UPMC Critical Care

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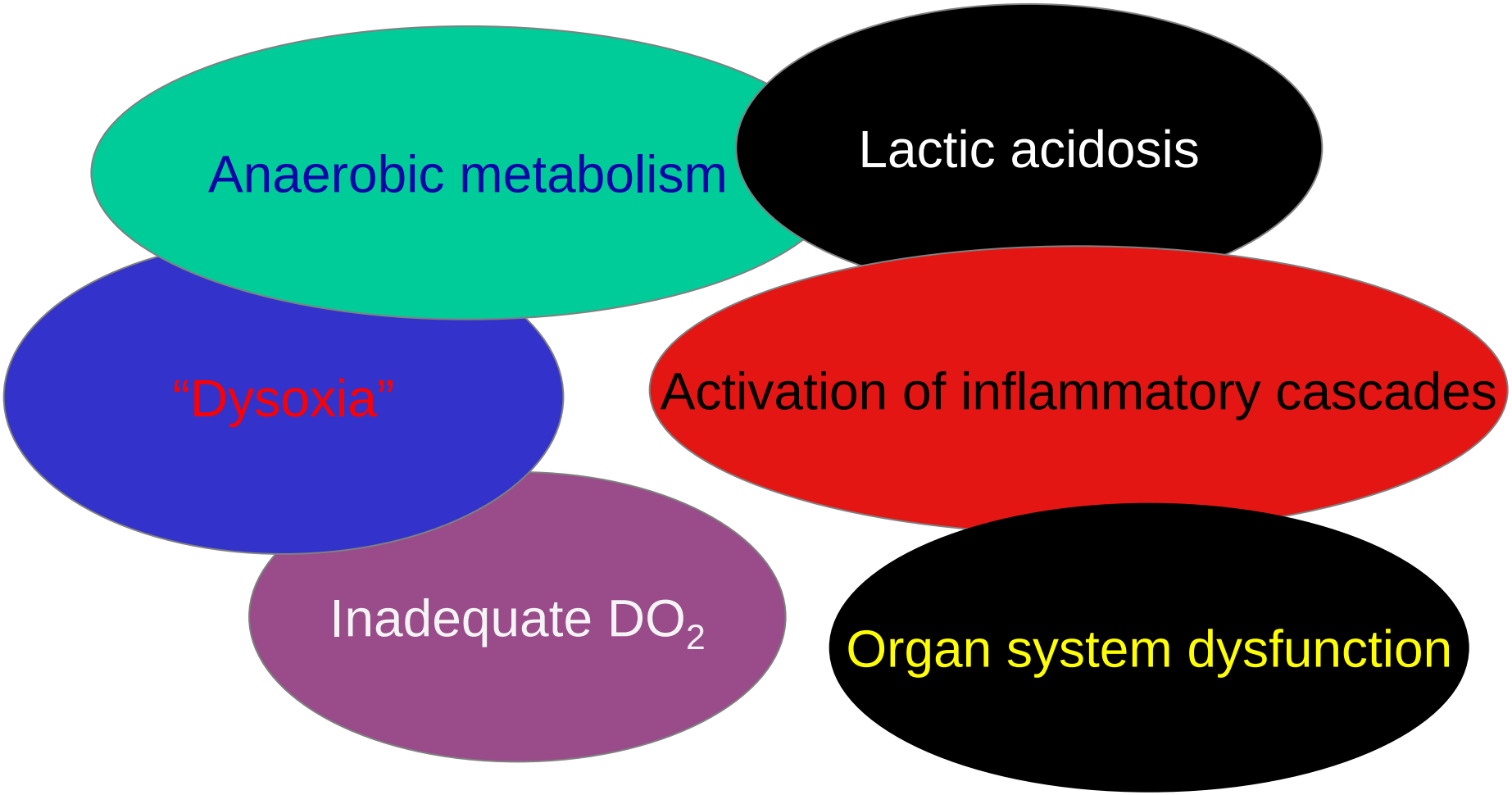
Shock and Monitoring

Samuel A. Tisherman, MD, FACS, FCCM
Professor
Departments of CCM and Surgery
University of Pittsburgh

Shock


Anaerobic metabolism
Lactic acidosis
"Dysoxia"
Activation of inflammatory cascades
Inadequate DO_2
Organ system dysfunction

Shock

- Normal cardiovascular system
- Pathophysiology of shock
- Categories of shock
- Resuscitation
- Monitoring

