Billings Clinic

Critical Care

Health Care, Education and Research

HPI and PE

74 yo male confused
SBP 90/20 MAP50, P 122, RR 34
Ox1 w/o nuchal rigidity
S1S2 wo m
RLL reduced breath sounds
Skin warm dry

Laboratory

» WBC 15,600 Hgb 8.4 HCt 23%, Plts 95000, Bands 40%
» Na 134 K 4.5 Cl 104 CO2 12 BUN 30 Cr 1.4
» pH 7.24 pCO2 40 PaO2 66 Lactate 4.7
» BC pending
» Uagn Positive for Pneumococcus

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Is shock present?

a. Yes
b. No

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Shock

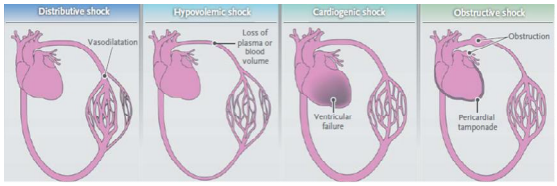
- Hypotension
  - SBP<90
  - MAP<65
- Clinical Evidence of Organ Hypoperfusion
  - Reduced UO (< 0.5 cc/kg/hr)
  - Altered Mentation
  - Skin (dry, warm, mottled)
  - Elevated Lactate

Types of Shock

BP = CO x SVR

- Cardiac
- Hypovolemic
- Obstructive
- Distributive

Types of Shock



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- How would you treat the shock?
- What are your priorities?

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Why do patients with Shock Die Acutely?

a. Cardiac Arrest from pump failure
b. Respiratory Failure from muscle fatigue
c. Cardiac Arrest from arrythmia
d. Respiratory Failure from pulmonary edema

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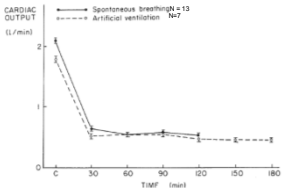
Dogs with Cardiogenic Shock Died of Respiratory Failure When Spontaneously Breathing



Aubier et al JAP 1981

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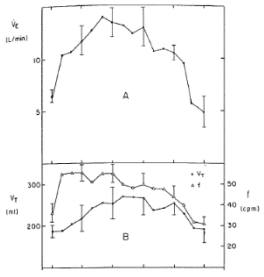
Cardiogenic Shock Resulted in Reduced Ve and Vt despite No Change in Pulmonary Compliance or Resistance



Aubier et al JAP 1981

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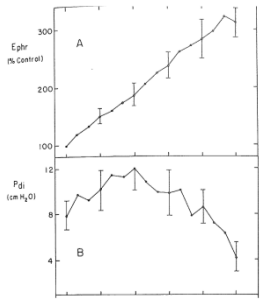
Respiratory Failure Occurred as a Result of Muscle Fatigue



Aubier et al JAP 1981

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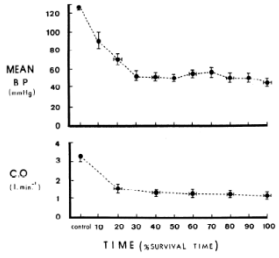
Endotoxin Injected Dogs Developed Hypotension



N= 10

Hussain et al JAP 1985

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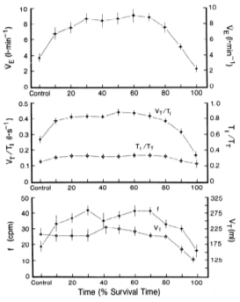
Endotoxin Injected Dogs Developed Respiratory Failure and Died of Respiratory Failure Prior to Cardiac Death



N = 10

No change in compliance or resistance, PaO2

Hussain et al JAP 1985

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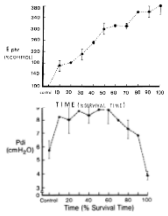
Respiratory Failure Developed as a Result of Respiratory Muscle Fatigue



N= 10

Hussain et al JAP 1985

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Why do patients with Shock Die Acutely?

