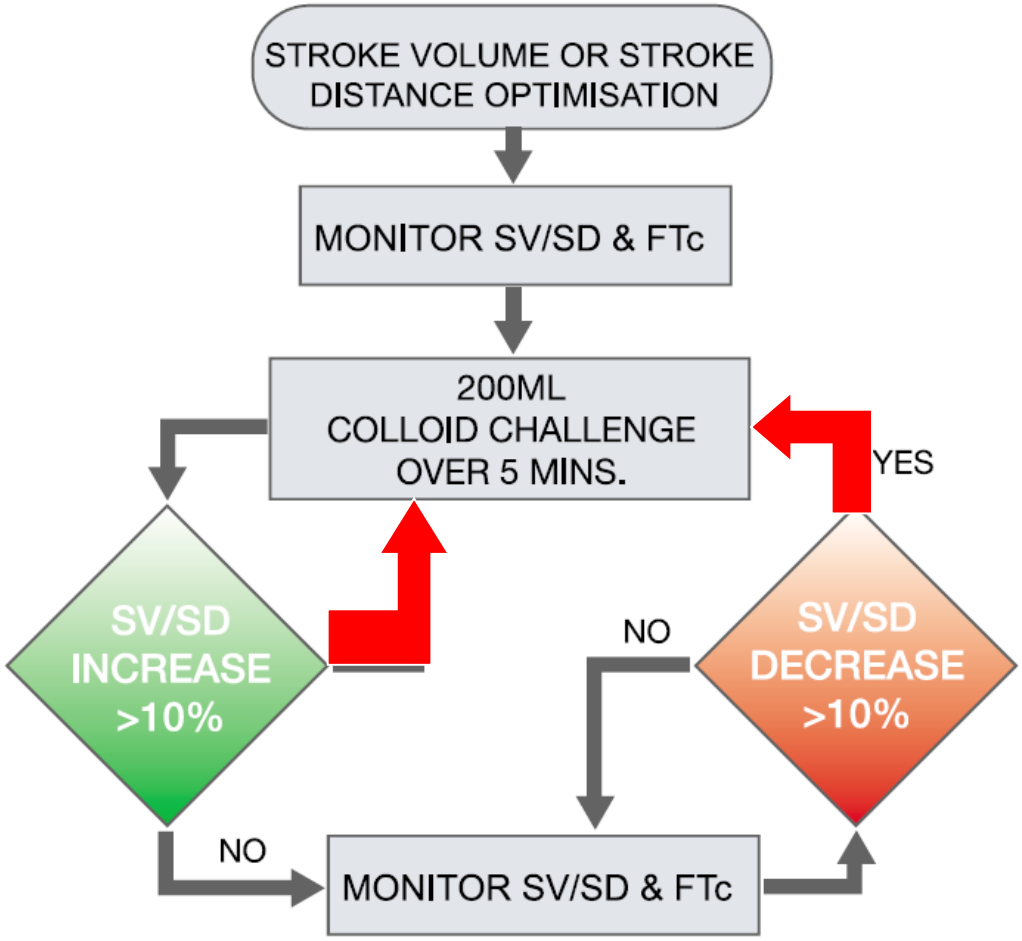
The limitations of Cardiac Output

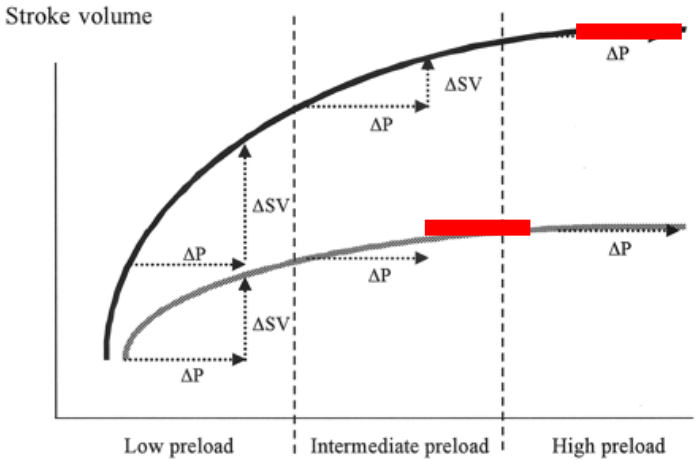
- The individual optimal CO is difficult to assess.
- A ‘normal’ or even high CO does not preclude the presence of inadequate regional and micro-circulatory flow.
- A low CO does not tell us WHAT to do.
- The CO does not predict fluid responsiveness.

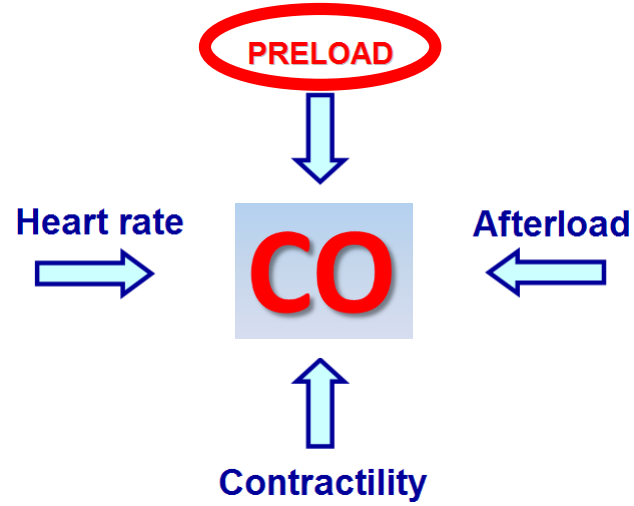
DELTEX MEDICAL

CardioQ Quick Reference Guide

Surgical Application - Interpreting results







OPTIMISE **JAMA. Published on line May 19, 2014.**

Characteristics	Cardiac Output–Guided Hemodynamic Therapy Algorithm (n = 367)	Usual Care (n = 362)
Intravenous crystalloid, median (IQR), mL[c]		
During surgery	1000 (459-2000)	2000 (1283-3000)
During 6 h following surgery	506 (410-660)	600 (450-800)
Intravenous colloid, median (IQR), mL[c]		
During surgery	1250 (1000-2000)	500 (0-1000)
During 6 h following surgery	500 (250-1000)	0 (0-500)
Blood products, mean (SD), mL[c]		
During surgery	141 (723)	95 (542)
During 6 h following surgery	80 (555)	10 (66)