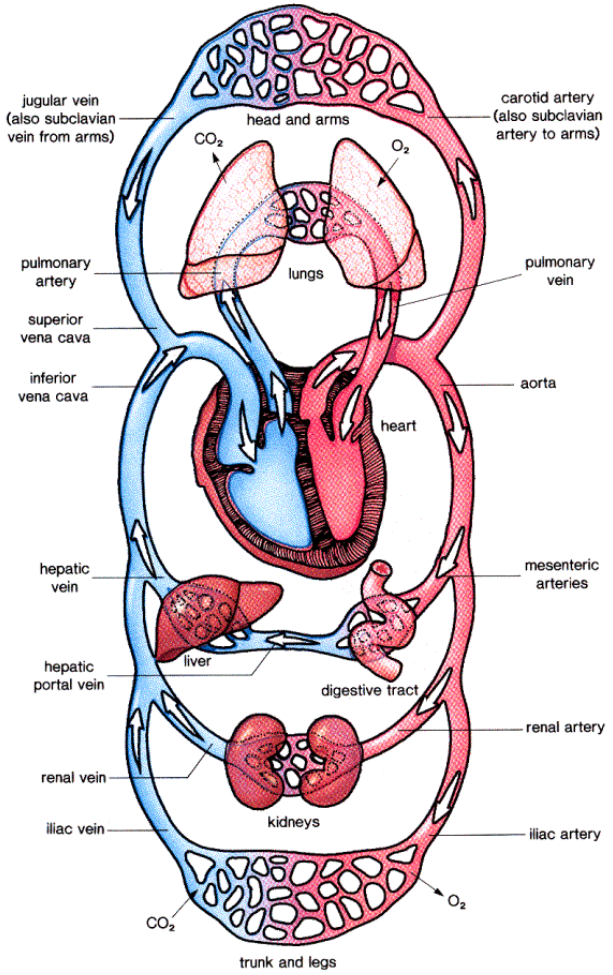
Key components of CV system

- **Intravascular volume**

- **Cardiac output**
  - Preload
  - Heart rate
  - Contractility
  - Afterload

Key components of CV system

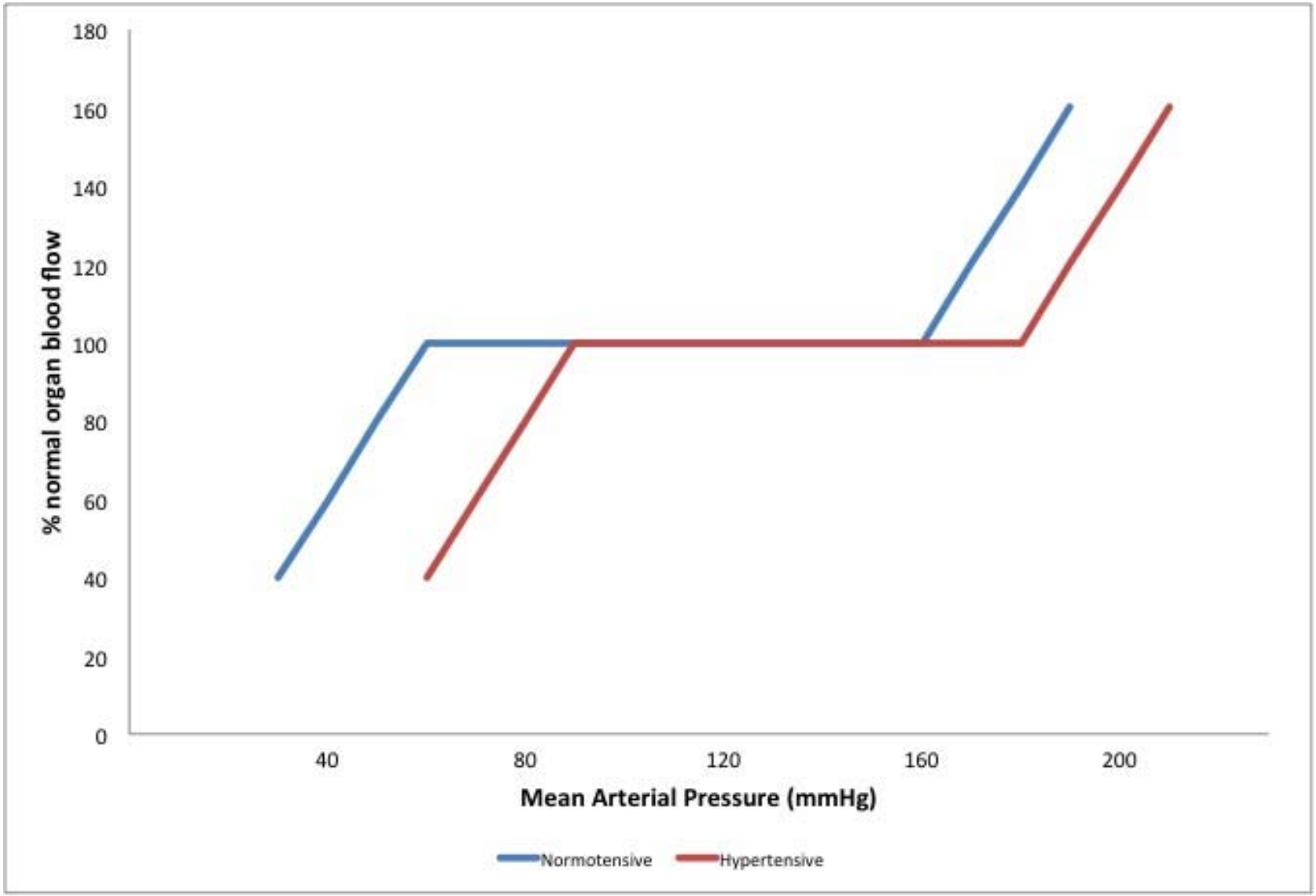
- **Resistance circuit – arterioles**
  - Distribution of organ flow
- **Capillaries**
  - Leak
  - Obstruction to flow
  - Shunts
- **Venous capacitance vessels**
  - Vary venous return



