## History

<table>
<thead>
<tr>
<th>Name</th>
<th>Definition</th>
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<tbody>
<tr>
<td>LeDran</td>
<td>‘Choc’ or Severe impact or jolt</td>
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<td>Guthrie</td>
<td>Physiologic response to injury</td>
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<td>Warren</td>
<td>‘Momentary pause in the act of death’</td>
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<td>Crile</td>
<td>Experimental surgical shock in dogs</td>
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<td>Cannon</td>
<td>‘Traumatic Shock’</td>
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<td>Blalock</td>
<td>non hemorrhagic ‘wound shock’</td>
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Shock: An Overview

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Defining Shock 1

Multifactorial syndrome resulting in inadequate tissue perfusion and cellular oxygenation affecting multiple organ systems
Defining Shock 2

Life-threatening, generalized mal-distribution of blood flow which results in failure to deliver adequate amounts of oxygen, leading to tissue dysoxia

International Consensus Conference, Antonelli et al, ICM 2007
Oxygen Delivery & Perfusion

- Cardiovascular performance
- Distribution cardiac output
- Micro-vascular function
- Oxygen unloading & diffusion
- Cellular function
UNDERSTANDING CONTINUOUS MIXED VENOUS OXYGEN SATURATION ($\text{S}_\text{vO}_2$) MONITORING WITH THE SWAN-GANZ OXIMETRY TD SYSTEM
Oxygen Delivery Content, DO$_2$, CaO$_2$

- $DO_2 = CaO_2 \times CO$
- $CO = HR \times SV$
- $CaO_2 = Hgb \times 1.34 \times SaO_2 + PaO_2 \times 0.003$

- $SaO_2$ expressed as fraction of 1.0 (98% = 0.98)
- Hemoglobin g/deciliter
- $PaO_2$ mmHg
- Oxygen solubility coefficient mL $O_2$/dl/mmHg
Normal: \( \text{SaO}_2, \text{Hgb}, \text{CaO}_2, \text{CO}, \text{DO}_2, \text{VO}_2 \)

- 100\%, Hgb 15, 100 mm Hg, HR 70, SV 70 ml
- \( \text{CaO}_2 = 20 \text{ ml/dl} \ (1.0 \times 15 \times 1.34 + 0.003 \times 100) \)
- \( \text{CO} = 5 \text{ liters/min} \ (70 \times 70) \)
- \( \text{DO}_2 = 1000 \text{ ml/min} \)
- \( \text{VO}_2 = 250 \text{ mls/minute} \)
Normal Mixed Venous SvO\(_2\), PvO\(_2\), CvO\(_2\)

- SvO\(_2\) = 75%
- PvO\(_2\) = 40 mmHg
- CvO\(_2\) = 15 ml/Dl(1.34 x 15 x 0.75 + 0.003 x 40)
Utility of CvO₂ & CaO₂

- Oxygen Extraction Ratio
  - \((\text{CaO}_2 - \text{CvO}_2)/\text{CaO}_2\)
  - Normal 0.25
  - Maximal normal organ OER coronary circulation

- \(\text{VO}_2 = Q \times (\text{CaO}_2 - \text{CvO}_2)\)
  - Cardiac Output Q by Fick Principle
  - \(Q = \text{VO}_2 / (\text{CaO}_2 - \text{CvO}_2)\)
High $SvO_2$

- Delivery increase
  - $FiO_2$
  - Hyperoxia

- Demand decrease
  - Hypothermia
  - Anesthesia
  - NMBA
  - Sepsis
Low $\text{SvO}_2$

- Demand increase
  - Hyperthermia
  - Shivering
  - Seizures
  - Pain
- Delivery decrease
  - Anemia
  - Hypoxia
  - Hypovolemia
  - Arrhythmias
Markers of Inadequate Perfusion

- Decreased ScvO$_2$, SvO$_2$
- Increased blood lactate
- Increased base deficit
- Perfusion-related low pH
Prognostic Significance of Blood Lactate and Lactate Clearance in Trauma Patients

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ABSTRACT

Background: Lactate has been shown to be a prognostic biomarker in trauma. Although lactate clearance has already been proposed as an intermediate endpoint in randomized trials, its precise role in trauma patients remains to be determined.

Methods: Blood lactate levels and lactate clearance (LC) were calculated at admission and 2 and 4 h later in trauma patients. The association of initial blood lactate level and lactate clearance with mortality was tested using receiver-operating characteristics curve, logistic regression using triage scores, Trauma Related Injury Severity Score as a reference standard, and reclassification method.