Individualised oxygen delivery targeted haemodynamic therapy in high-risk surgical patients: a multicentre, randomised, double-blind, controlled, mechanistic trial

*Gareth L Ackland, Sadaf Iqbal, Laura Gallego Paredes, Andrew Toner, Craig Lyness, Nicholas Jenkins, Phoebe Bodger, Shamir Karmali, John Whittle, Anna Reyes, Mervyn Singer, Mark Hamilton, Maurizio Cecconi, Rupert M Pearse, Susan V Mallett, Rumana Z Omar, for the POM-O (PostOperative Morbidity-Oxygen delivery) study group**

Lancet Respir Med 2015; 3: 33–41

	Control (n=92)	Goal-directed therapy (n=95)
APACHE II score on intensive care unit admission	16 (5)	15 (6)
Crystalloid (mL/kg per h)	1·0 (1·0–1·1)	1·0 (1·0–1·2)
Colloid (mL/kg per h)	1·4 (0–2·8)	2·9 (1·7–3·6)
Blood transfusion	11 (12%)	22 (23%)
Dobutamine infusion	0	38 (40%)

Dynamic preload markers to predict fluid responsiveness during and after major gastrointestinal surgery: an observational substudy of the OPTIMISE trial

N. MacDonald[1], T. Ahmad[1], O. Mohr[2], J. Kirk-Bayley[3], I. Moppett[4], C. J. Hinds[1] and R. M. Pearse[1*]

British Journal of Anaesthesia **114** (4): 598–604 (2015)

- **Sub-study of the OPTIMISE trial including 100 of the original 368 patients enrolled in the intervention group.**
- **Only 28.6% of the fluid challenges were associated with increased stroke volume.**

28.6%!

Some of the perioperative goal-directed strategies failed to show any outcome benefit because they were based on CO/SV maximization without taking into account fluid responsiveness.

Perioperative fluid theory: a statement from the international Fluid Optimization Group

Perioperative Medicine (2015) 4:3

Navarro LHC[1], Bloomstone JA[2], Auler JOC Jr[3], Cannesson M[4], Della Rocca G[5], Gan TJ[6], Kinsky M[7], Magder S[8], Miller TE[6], Mythen M[9], Perel A[10], Reuter DA[11], Pinsky MR[12], Kramer GC[7].

Fluids should be administered *when* patients require augmentation of their perfusion *and* are also volume responsive.

EJA

Eur J Anaesthesiol 2016; **33:**1–5

INVITED COMMENTARY

The quest for the holy volume therapy

Edoardo De Robertis, Arash Afshari and Dan Longrois

The guidelines tell us that:

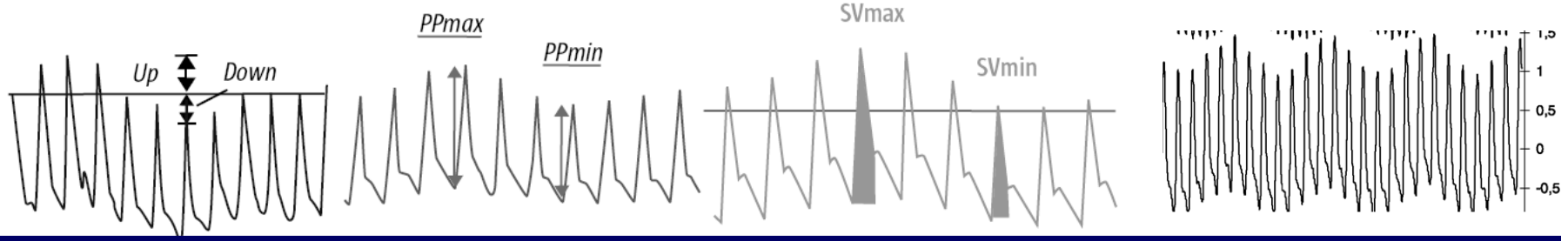
(1) Fluid therapy should be based on monitoring. Volume responsiveness is best evaluated by dynamic indices.

Bench-to-bedside review: Functional hemodynamics during surgery - should it be used for all high-risk cases?

Critical Care 2013, **17**:203

Azriel Perel*[1,2], Marit Habicher[1] and Michael Sander[1]

Dynamic parameters should be used to guide fluid therapy in all surgical patients in whom their use is appropriate, as part of, or independently of, GDT strategies.