Organ blood flow

- **Most dependent upon mean arterial pressure (MAP)**
- **Autoregulation**
  - Maintained during large variations of MAP
  - 60-130 mmHg
  - Can be impaired - hypertension

Autoregulation



Supply and demand

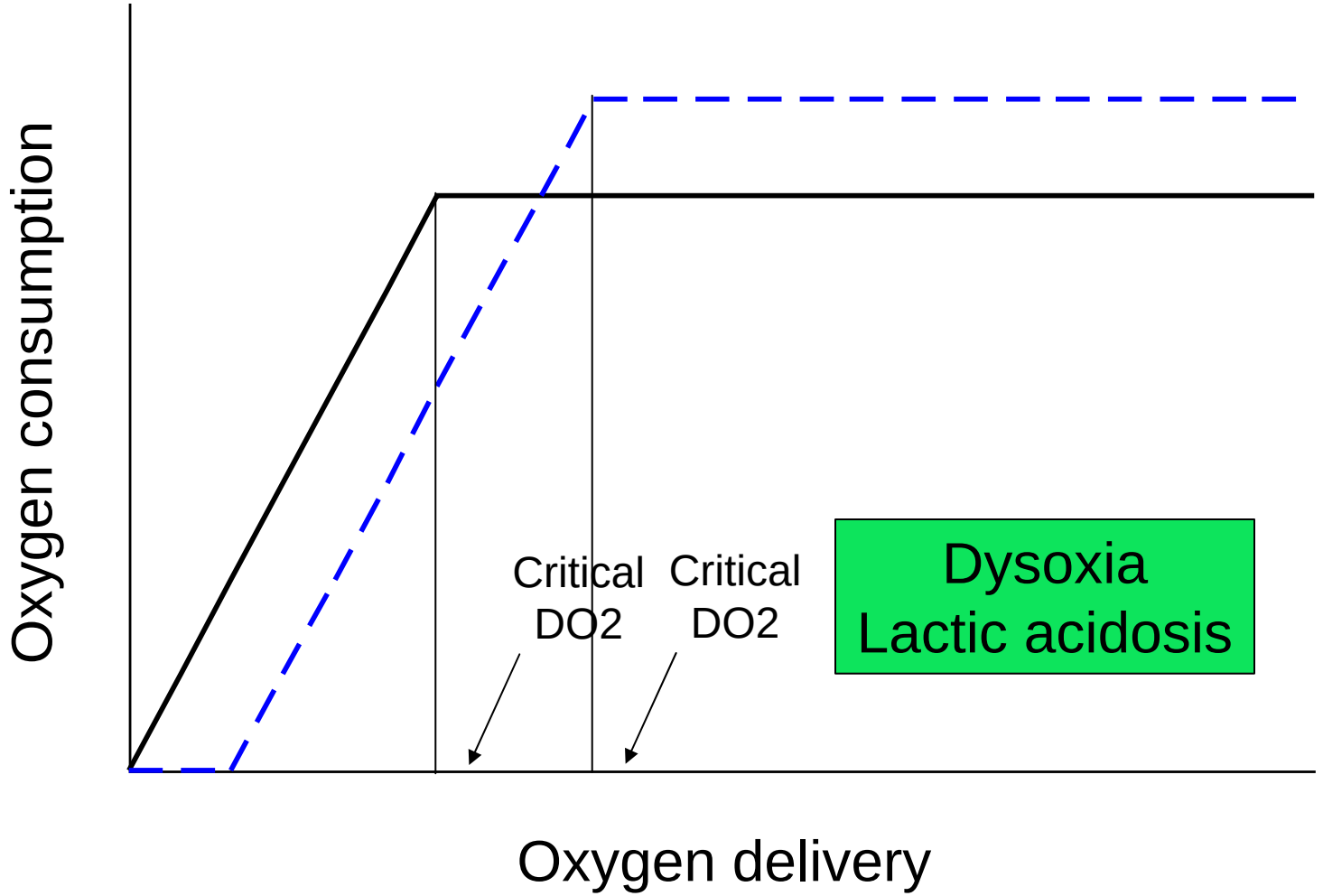
- O_2 delivery
  - Hemoglobin
  - Saturation
  - Cardiac output
- O_2 demand