a. Cardiac Arrest from pump failure

b. Respiratory Failure from muscle fatigue

c. Cardiac Arrest from arrythmia

d. Respiratory arrest from pulmonary edema

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Oxygenation/Ventilation

- Oxygen
  - Nasal Cannula, Face Mask
  - High Flow Humidified Oxygen
- Mechanical Ventilation
  - Non Invasive Ventilation (NIV)
  - Invasive Ventilation
    - Reduce Oxygen cost of breathing
    - Hemodynamic support

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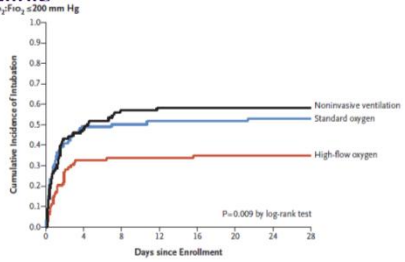
High Flow Oxygen Reduced Intubation Rate
In Patients with PaO2:FiO2 < 200



No. at Risk

High-flow oxygen	83	55	54	54	53	53	53	53
Standard oxygen	74	37	35	34	34	34	33	33
Noninvasive ventilation	81	41	34	32	32	32	32	32

Frat et al NEJM 2015

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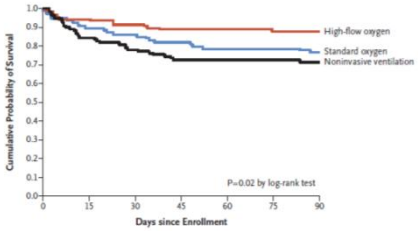
High Flow Oxygen Improved 90 Day Mortality in
Patients with Hypoxemic Respiratory Failure
PaO2:FiO2 < 300 w/o Change in Intubation Rate



No. at Risk

High-flow oxygen	106	100	97	94	94	93	93
Standard oxygen	94	84	81	77	74	73	72
Noninvasive ventilation	110	93	86	80	79	78	77

Frat et al NEJM 2015

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Would you Use High Flow Nasal Cannula or NIV to support the patient?

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Exclusion Criteria for NIV and High Flow Oxygen

Reduced LOC
Hemodynamic Instability

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Hospital Course

Patient was intubated with rapid sequence Fentanyl, Etomidate and Versed

SBP80/40 MAP 50 P 130 RR 18 T 101

Antibiotics Rocephin and Azithromycin started

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How would you improve hemodynamics?

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BP = CO x SVR

HR SV

Pre-Load Contractility Obstruction

SIRS
Anaphylaxis
Spinal Cord Dx
Liver Dx
Thyrotoxicosis
BeriBeri
Anemia
AV malformation
Pagets
Vasodilators

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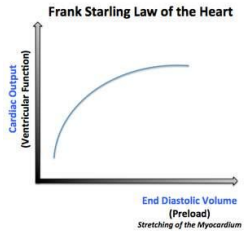
Preload v SV



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How would you increase **LV Preload** in this patient?

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Volume Resuscitation

- Type of Fluid
- Rate of Fluid Administration
- End Points

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What Fluid would you use?

A. Colloid
B. Crystalloid
C. Blood

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Fluid Types

- Colloid
  - Albumin
    - Equivalent mortality to saline in SAFE trial
    - 1.3:1
    - Increased mortality in CHI
    - Improved Renal Function in SBP Salerno et al Gastroenterol Hepato Clinics 2011:9:260
  - Hetastarch
    - Increased Tissue Half life in Skin, Kidney and Liver
    - 1.3:1
    - Increased Renal Failure

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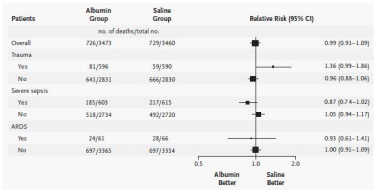
SAFE Sub-Group Analysis of Relative Risk of Death Suggested Benefit in Sepsis



SAFE Investigators NEJM 2004

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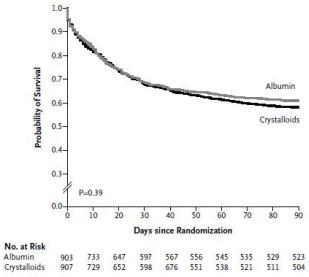
Albumin Replacement in Patients with Severe Sepsis



