MONITORING AND OPTIMIZATION OF TISSUE OXYGENATION IN CRITICALLY ILL PATIENTS

An Essay

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By
Reda Ramadan Abd Elbakey
M.B., B.Ch

Under Supervision of

Prof. Dr. Ahmed Mohammed Elsaid El-Henawy
Assistant Professor of Anesthesiology and Intensive Care
Faculty of Medicine, Ain Shams University

Dr. Mohammed Abd Elsalam El-Gendy
Lecturer of Anesthesiology and Intensive Care
Faculty of Medicine, Ain Shams University

Faculty of Medicine
Ain Shams University
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Reda Ramadan Abd Elbakey

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List of Abbreviations

Abb.	Mean
AABB	American Association of Blood Banks
ACS	Abdominal Compartment Syndrome
ACS	American College of Surgeons
ADH	Anti-diuretic hormone
ADP	Adenosine diphosphate
AKI	Acute kidney injury
ALBIOS	Albumin Italian Outcome Sepsis Study
ALI	Acute lung injury
AMP	Adenosine monophosphate
ANP	Atrial natriuretic peptide
ARDS	Acute Respiratory Distress Syndrome
ATP	Adenosine Triphosphate
AVP	Arginine Vasopressin
BGB	Blood Gas Barrier
BNP	Brain natriuretic peptide
BP	Blood pressure
BSA	Body Surface Area
BTS	British Thoracic Society
cAMP	cyclic adenosine monophosphate
CaO2	arterial blood O2 content
cGMP	Cyclic guanosine monophosphate
CI	Cardiac index
CO	Cardiac Output
CO2	Carbon dioxide
COHb	Carboxyhemoglobin
COPD	Chronic obstructive pulmonary disease
CRT	Capillary Refill Time
CVC	Central venous catheter
CVP	Central Venous Pressure
DBP	Diastolic Blood Pressure
DO2	Oxygen Delivery
DO2crit	Critical DO2

Abb.	Mean
dPCO2	The arterio-venous carbon dioxide tension difference
DPG	Diphosphoglycerate
dVR	Pressure gradient of venous return
ECOM	Endotracheal cardiac output monitor
EDM	Esophageal Doppler monitor
EF	Ejection fraction
EGDT	Early goal directed therapy
eNOS	Endothelial NO synthase
EPSS	point septal separation
EtCO2	The end-tidal pressure of expired CO2
EVLW	Extravascular lung water
F	Fraction of the gas
FAD	Flavin adenine dinucleotide
FiO2	Fraction of Inspired Oxygen
FTc	Flow time corrected for heart rate
g/dL	Grams per deciliter
GDT	Goal directed therapy
GEDI	Global end-diastolic index
GEDV	Global end diastolic volume
HALI	Hyperoxic acute lung injury
Hb	Hemoglobin
HcueArt	Arterial blood Hb measurement by CO-Oximetry
HcueCap	Capillary blood Hb measurement by CO-Oximetry
HFOV	High frequency oscillatory ventilation
HIF	Hypoxia-inducible transcription factor
HR	Heart Rate
ICU	Intensive care unit
ITBV	Intrathoracic blood volume
IVC	Inferior vena cava
kPa	kilopascals
LiDCO	Lithium dilution cardiac output monitor
LVEDA	LV end-diastolic area

Abb.	Mean
LVEDA	LV end-diastolic area
LVSWI	left ventricular stroke work index
MAP	Mean arterial blood pressure
MetHb	Methemoglobin
MI	Myocardial infarction
MODS	Multi-organ Dysfunction Syndrome
mPAP	Mean pulmonary artery pressure
NAD	Nicotinamide Adenine Dinucleotide
NE	Norepinephrine
NIRS	Near-infrared spectroscopy
NO	Nitric oxide
NPPV	Noninvasive positive pressure ventilation
O2	oxygen
O2 ER	oxygen extraction ratio
OPS	Orthogonal polarization spectral
P	Partial Pressure
P (A-a) O2	Alveolar-arterial oxygen gradient
P50	PO2 at which hemoglobin is half saturated
PAC	Pulmonary Artery Catheter
PACO2	Alveolar CO2 Partial pressure
PaCO2	Partial pressure of CO2 in arterial blood
PAO2	Alveolar Oxygen Tension
PaO2	Partial pressure of oxygen in arterial blood
PaO2	Arterial oxygen partial pressure
PAOP	Pulmonary artery occlusion pressure
PAP	Pulmonary artery pressure
PATM	Total Atmosphere Pressure
PbtO2	Intracellular PO2 values in brain tissue
PCAO	Precise control of arterial oxygenation
PCO2	Partial Pressure of CO2
PCR	Polymerase chain reaction
PCWP	Pulmonary capillary wedge pressure
PEEP	Positive End Expiratory Pressure
PgCO2	gastric intra-mucosal carbon dioxide pressure
PH2O	Partial Pressure of water