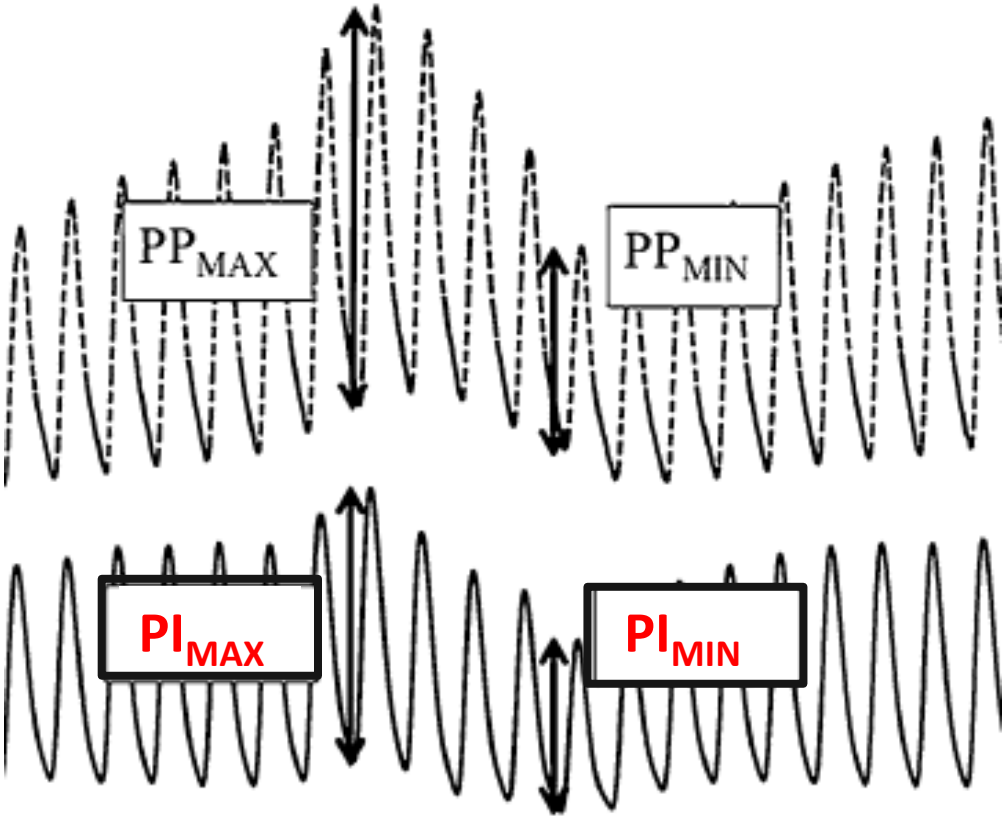


SPV PPV SVV PVI

The Pleth Variability Index (PVI)