Caironi et al NEJM 2014

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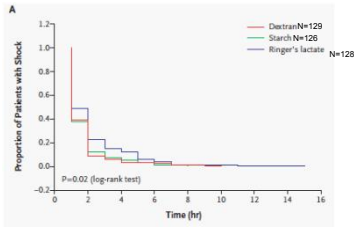
Crystalloid v Colloid Resuscitation in Dengue Fever Shock



Wills et al NEJM 2005

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Fluid Types

- Crystalloid
  - Saline
    - Increased Incidence of Renal Failure
    - Metabolic acidosis
  - Balanced Solutions
    - Lactate (hepatic converted to HCO3)
    - Acetate (Myocardial depressant)
    - Calcium (Blood product precipitation)
- Blood Products
  - PRBCs
    - Equivalent mortality when Hgb 7 in Sepsis, GI bleed

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Chloride Restrictive Strategy Resulted in Less Renal Injury

	No. (%) [95% CI] of Patients[a]		
	Control Period (n = 760)	Intervention Period (n = 773)	*P* Value
RIFLE class			
Risk	71 (9.0) [7.2-11.0]	57 (7.4) [5.5-9.0]	.16
Injury	48 (6.3) [4.5-8.1]	23 (3.0) [1.8-4.2]	.002
Failure	57 (7.5) [5.6-9.0]	42 (5.4) [3.8-7.1]	.10
Injury and failure	105 (14) [11-16]	65 (8.4) [6.4-10.0]	<.001

[a] The control period was from February 18 through August 17, 2008, and the intervention period was from February 18 through August 17, 2009.

Junos et al JAMA 2012

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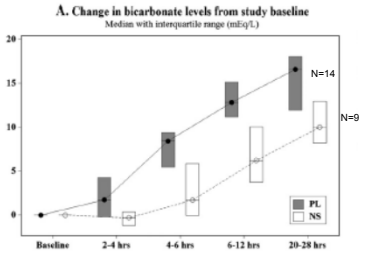
PlasmaLyte Infusion During DKA resulted in Faster Metabolic Acidosis, BP and UO Improvement than Normal Saline Infusion



Chua J Crit Care 2012

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Variations in Crystalloids Formulations

Solution	pH	Na^+	Cl^-	K^+	Ca^{++}	Mg++	Acetate	Gluconate	Lactate	Glucose	Osmolality
NS	5.0	154	154	0	0	0	0	0	0	0	308
LR	6.5	130	109	4	3	0	0	0	28	0	275
D5W	4.0	0	0	0	0	0	0	0	0	50 g/L	252
D5W+NS	4.3	154	154	0	0	0	0	0	0	50 g/L	560
D5W+LR	4.6	130	112	4	3	0	0	0	28	50 g/L	530
D5W + 1/2NS	4.5	77	77	0	0	0	0	0	0	50 g/L	406
Normosol-R	6.6	140	98	5	0	3	27	23	0	0	294
Normosol-R +D5W	5.2	140	98	5	0	3	27	23	0	50g/L	280

All electrolyte ions are expressed in meq/L.

NS=0.9% normal saline
D5w= 5% dextrose
LR = lactated ringer's
½ NS= 0.45% normal saline

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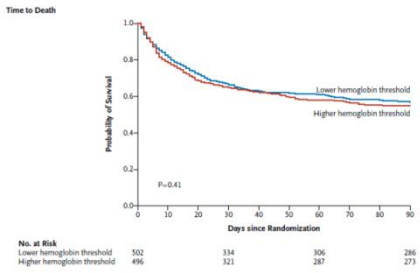
Lower Hgb Threshold in Sepsis Does not Alter Mortality



Holst et al NEJM 2015

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Quantity and Rate of Fluid Delivery

Benefit:
Enough Fluid:
Increased BP,
LVEDV and CO

Harm:
Too Much Fluid:
Interstitial Edema
Pulmonary Edema
Mortality

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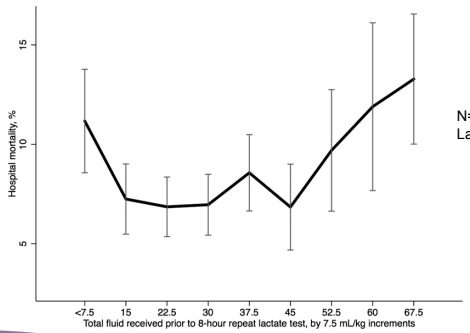
Mortality vs Volume Resuscitation in Sepsis