Results: The authors evaluated 586 trauma patients (mean age 38 ± 16 yr, 84% blunt and 16% penetrating, mortality 13%). Blood lactate levels at admission were elevated in 327 (56%) patients. The lactate clearance should be calculated within the first 2 h after admission as LC_{0–2h} was correlated with LC_{0–4h} ($R^2 = 0.55$, $P < 0.001$) but not with LC_{2–4h} ($R^2 = 0.04$, not significant). The lactate clearance provides additional predictive information to initial blood lactate levels and triage scores and the reference score. This additional information may be summarized using a categorical approach (i.e., less than or equal to 20 %/h) in contrast to initial blood lactate. The results were comparable in patients with high (5 mmol/L or more) initial blood lactate.

Conclusions: Early (0–2 h) lactate clearance is an important and independent prognostic variable that should probably be incorporated in future decision schemes for the resuscitation of trauma patients.
Arterial Base Deficit in Trauma

• Persistently high arterial base deficit increased risk of
  – Multiple organ failure
  – Mortality

• Serial monitoring of base deficit
  – Assess adequacy of oxygen transport & resuscitation

Edward H Kincaid, MD, J Am Coll Surg 1988
Classification Shock

- Hypovolemic
- Cardiogenic
- Obstructive
- Distributive

Chapter 22, Critical Care Medicine
Principles Diagnosis and Management in the Adult
3rd Edition, JE Parrillo, RP Dellinger
Non-Hemorrhagic Hypovolemia

• GI
  – Vomiting
  – Diarrhea
  – Obstruction
  – Pancreatitis

• Burns

• Neglect

• Environmental
Hemorrhagic Hypovolemicia

- GI bleed
  - Upper
  - Lower
- Trauma
  - External
  - Internal
- Retroperitoneal
- AAA rupture
- OB (Ectopic pregnancy, Post Partum)
Cardiovascular performance

• Myopathic
  – Ischemia, Infarction, Stunning
  – Inflammation
  – Contusion/trauma

• Mechanical
  – Valve failure regurgitant, stenotic
  – Hypertrophic cardiomyopathy, VSD

• Arrhythmic
  – Bradycardia AV block, vagal,
  – Tachycardia SVT, VT
Figure 1. Current concept of CS pathophysiology.

Extra-cardiac Obstructive

• Diastolic performance
  – Tension pneumothorax
  – Tamponade
  – Constrictive pericarditis
  – Venous obstruction
    • Intra-thoracic / caval tumors
    • High PEEP / mechanical ventilation

• Systolic performance
  – Pulmonary embolus
  – Acute pulmonary HTN
  – Aortic dissection
Early Goal Directed Therapy

• Significant benefits with respect to outcome in patients with severe sepsis and septic shock
• RCT, blinded, 263 enrolled
• Mortality EGDT 30% vs. ‘Standard’ 46%
• Improved ScvO$_2$, lactate, BD, pH, APACHE II

• E Rivers, NEJM 2001
Systemic Inflammatory Response Syndrome (SIRS)

- 1992 ACCP/SCCM Consensus Conference
- Temperature < 36 > 38 Centigrade
- Heart rate > 90 bpm
- Respirations >20 /min or PaCO$_2$ < 32 mmHg
- WBC < 4 or >12k or >10% bands
- SIRS can be diagnosed when two or more of these criteria are present
Sepsis, Severe Sepsis, Septic Shock

- Sepsis: SIRS + suspected/proven infection
- Severe Sepsis: sepsis + organ dysfunction
- Septic Shock: refractory hypotension
- Mortality
  - 10% Sepsis
  - 20% Severe sepsis
  - 40% Septic shock

The definition of septic shock: implications for treatment, PE Marik, Crit Care Resusc 2007

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Objective: To provide an update to the "Surviving Sepsis Campaign Guidelines for Management of Severe Sepsis and Septic Shock," last published in 2008.

Design: A consensus committee of 68 international experts representing 30 international organizations was convened. Nominal groups were assembled at key international meetings (for those committee members attending the conference). A formal conflict of interest policy was developed at the outset of the process and enforced throughout. The entire guidelines process was conducted independent of any industry funding. A stand-alone meeting was held for all subgroup heads, co- and sub-chairs, and selected individuals. Teleconferences and electronic-based discussion among subgroups and among the entire committee served as an integral part of the development.