20-60%

$$VO_2 = DO_2 \times ERO_2$$

ER = extraction ratio

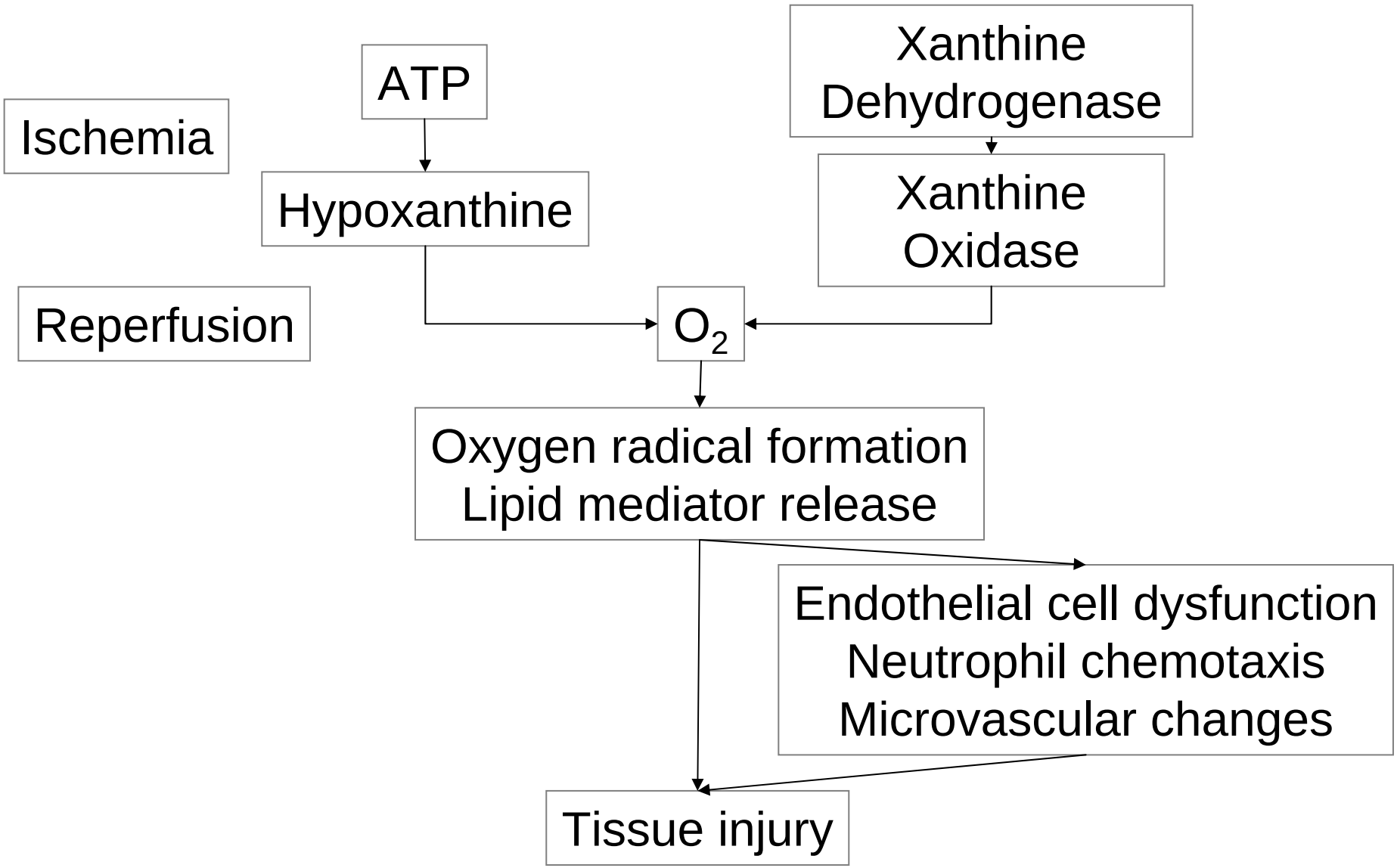
O_2 supply dependency



Cytopathic Hypoxia

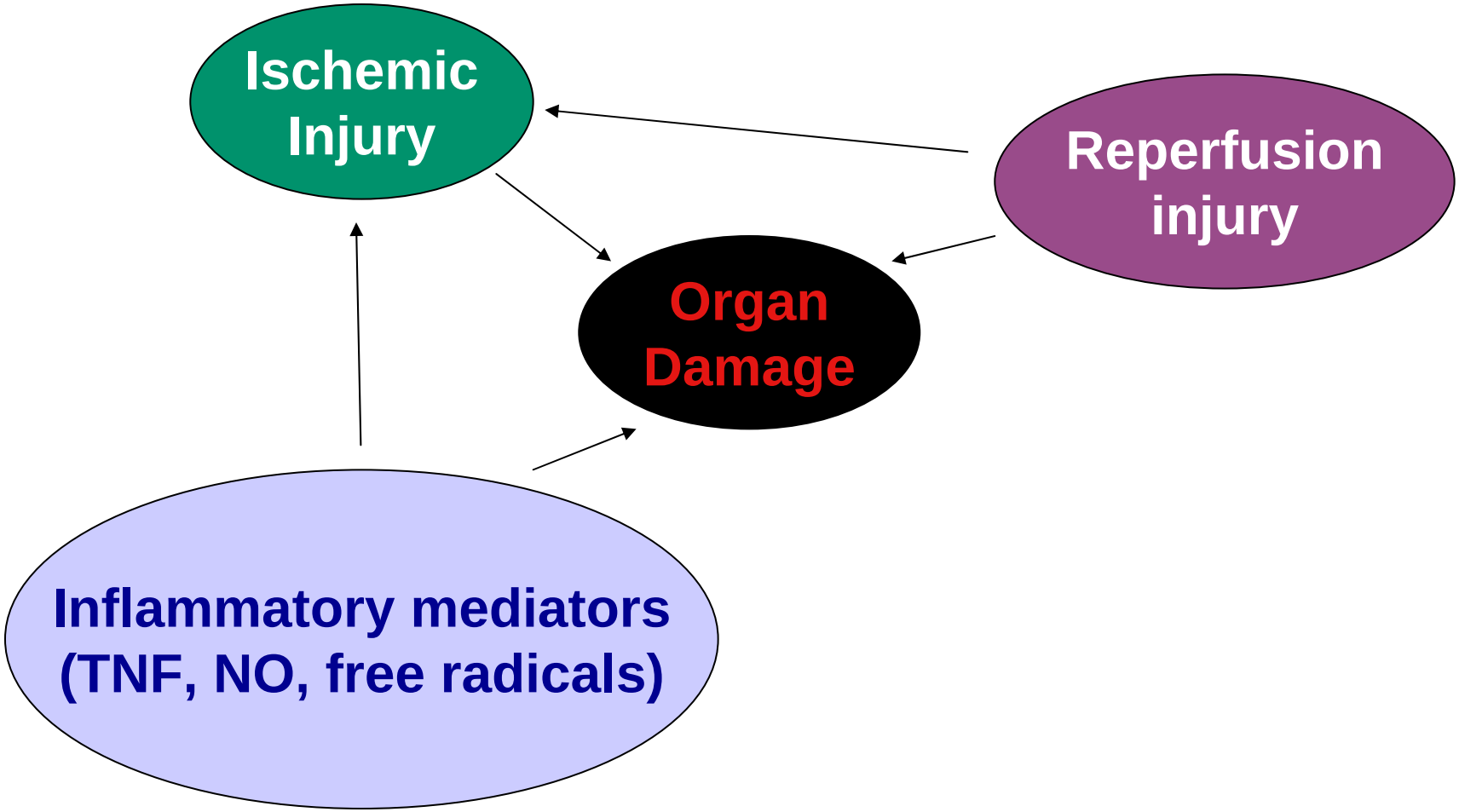
- **Sepsis**
  - Normal oxygen delivery
  - Impaired mitochondrial O_2 utilization
- **Mediators**
  - Inflammatory cytokines
  - Inhibition of pyruvate dehydrogenase
  - Inhibition of cytochrome a,a3 by NO
  - Irreversible inhibition of one or more mitochondrial respiratory complexes by peroxynitrite
  - Poly(ADP-ribose) polymerase-1