Too Little and Too Much are Harmful



N= 9190
Lactate>2.0

Liu et al Annals ATS 2013

Billings Clinic — Assessing Volume Responsiveness

Volume Challenge:

a. 500 cc Volume
b. Passive Leg Raising
c. Mechanical Ventilation (TV 800, NSR, AC)
   i. IVC variation
   ii. Pulse Pressure variation

Observation:

a. BP, HR, UOP
b. Pulse Pressure variation
c. Echo derived SV
d. NICOM: Bio-Reactance

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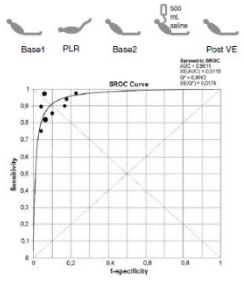

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Assessing Harm of Fluid Administration

Physical Exam
- a. Rales, Tachypnea
- b. Edema

CXR
- a. Interstitial/Alveolar edema
- b. Kerley B lines

Ultrasound
- a. B lines
- b. Consolidation

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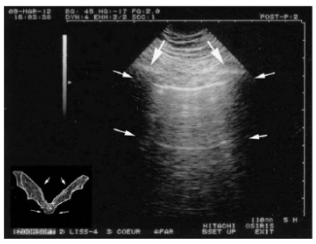
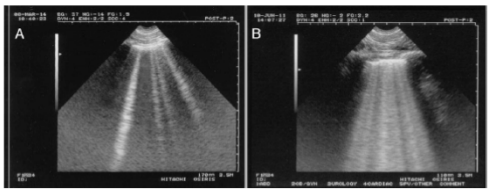
FALLS Protocol
A Lines



Lichenstein Chest 2015

FALLS Protocol
B Lines



Lichenstein Chest 2015

End Diastolic Volume is a Function of Atrial Kick/Heart Rate

a. Maintain Sinus Rhythm
b. HR Control

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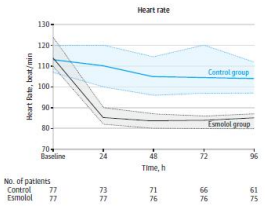
ESMOLOL titrated to HR 80-95 Improved Mortality



Morelli JAMA 2013

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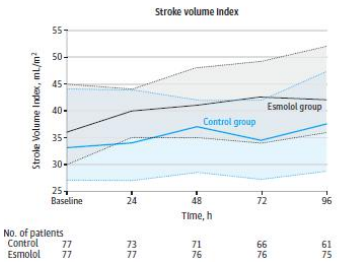
ESMOLOL titrated to HR 80-95 Improved Mortality



Morelli JAMA 2013

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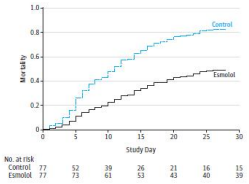

Morelli JAMA 2013

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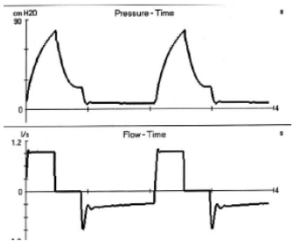
Patient was Volume Loaded with 20 ml/kg and B lines present, HR was titrated with Esmolol to Pulse Under 100/min.
AC 18, TV 600, PEEP 5, Flow 60
The following Ventilator Flow graphic was observed.



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How could you increase LV Preload further?