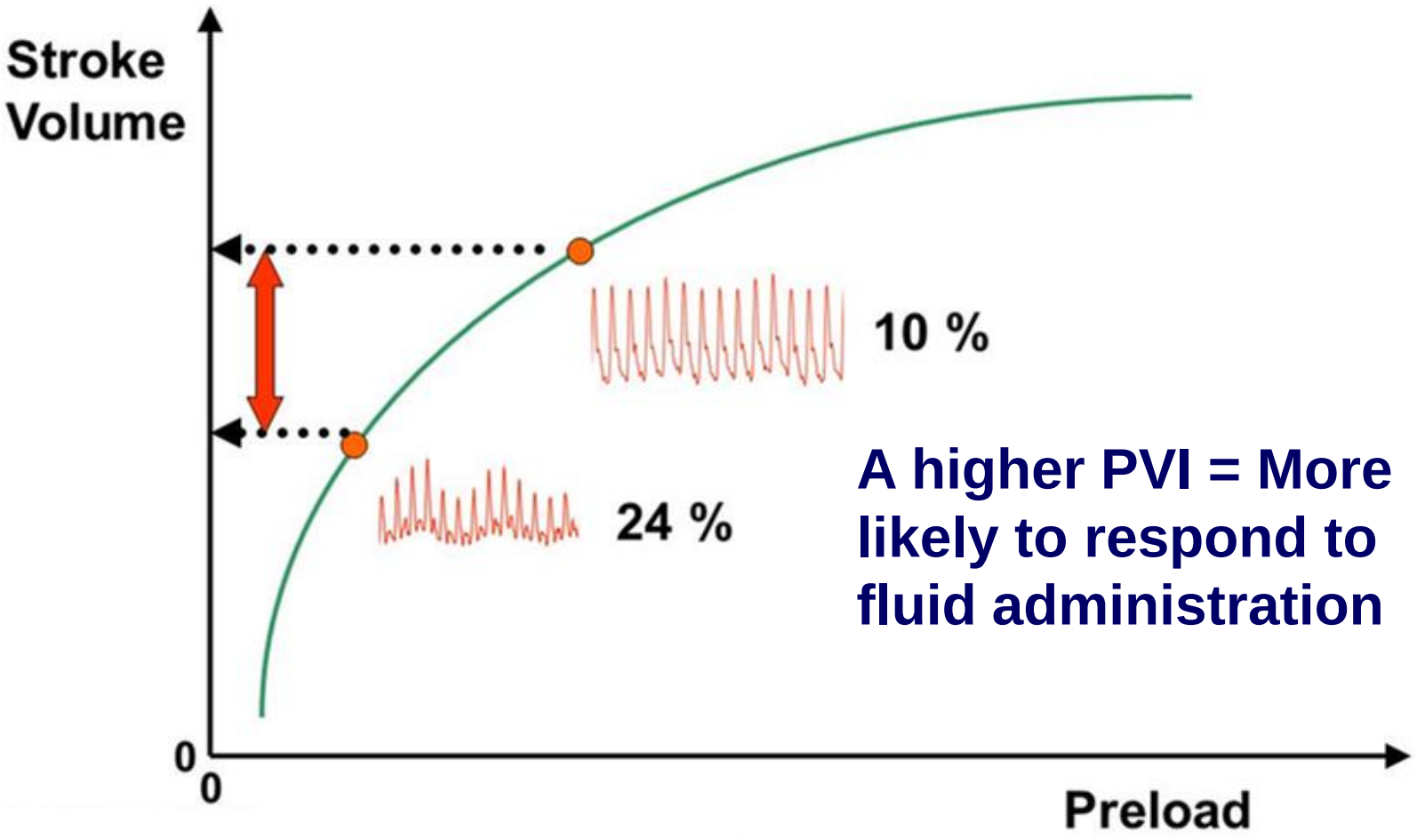
Arterial waveform

Pleth waveform



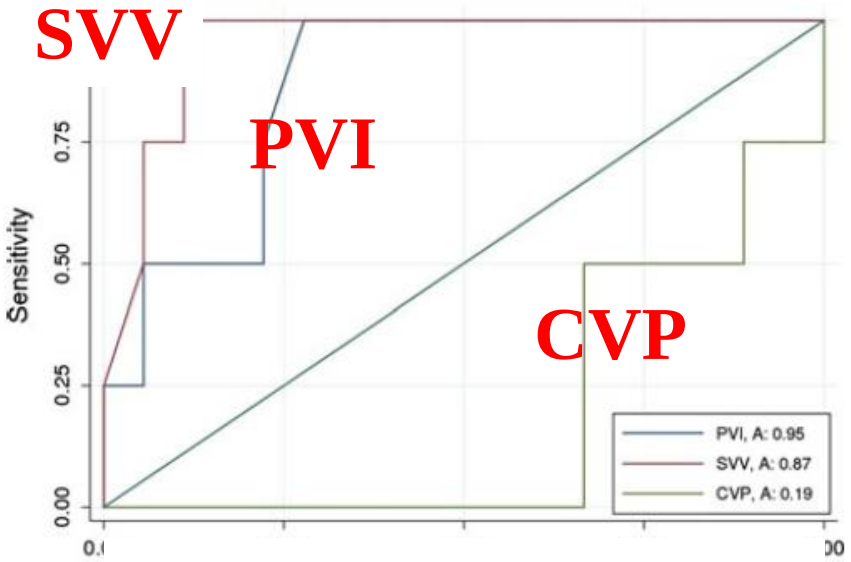
PVI = [(PImax - PImin) / PImax]

The Pleth Variability Index (PVI)