Methods: The authors were advised to follow the principles of the Grading of Recommendations Assessment, Development and Evaluation (GRADE) system to guide assessment of quality of evidence from high (A) to very low (D) and to determine the strength of recommendations as strong (1) or weak (2). The potential drawbacks of making strong recommendations in the presence of low-quality evidence were emphasized. Some recommendations were ungraded (U). Recommendations were classified into three groups: 1) those directly targeting severe sepsis; 2) those targeting general care of the critically ill patient and considered high priority in severe sepsis; and 3) pediatric considerations.

Results: Key recommendations and suggestions, listed by category, include: early quantitative resuscitation of the septic patient during the first 6 hrs after recognition (1C); blood cultures

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Protocols & Quantitative Resuscitation

• Do not delay Rx sepsis-induced hypotension

• Goals
  – CVP 8-12 mmHg
  – MAP > 65 mmHg
  – Urine > 0.5 ml/kg/hour
  – ScvO₂ > 70% or SvO₂ > 65%

• Target to normalization lactate
Must Complete within 3 Hours

• Measure lactate level
• Obtain blood cultures prior to antibiotics
• Administer broad spectrum antibiotics
• Administer 30 mL/kg crystalloid for hypotension or lactate 4mmol/L
Fluid Therapy of Severe Sepsis

- Crystalloids initial choice
- Against the use of hydroxyethyl
- Albumin if requiring substantial amounts crystalloids
- Fluid challenge as long as hemodynamics improve
  - Dynamic
    - change in pulse pressure
    - stroke volume variation
  - Static
    - arterial pressure
    - heart rate
SOAP II Trial

- Sepsis Occurrence in Acutely Ill Patients II
- 1679 patients with shock
- Mean arterial pressure of $\geq 65$ mmHg
- Norepinephrine vs. Dopamine
- DA significantly more cardiac arrhythmias
- No other differences
Vasopressors 1

- Norepinephrine (NE) first choice
- Epinephrine in addition to, or NE replacement
- Vasopressin can be added to NE
  - not recommended single initial vasopressor
  - doses > 0.04 units/minute for salvage
Vasopressors 2

- Dopamine replace NE for bradycardia or low risk for tachyarrhythmia
- Phenylephrine not recommended except
  - NE is associated with serious arrhythmias
  - High CO but MAP persistently low
  - Failure of inotrope/vasopressor drugs/low dose vasopressin
- Low-dose DA should not be used for renal protection
- Arterial catheter placed as soon as practical
Vasopressors: Cochrane Review 2011

• RCT 23
• > 3000 patients
• 6 vasopressors alone/combination
• Most data are available for norepinephrine
• Dopamine seems to increase the risk for heart arrhythmias

C Havel, Cochrane Review
Vasopressin

- Decreased levels have been noted in septic shock
- Norepinephrine vs. Vasopressin
- No mortality difference

- possible synergistic mortality benefit of vasopressin and corticosteroids
Inotropic Therapy (SSC)

• Dobutamine infusion up to 20 mcg/kg/min
  – myocardial dysfunction as suggested by elevated cardiac filling pressures & low cardiac output
  – ongoing signs of hypo perfusion, despite achieving adequate intravascular volume & adequate MAP

• Not using a strategy to increase cardiac index to predetermined supra-normal levels
Blood Product Administration (SSC)

• Target 7-9 g/dL
• Extenuating circumstances:
  – myocardial ischemia
  – ischemic heart disease
  – severe hypoxemia
  – acute hemorrhage
Anaphylaxis

- IgE release Histamine, serotonin, ECF
- Hypovolemia & myocardial depression
- Urticaria, Laryngeal/angioedema, Bronchospasm

- Causes
  - Antibiotics, Tetanus, Vaccine, Transfusion
  - Iodine, hydroxyethyl starch
  - NMBA, anesthetics
Neurogenic

- Occurs after acute spinal cord injury
- Sympathetic outflow is disrupted leaving unopposed vagal tone
- Results in hypotension and bradycardia
- Spinal shock - temporary loss of spinal reflex activity below a total or near total spinal cord injury (not the same as neurogenic shock, the terms are not interchangeable)
Spinal shock

• Temporary loss of spinal reflex activity below a total or near total spinal cord injury
• Not neurogenic shock
• Terms are not interchangeable
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