

# **MONITORING AND OPTIMIZATION OF TISSUE OXYGENATION IN CRITICALLY ILL PATIENTS**

*An Essay*

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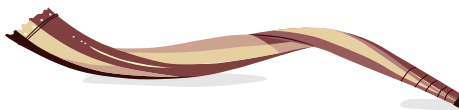


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## ***List of Abbreviations***

<b>Abb.</b>	<b>Mean</b>
<b>AABB</b>	American Association of Blood Banks
<b>ACS</b>	Abdominal Compartment Syndrome
<b>ACS</b>	American College of Surgeons
<b>ADH</b>	Anti-diuretic hormone
<b>ADP</b>	Adenosine diphosphate
<b>AKI</b>	Acute kidney injury
<b>ALBIOS</b>	Albumin Italian Outcome Sepsis Study
<b>ALI</b>	Acute lung injury
<b>AMP</b>	Adenosine monophosphate
<b>ANP</b>	Atrial natriuretic peptide
<b>ARDS</b>	Acute Respiratory Distress Syndrome
<b>ATP</b>	Adenosine Triphosphate
<b>AVP</b>	Arginine Vasopressin
<b>BGB</b>	Blood Gas Barrier
<b>BNP</b>	Brain natriuretic peptide
<b>BP</b>	Blood pressure
<b>BSA</b>	Body Surface Area
<b>BTS</b>	British Thoracic Society
<b>cAMP</b>	cyclic adenosine monophosphate
<b>CaO<sub>2</sub></b>	arterial blood O <sub>2</sub> content
<b>cGMP</b>	Cyclic guanosine monophosphate
<b>CI</b>	Cardiac index
<b>CO</b>	Cardiac Output
<b>CO<sub>2</sub></b>	Carbon dioxide
<b>COHb</b>	Carboxyhemoglobin
<b>COPD</b>	Chronic obstructive pulmonary disease
<b>CRT</b>	Capillary Refill Time
<b>CVC</b>	Central venous catheter
<b>CVP</b>	Central Venous Pressure
<b>DBP</b>	Diastolic Blood Pressure
<b>DO<sub>2</sub></b>	Oxygen Delivery
<b>DO<sub>2</sub>crit</b>	Critical DO <sub>2</sub>

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

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

<b>Abb.</b>	<b>Mean</b>
<b>Pi</b>	Inorganic phosphate
<b>PI</b>	Perfusion index
<b>PiCCO</b>	Pulse Index Contour Cardiac Output
<b>PLR</b>	Passive leg raise
<b>Pmsf</b>	Mean systemic filling pressure
<b>PO2</b>	partial pressure of oxygen
<b>POC</b>	Point-of-care
<b>PPG</b>	Photo-plethysmograph
<b>PPV</b>	Pulse pressure variation
<b>PRAM</b>	Pressure recording analytic method
<b>PslCO2</b>	Sublingual partial pressure of CO2
<b>PvCO2</b>	Partial pressure of CO2 in mixed venous blood
<b>PvO2</b>	Partial pressure of oxygen in mixed venous blood
<b>PVRI</b>	Pulmonary vascular resistance index
<b>RAP</b>	Right atrial pressure
<b>RBC</b>	Red Blood Cell
<b>RBCT</b>	Red blood cell transfusions
<b>ROS</b>	Reactive Oxygen Species
<b>RR</b>	Respiratory Exchange Ratio
<b>RUSH</b>	Rapid Ultrasound in Shock
<b>RVR</b>	Resistance to venous return
<b>RVSWI</b>	right ventricular stroke work index
<b>SAFE</b>	Saline vs Albumin Fluid Evaluation
<b>SaO2</b>	Arterial haemoglobin oxygen saturation
<b>SBP</b>	Systolic blood pressure
<b>ScvO2</b>	Central venous oxygen saturation
<b>SDF</b>	Sidestream dark-field
<b>SI</b>	system The International System of Units
<b>SIRS</b>	Systemic inflammatory response syndrome
<b>S02</b>	Hemoglobin Saturation
<b>SpHb</b>	Hb measurement with Pulse CO-Oximetry
<b>SpO2</b>	Pulse oximetry S02
<b>SPV</b>	systolic pressure variation
<b>StO2</b>	Tissue hemoglobin oxygen saturation

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