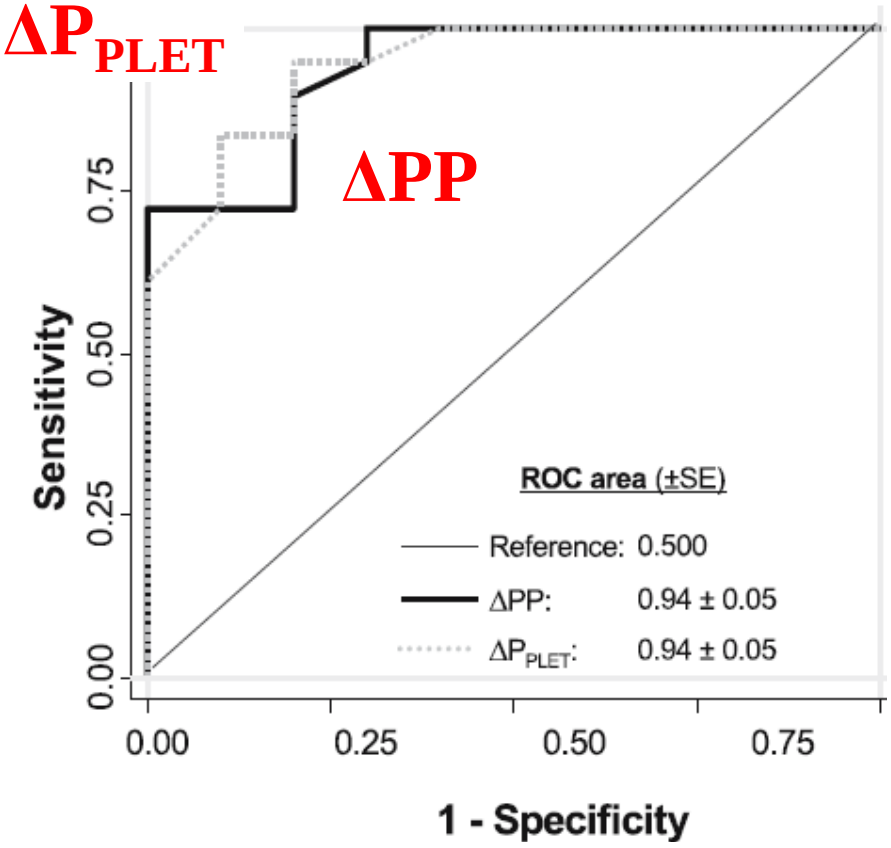


A higher PVI = More likely to respond to fluid administration

The PVI is similar to the PPV and SVV as a predictor of fluid responsiveness

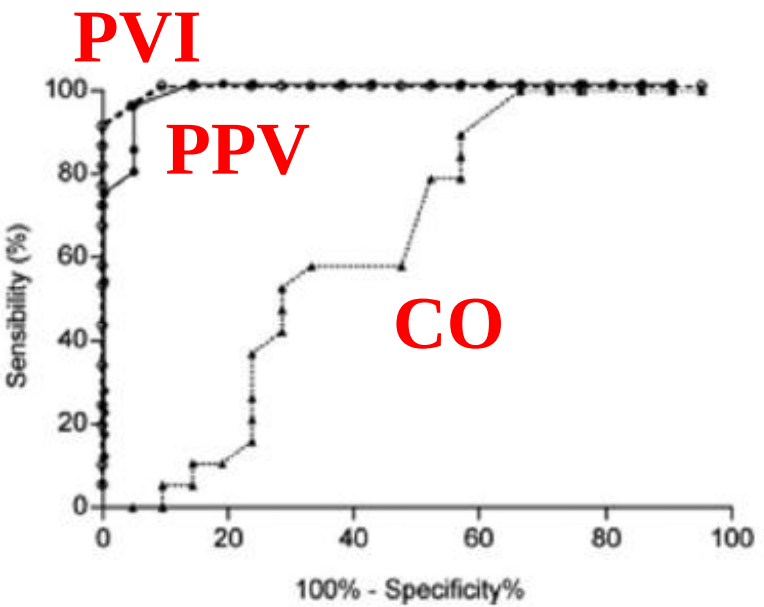


J Anesth (2012) 26:696–701

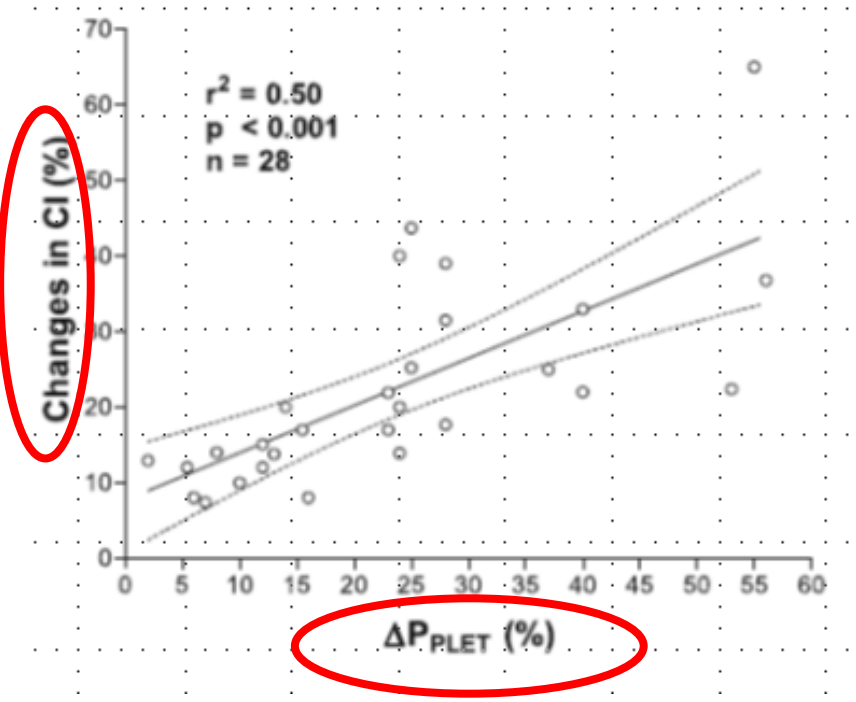


Intensive Care Med (2007) 33:993–999

(Crit Care Med 2011; 39:294–299)

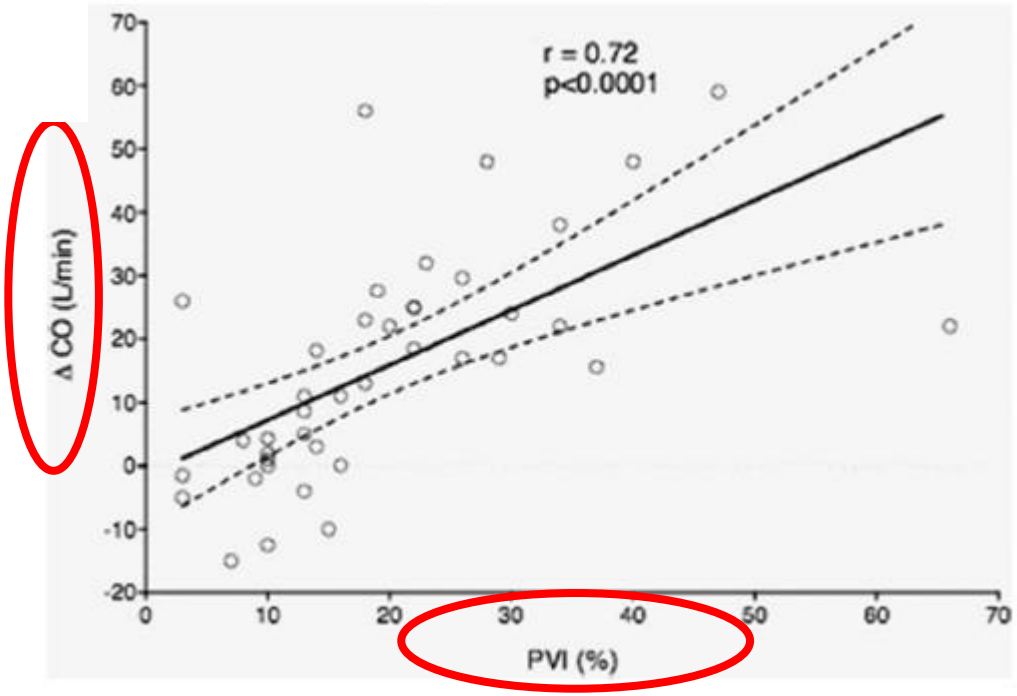


Intensive Care Med (2007) 33:993–999



There is a significant relationship between PVI before volume expansion and change in CI after volume expansion.

(Crit Care Med 2011; 39:294–299)



Hence if the PVI decreases significantly in response to volume expansion it may be a sign of a significant increase in CO.

The Ability of Pleth Variability Index to Predict the Hemodynamic Effects of Positive End-Expiratory Pressure in Mechanically Ventilated Patients Under General Anesthesia

Olivier Desebbe, MD,* Cécile Boucau, MD,* Fadi Farhat, MD, PhD,† Olivier Bastien, MD, PhD,* Jean-Jacques Lehot, MD, PhD,* and Maxime Cannesson, MD, PhD*

(Anesth Analg 2010;110:792–8)

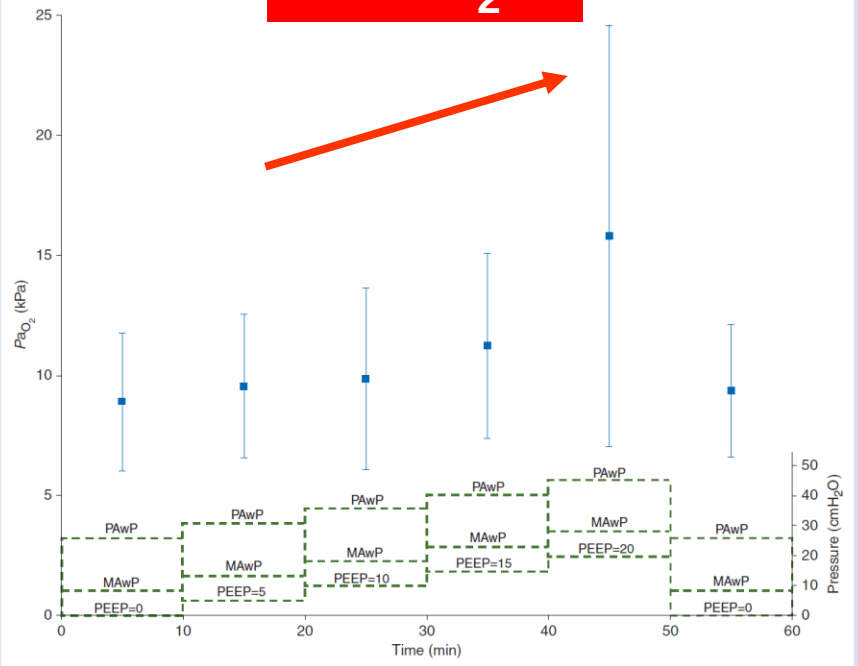
PVI may be useful in detecting, automatically and non-invasively, the hemodynamic effects of PEEP when VT is > 8 mL/kg in ventilated and sedated patients.