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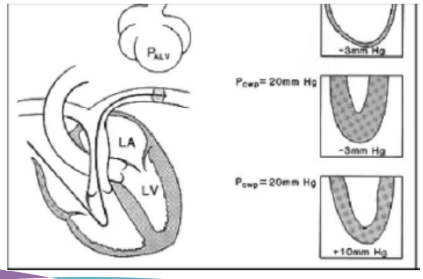
End Diastolic Volume is a Function of Trans-Mural Pressure

EDV = (Pi-Pe) x Compliance



Etiology of Increased Juxta-Cardiac Pressure

Pericardial Disease
Auto-PEEP
Intra-abdominal Pressure Elevation
Pneumothorax
Obesity

End Diastolic Volume Optimization

- **Optimize Volume Status**
  Rx Hypovolemia
  Type, Rate, Amount of fluid
- **Optimize Filling Time**
  Rx Tachycardia or loss of atrial kick
- **Optimize LV Juxta-cardiac pressure**

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Would you administer Steroids?

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Etomidate Usage during Intubation Results in More Adrenal Insufficiency in Septic Patients

	Etomidate (n=116)	Ketamine (n=116)	p value
Cortisol (nmol/L; median [IQR])			
Baseline	441 (304-717)	690 (469-938)	<0·0001
30 min after ACTH test	497 (331-800)	911 (690-1131)	<0·0001
60 min after ACTH test	524 (386-828)	1048 (776-1324)	<0·0001
Non-responder in ACTH test (n [%, 95% CI])*	93 (81%, 76-86)	49 (42%, 36-48)	<0·0001
Adrenal insufficiency (n [%, 95% CI])	100 (86%, 82-90)	56 (48%, 42-54)	<0·0001

ACTH=adrenocorticotropin hormone. *Patient was a non-responder if maximum change was less than 250 nmol/L. †Patient had adrenal insufficiency if baseline cortisol was less than 276 nmol/L or the maximum change (peak cortisol minus baseline cortisol) was less than 250 nmol/L, or both.

Table 3: Adrenal function assessment in study patients†

Combes et al Lancet 2009

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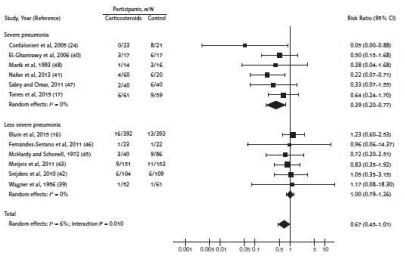
Effect of Steroids on All Cause Mortality In CAP

Curb-65>2



Siemieniuk et al Annals Intern Med 2015

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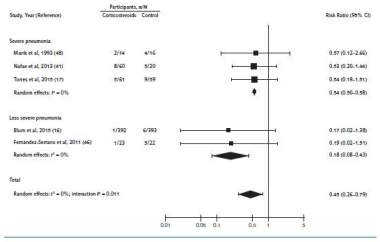
Effect of Steroids on Need for Mechanical Ventilation
In Community Acquired Pneumonia



Siemieniuk et al Annals Intern Med 2015

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Once Pre-Load is Optimized, which pressor would you choose to increase MAP>65 ?

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Vasoactive Agents

- Vasopressors
  - Adrenergic agents (Dopamine, Levophed)
  - Vasopressin (V1)
- Inotropes
  - Dobutamine
  - PDIII inhibitors (Milrinone)

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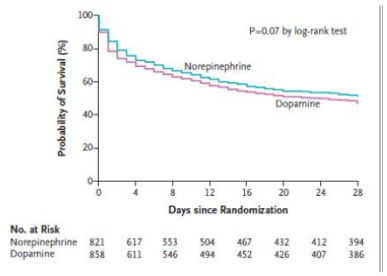
Dopamine v NE in Shock



Debacker et al NEJM 2010

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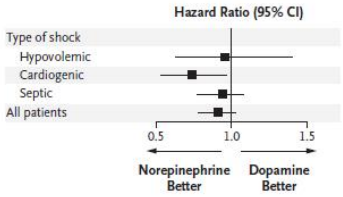
Dopamine Increased Cardiac Arrythmia in Cardiogenic Shock Compared to NE



DeBacker et al NEJM 2010

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Mechanical Aids

- **Intra-aortic Balloon Pump**
- **ECMO**
- Impella

Shock Strategy

Time Sensitive

- Airway / Ventilatory Support
- Hemodynamic Support
  - Restore adequate cellular metabolism
  - MAP>65 mm Hg
  - SvO2; CO
  - Lactate Clearance
- Identify Cause