Reperfusion Injury

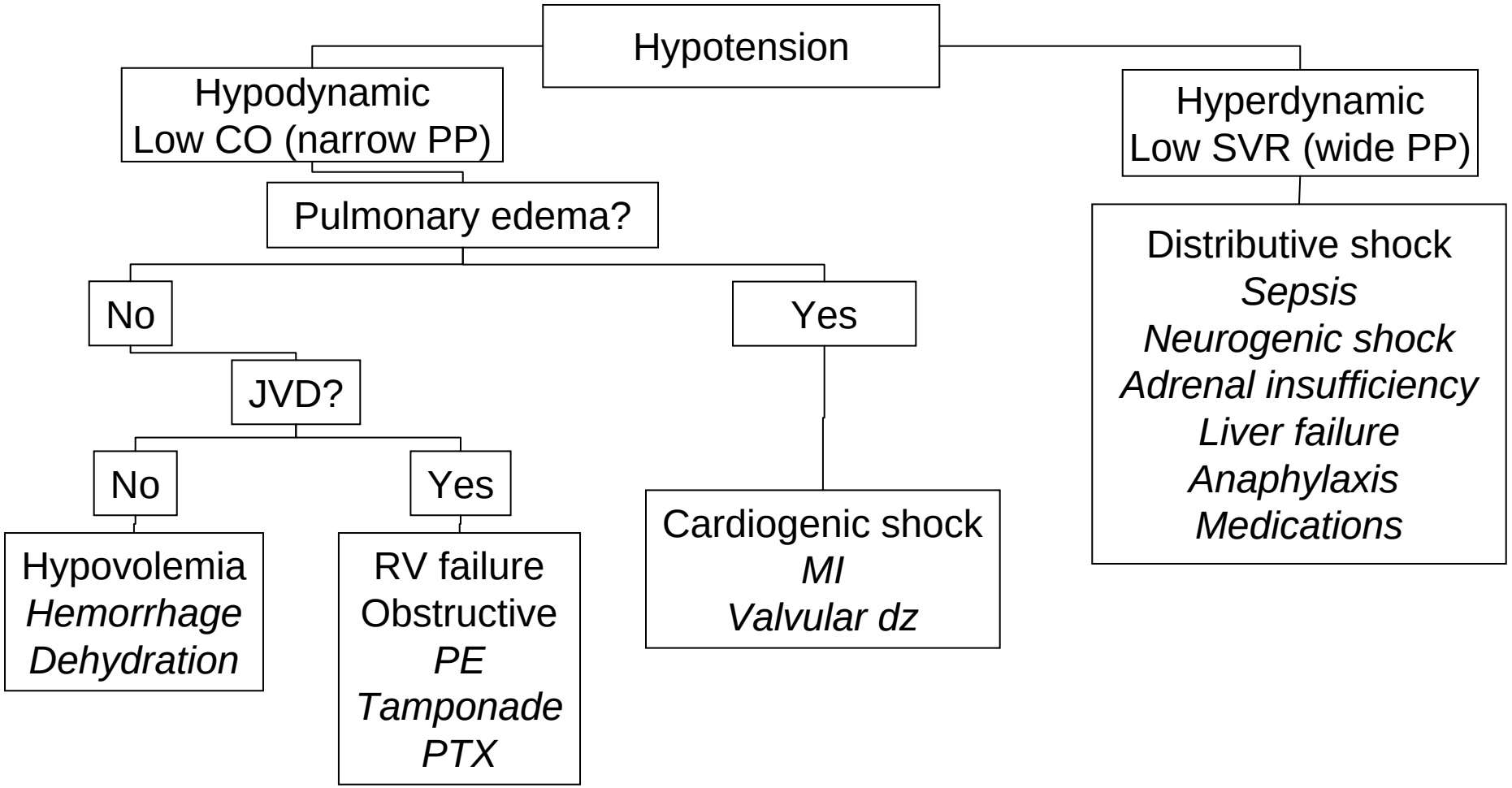


It’s not the fall that gets you….

Organ failure



Classifications of shock



Hemorrhagic shock

- **Most common cause of hypotension in trauma patients**
- **Initial fluid should be crystalloid**
- **Transfusion**
  - Hypotensive after 2 L crystalloid (ATLS)
  - Earlier for severe shock
- **Uncontrolled hemorrhage**
  - Stop hemorrhage
  - Limited fluid resuscitation

Cardiogenic shock

- Resuscitation simultaneous with revascularization
- Patients may need higher than normal filling pressures (poor LV compliance)
- Inotropes may worsen ischemia
- Pacing may be helpful for relative bradycardia
- Intra-aortic balloon pump improves coronary perfusion and decreases afterload

Pulmonary embolism

- **Risk factors**
  - Hypercoagulability, stasis, trauma
- **Presentation**
  - Respiratory
  - Cardiovascular
- **Diagnosis**
  - CT angio, VQ, echo, angio, d-dimer
- **Management**
  - Anticoagulation, thrombolytic, embolectomy
  - Prevent the next one -?filter