High PEEP in acute respiratory distress syndrome: quantitative evaluation between improved arterial oxygenation and decreased oxygen delivery

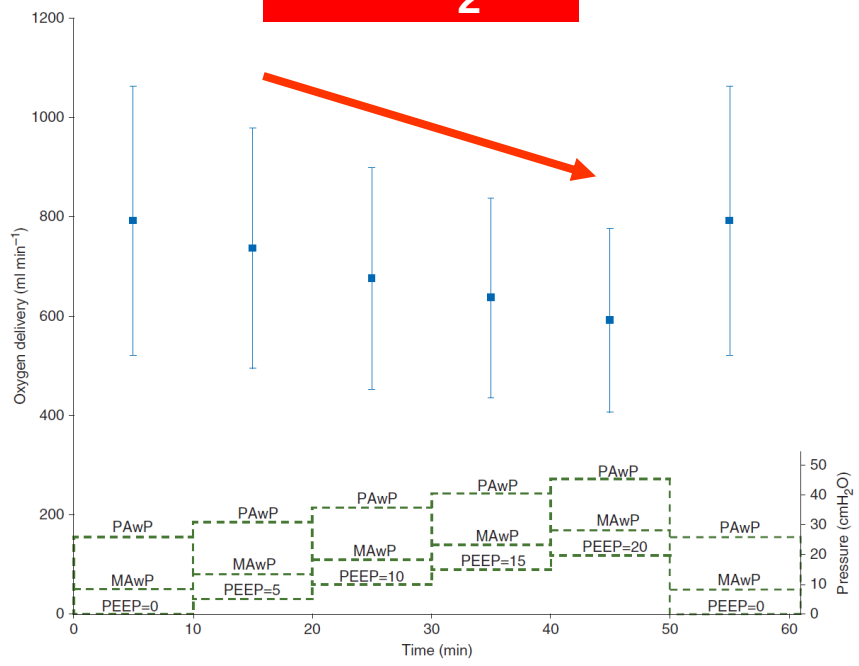
M. Chikhani[1,2,†], A. Das[3,†], M. Haque[1], W. Wang[3], D. G. Bates[3] and J. G. Hardman[1,2,*]

British Journal Of Anaesthesia, 117 (5): 650–8 (2016)

PaO_2



DO_2



Critical Care Medicine October 2016 • Volume 44 • Number 10

Fluid Responsiveness and the Six Guiding Principles of Fluid Resuscitation

Paul E. Marik, MD, FCCM

Dynamic Measures to Determine Volume Responsiveness: Logical, Biologically Plausible, and Unproven

Jonathan E. Sevransky, MD, MHS, FCCM

Cumulative Fluid Balance: The Dark Side of the Fluid*

Jan Benes, MD, PhD

Fluid resuscitation for acute kidney injury: an empty promise

Scott C. Watkins[a] *and Andrew D. Shaw*[b]

Curr Opin Crit Care 2016, 22:000–000

KEY POINTS

- Evidence is mounting that the practice of aggressive fluid therapy with the intent of improving end organ perfusion and function is misguided and in fact may lead to fluid overload and further end organ injury.
- After the initial acute phase of illness, additional fluids are unlikely to augment *CO* and tissue perfusion and may in fact contribute to worsening organ dysfunction.
- GDT or protocol-based fluid therapy offers no benefit over conventional fluid therapy that maintains organ perfusion and avoids fluid overload.
- The composition, quantity, and timing of fluid therapy should be personalized to each patient based on the patient's unique physiological response to fluids.

Intensive Care Med (2016) 42:1461–1463
DOI 10.1007/s00134-015-4172-8

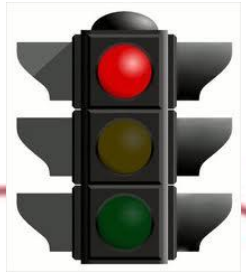
EDITORIAL

Jukka Takala

Volume responsive, but does the patient need volume?

Giving volume to fluid responders as long as they respond should not become the iatrogenic syndrome of the decade;

The major benefit provided by dynamic parameters is the identification of the “non-responders”



“Non-Responder”

The use of PVI-based protocols led to a significantly decreased intraoperative net fluid balance

Goal-Directed Fluid Management Based on the Pulse Oximeter–Derived Pleth Variability Index Reduces Lactate Levels and Improves Fluid Management

Patrice Forget, MD,* Fernande Lois, MD,* and Marc de Kock, MD, PhD*

(Anesth Analg 2010; 111:910–4)

Pleth variability index-directed fluid management in abdominal surgery under combined general and epidural anesthesia

Yinan Yu · Jing Dong · Zifeng Xu · Hao Shen · Jijian Zheng

J Clin Monit Comput
Published online: 21 February 2014

Standardization of Care: Impact of an Enhanced Recovery Protocol on Length of Stay, Complications, and Direct Costs after Colorectal Surgery

Robert H Thiele, MD, Kathleen M Rea, MSN, APRN, Florence E Turrentine, PhD, RN, Charles M Friel, MD, FACS, Taryn E Hassinger, MD, Bernadette J Goudreau, BS, Bindu A Umapathi, MD, Irving L Kron, MD, FACS, Robert G Sawyer, MD, FACS, Traci L Hedrick, MD, FACS, Timothy L McMurry, PhD

J Am Coll Surg 2015;220:430–443

Goal-Directed Fluid Management Based on the Pulse Oximeter–Derived Pleth Variability Index Reduces Lactate Levels and Improves Fluid Management