Abb.	Mean
Pi	Inorganic phosphate
PI	Perfusion index
PiCCO	Pulse Index Contour Cardiac Output
PLR	Passive leg raise
Pmsf	Mean systemic filling pressure
PO2	partial pressure of oxygen
POC	Point-of-care
PPG	Photo-plethysmograph
PPV	Pulse pressure variation
PRAM	Pressure recording analytic method
PslCO2	Sublingual partial pressure of CO2
PvCo2	Partial pressure of CO2 in mixed venous blood
PvO2	Partial pressure of oxygen in mixed venous blood
PVRI	Pulmonary vascular resistance index
RAP	Right atrial pressure
RBC	Red Blood Cell
RBCT	Red blood cell transfusions
ROS	Reactive Oxygen Species
RR	Respiratory Exchange Ratio
RUSH	Rapid Ultrasound in Shock
RVR	Resistance to venous return
RVSWI	right ventricular stroke work index
SAFE	Saline vs Albumin Fluid Evaluation
SaO2	Arterial haemoglobin oxygen saturation
SBP	Systolic blood pressure
ScvO2	Central venous oxygen saturation
SDF	Sidestream dark-field
SI	system The International System of Units
SIRS	Systemic inflammatory response syndrome
SO2	Hemoglobin Saturation
SpHb	Hb measurement with Pulse CO-Oximetry
SpO2	Pulse oximetry SO2
SPV	systolic pressure variation
StO2	Tissue hemoglobin oxygen saturation

Abb.	Mean
SV	stroke volume
SVI	Stroke volume index
SvO2	Mixed venous oxygen saturation
SVR	Systemic Vascular Resistance
SVRI	Systemic Vascular Resistance Index
SVT	Supra-ventricular tachycardia
SVV	Stroke volume variation
TACO	Transfusion-associated circulatory overload
tCO2	Tissue CO2
TEE	Transesophgeal echocardiography
TNF	Tumor necrosis factor
tPO2	tissue oxygen tension
TPR	Total peripheral resistance
TRACS	Transfusion Requirements after Cardiac Surgery
TRALI	Transfusion-related acute lung injury
TRICC	Transfusion Requirements In Critical Care
TRIM	Transfusion-related immunomodulation
UOP	Urine output
V˙ A/Q˙	Ventilation-Perfusion ratio
V˙A	Alveolar ventilation
V˙CO2	Volume of CO2 in Expired gas per minute
VILI	Ventilator-associated lung injury
VIP	Vasoactive intestinal polypeptide
VO2	Oxygen consumption
VR	Venous Return
Vs	stressed volume

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Introduction

Despite improvements in resuscitation and supportive care, progressive organ dysfunction occurs in a large proportion of patients with acute, life threatening illness. It has been proposed that the multi-organ dysfunction syndrome (MODS) of the critically ill is a consequence of tissue dysoxia attributable to inadequate oxygen delivery, often exacerbated by a microcirculatory injury and increased tissue metabolic demands (distributive hypoxia) ***(Ince & Sinaasappel, 1999).***

This may be further compounded by cytopathic hypoxia attributable to mitochondrial dysfunction ***(Fink, 2002).***

So, Maintenance of tissue perfusion is critical, because global tissue hypoxia is a key step toward multiple organ failure ***(Rivers et al., 2001).***

Emerging data suggest that early aggressive resuscitation of critically ill patients may limit and/or reverse tissue dysoxia and progression to organ failure and improve outcome. Hemodynamic monitoring is essential to resuscitation efforts based on attaining specified targets ***(Dellinger et al., 2008).***

When resuscitation goals for CVP and MAP have been achieved, additional measurements of venous oxygenation and lactate may reveal inadequate tissue oxygenation indicating that additional resuscitation efforts are required ***(Rady et al., 1996)***.

Both invasive and noninvasive monitoring tools have been used in critically ill patients in an attempt to optimize resuscitation. Most of these technologies focus on ‘‘upstream’’ markers of resuscitation and provide information on cardiac output and fluid responsiveness ***(Marik & Baram, 2007).***

In this respect, the pulmonary artery catheter (PAC) was regarded as the gold standard, as it provides an accurate estimate of the cardiac output and can be used to determine fluid Responsiveness ***(Ganz et al., 1971).***

However, the role of invasive hemodynamic monitoring in critically ill patients is controversial as the PAC has not been proven to improve patient outcome. Furthermore, the PAC does not provide enough information about the adequacy of tissue oxygenation, i.e., ‘‘downstream’’ markers ***(Marik & Baram, 2007).***

Alternatively, it has been argued that measurements of oxygenation at the level of specific tissues offer more sensitive information ***(Ward et al., 2001).***

Therefore, measurements of tissue perfusion and oxygenation are necessary to determine whether the ultimate goal of resuscitation, and adequate oxygen supply to tissues, has been attained ***(Ahrens, 2006).***

Aim of the Work

The aim of this study is to highlight currently available devices for hemodynamic monitoring as well as techniques for assessing the adequacy of organ perfusion, tissue oxygenation and available modalities that can be used to improve tissue oxygenation.