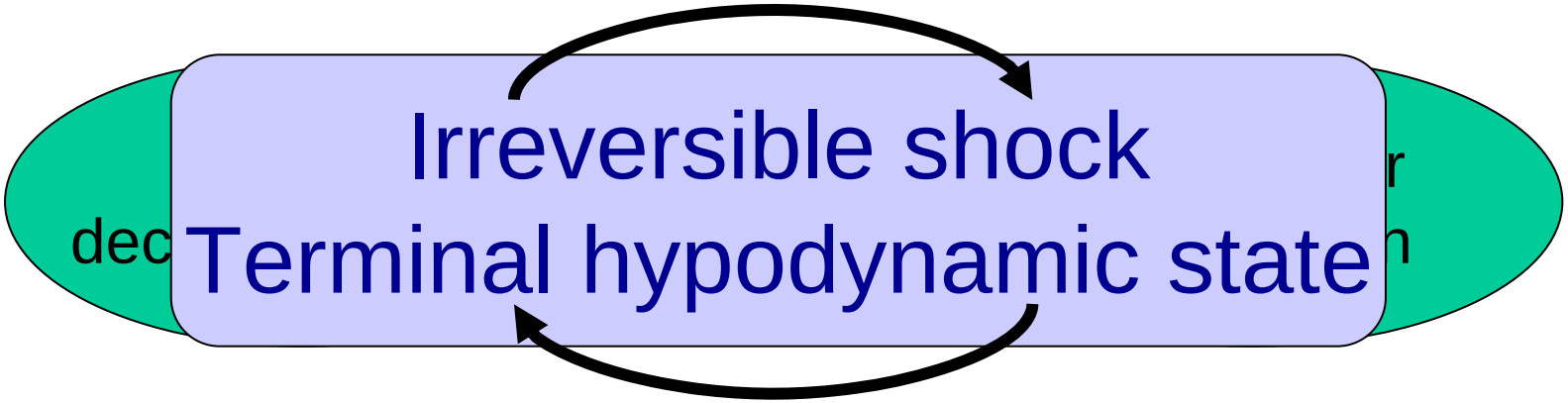
Cardiac tamponade

- **Pentrating trauma more common than blunt**
- **Beck's triad (hypotension, distant heart sounds, JVD) obscured by hypovolemia**
- **High index of suspicion**
- **Diagnose: echo or pericardial window**
- **Treatment:**
  - Need sternotomy or thoracotomy (trauma)
  - Pericardiocentesis (non-trauma)

Septic shock

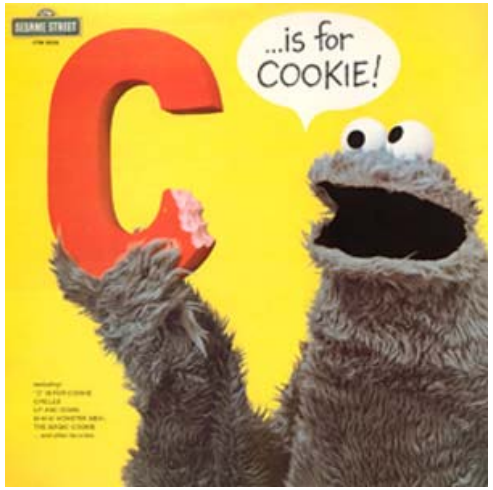
- **Decreased preload**
  - Hypovolemia (capillary leak)
  - Increased venous capacitance
- **Vasodilatation**
- **Cardiac dysfunction**
  - Ventricular dilatation
  - Decreased ejection fraction
- **Cytopathic hypoxia**