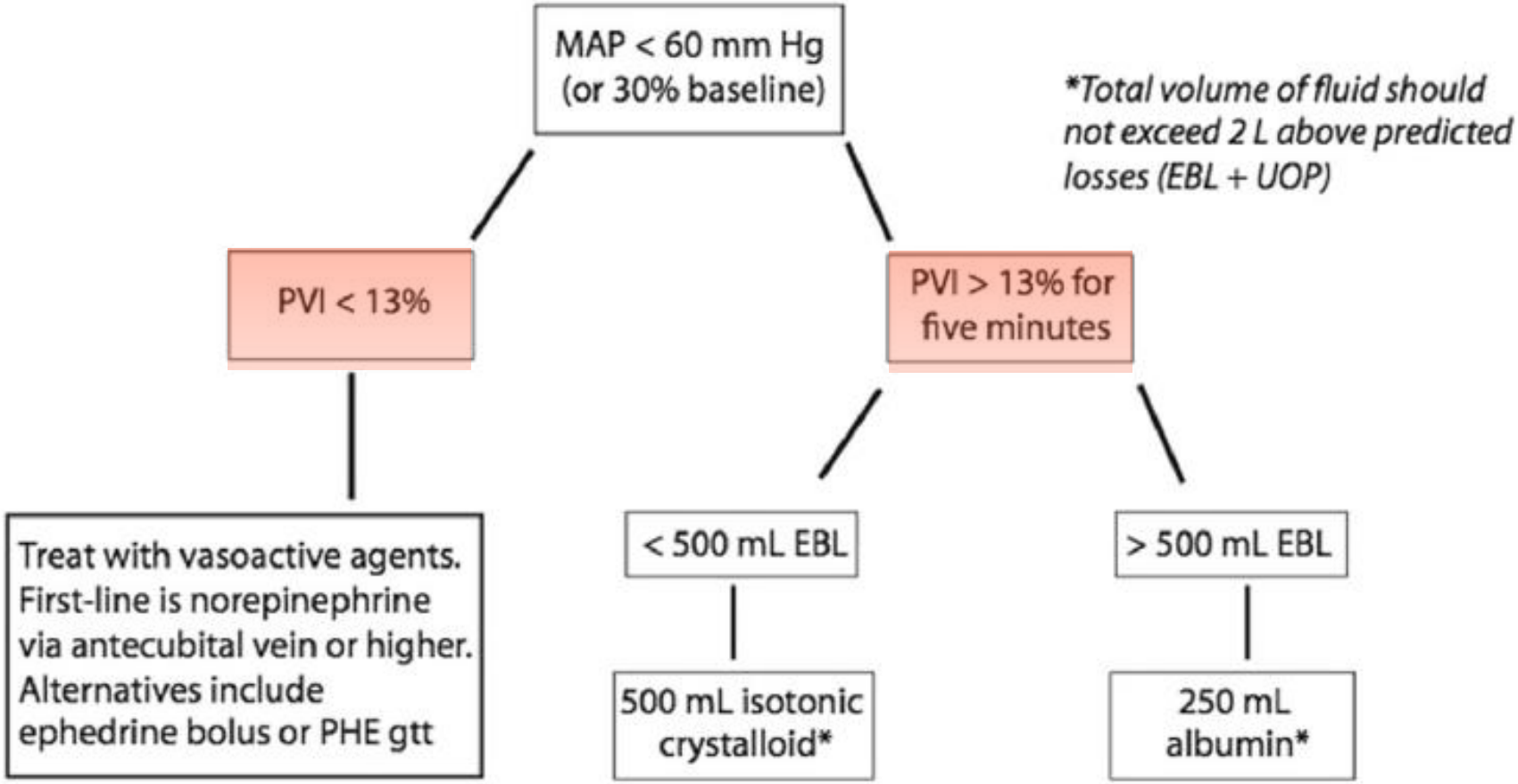
Patrice Forget, MD,* Fernande Lois, MD,* and Marc de Kock, MD, PhD*

(Anesth Analg 2010; 111:910–4)

Intraoperative crystalloids and total volume infused were significantly lower in the goal-directed PVI group.

	PVI group (*N* = 41)	Control group (*N* = 41)
Intraoperative fluids (mL)		
Crystalloids	1363	1815
Colloids	890	1003

PVI-based protocol decreased intra-operative net fluid balance from 2733 to 848 mL (p < 0.0001).



J Am Coll Surg 2015;220:430–443

Clinical review: Update on hemodynamic monitoring - a consensus of 16

Jean-Louis Vincent[1*], Andrew Rhodes[2], Azriel Perel[3], Greg S Martin[4], Giorgio Della Rocca[5], Benoit Vallet[6], Michael R Pinsky[7], Christoph K Hofer[8], Jean-Louis Teboul[9], Willem-Pieter de Boode[10], Sabino Scolletta[11], Antoine Vieillard-Baron[12], Daniel De Backer[1], Keith R Walley[13], Marco Maggiorini[14] and Mervyn Singer[15]

Critical Care 2011, 15:229

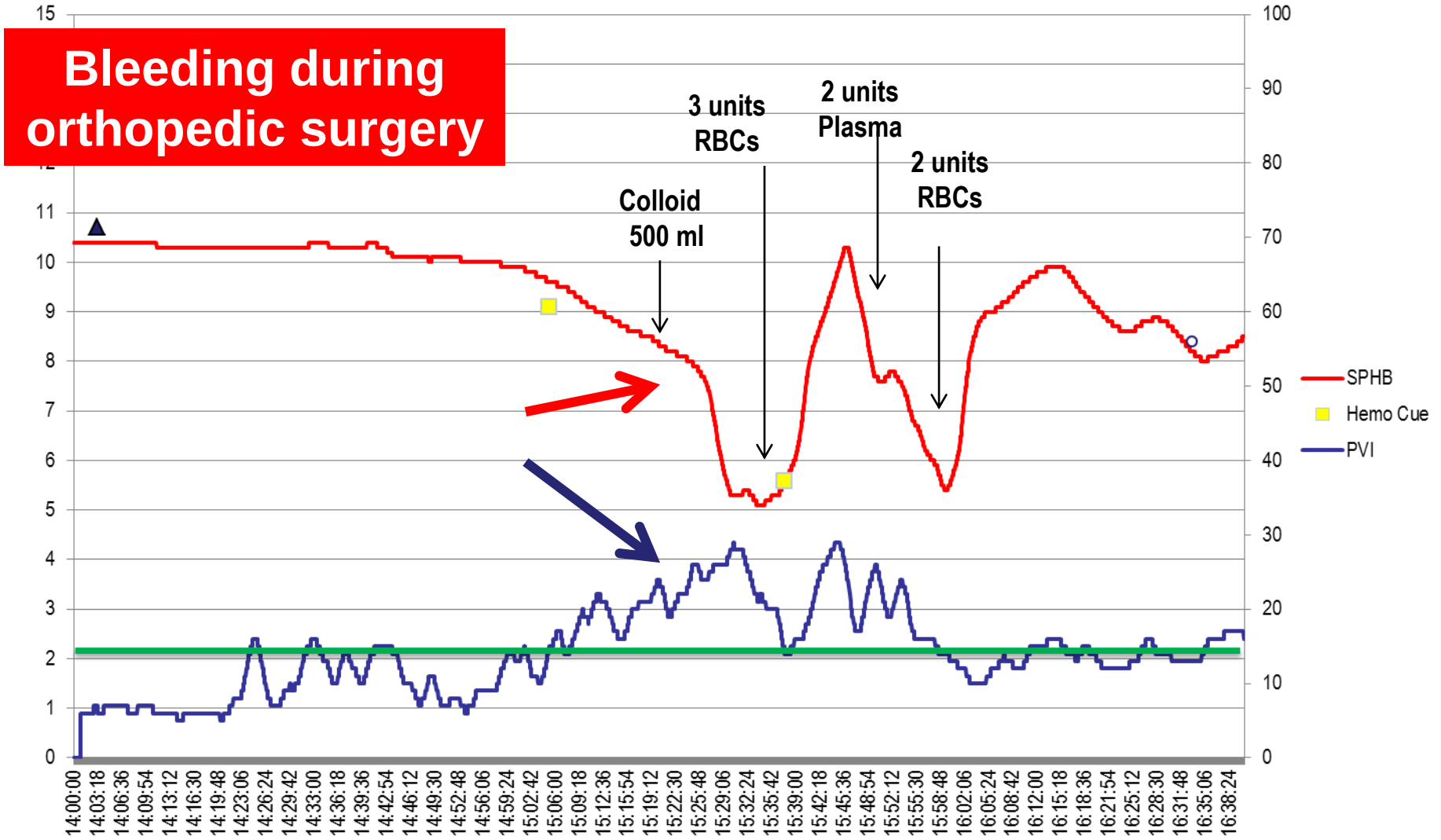
Perioperative cardiovascular monitoring of high-risk patients: a consensus of 12

Jean-Louis Vincent[1*], Paolo Pelosi[2], Rupert Pearse[3], Didier Payen[4], Azriel Perel[5], Andreas Hoeft[6], Stefano Romagnoli[7], V Marco Ranieri[8], Carole Ichai[9], Patrice Forget[10], Giorgio Della Rocca[11] and Andrew Rhodes[12]

Critical Care (2015) 19:224

"We need to combine and integrate parameters from various sources. Any variable on its own is just one piece of a larger puzzle."

The value of combined SpHb + PVI monitoring



A1103
October 22, 2016
10/22/2016 10:30:00 AM - 10/22/2016 12:00:00 PM
Room W474b

Impact of Continuous Perioperative SpHb Monitoring

Nathalie Nathan, M.D., et al, Chu Dupuytren, Limoges, France

- **SpHb and PVI data of 3540 patients were collected by the SafetyNet™ system in 2014.**
- **At a scale of a whole hospital with different clinical practices (and practitioners) and unselected patients, Integrating SpHb and PVI in a fluid administration algorithm allowed earlier transfusion and reduced 30 days mortality.**

$DO_2 = CO \times \{ Hgb \times 1.34 \times SaO_2 + (PaO_2 \times 0.0032)\}$

Conclusions

- Oxygen delivery is a useful concept, but its major components have to be individually managed.
- New technological developments in pulse oximetry allow us to monitor the components of DO_2 non-invasively, continuously and simultaneously.
- The correct way to manage these components is a matter of significant controversy since Oxygen, Blood and Fluids may be detrimental when given in excess.

BECOMING A PHYSICIAN

Tolerating Uncertainty — The Next Medical Revolution?

Arabella L. Simpkin, B.M., B.Ch., M.M.Sc, and Richard M. Schwartzstein, M.D.

N ENGL J MED 375;18 NEJM.ORG NOVEMBER 3, 2016

- **In medicine today, uncertainty is generally suppressed and ignored, consciously and subconsciously.**
- **Yet the reality is that doctors continually have to make decisions on the basis of imperfect data and limited knowledge, which leads to diagnostic uncertainty, coupled with the uncertainty that arises from unpredictable patient responses to treatment and from health care outcomes that are far from binary.**

Saugel *et al. Critical Care* _####################_
DOI 10.1186/s13054-016-1534-8

Critical Care

EDITORIAL Open Access

Hemodynamic monitoring in the era of evidence-based medicine

Bernd Saugel[1*], Manu L. N. G. Malbrain[2] and Azriel Perel[3]

Abstract

Hemodynamic instability frequently occurs in critically ill patients. Pathophysiological rationale suggests that hemodynamic monitoring (HM) may identify the causes of hemodynamic instability and therefore may allow

"Hemodynamic monitoring can be viewed as a mean to minimize the uncertainty that often surrounds the patient's hemodynamic status".

formal evidence that HM can improve patient outcome may be explained by both the shortcomings of the EBM methodology in the field of intensive care medicine and the shortcomings of HM itself.

$DO_2 = CO \times \{ Hgb \times 1.34 \times SaO_2 + (PaO_2 \times 0.0032)\}$

Oxygen

Hypoxia

Hyperoxia

SpO_2

ORI

SpHb

PVI

Blood

Fluids

Dziękuję bardzo!