Endstage shock



Initial management

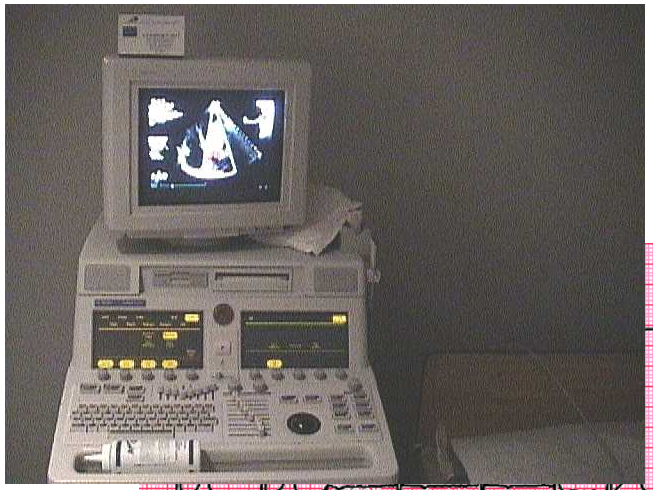
ABCs

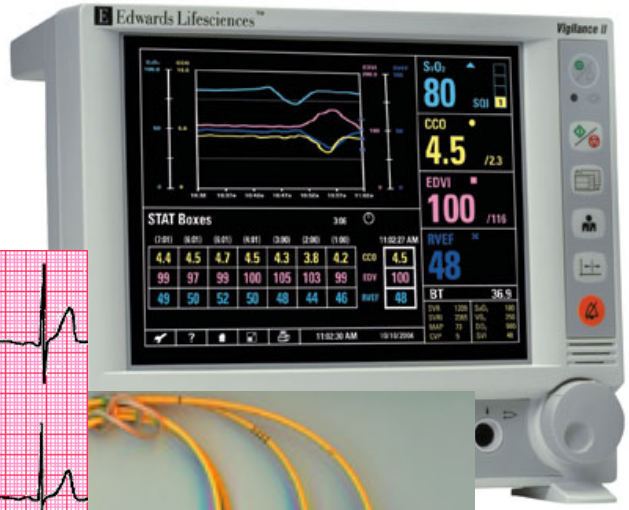


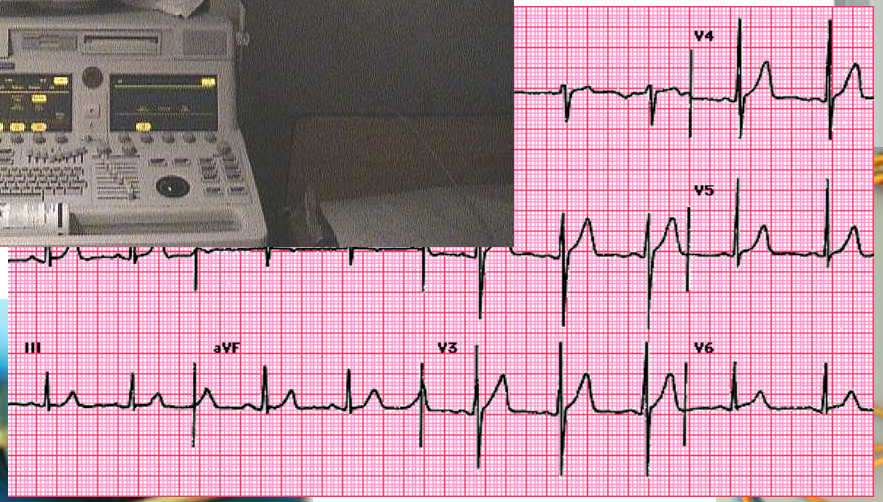
Initial management

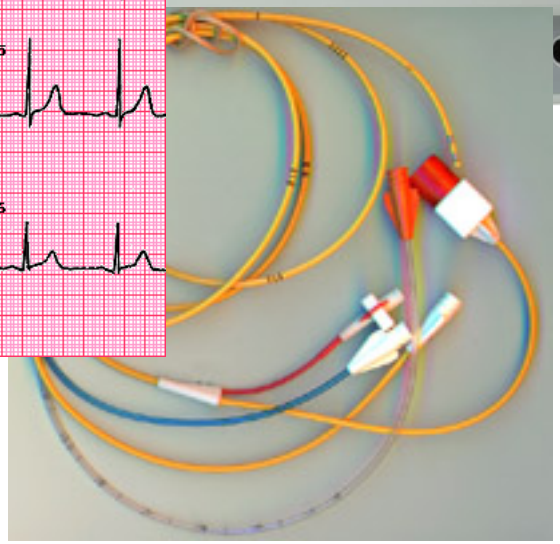
- **Resuscitation**
  - Ventilation
    - ?intubation early
  - Infusion
    - Bolus to effect
    - ?blood
    - Clear lactate
  - Pump therapy
    - Inotropic support
    - Afterload reduction
  - Vasodilatation
    - Vasopressor support
- **Definitive therapy**
  - Stop bleeding
  - Circulatory assist
  - Antibiotics and drainage/debridement

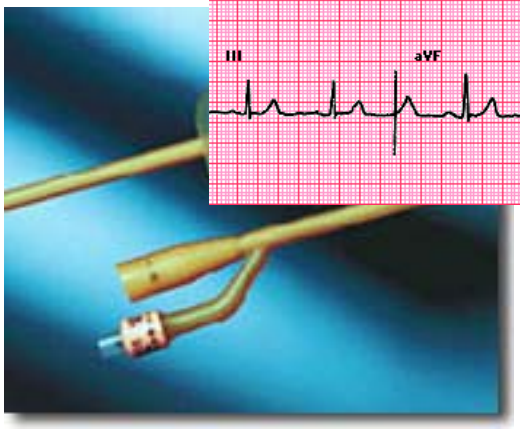
Monitoring




Edwards Lifesciences
Vigilance II
STAT Boxes


V4
V5
III
aVF
V3
V6





CVP

- **Only elevated in disease**
  - RV dysfunction
  - Pulmonary hypertension
  - LV dysfunction
  - Tamponade
  - Hyperinflation
  - Intravascular volume expansion
- **Poor correlation with volume responsiveness**

PAOP and Preload

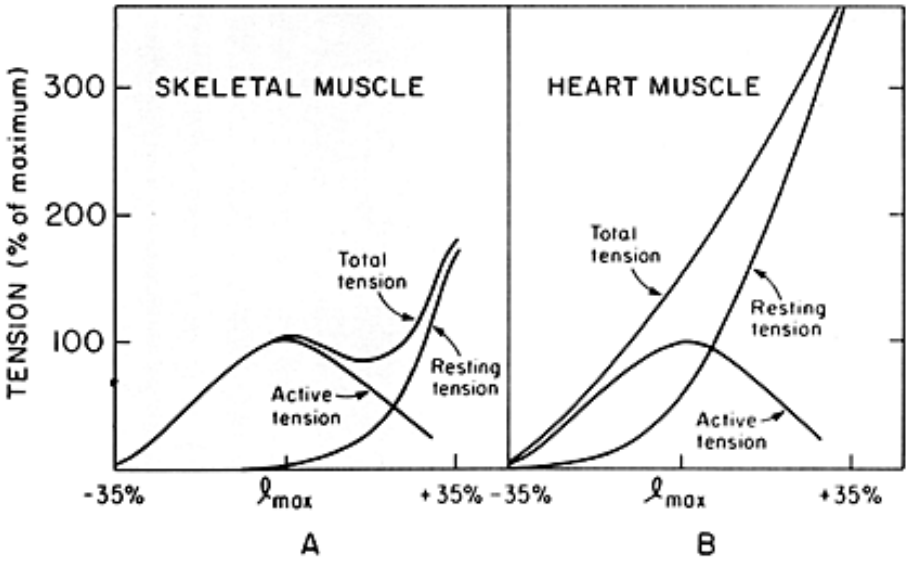
Muscle

LVEDV

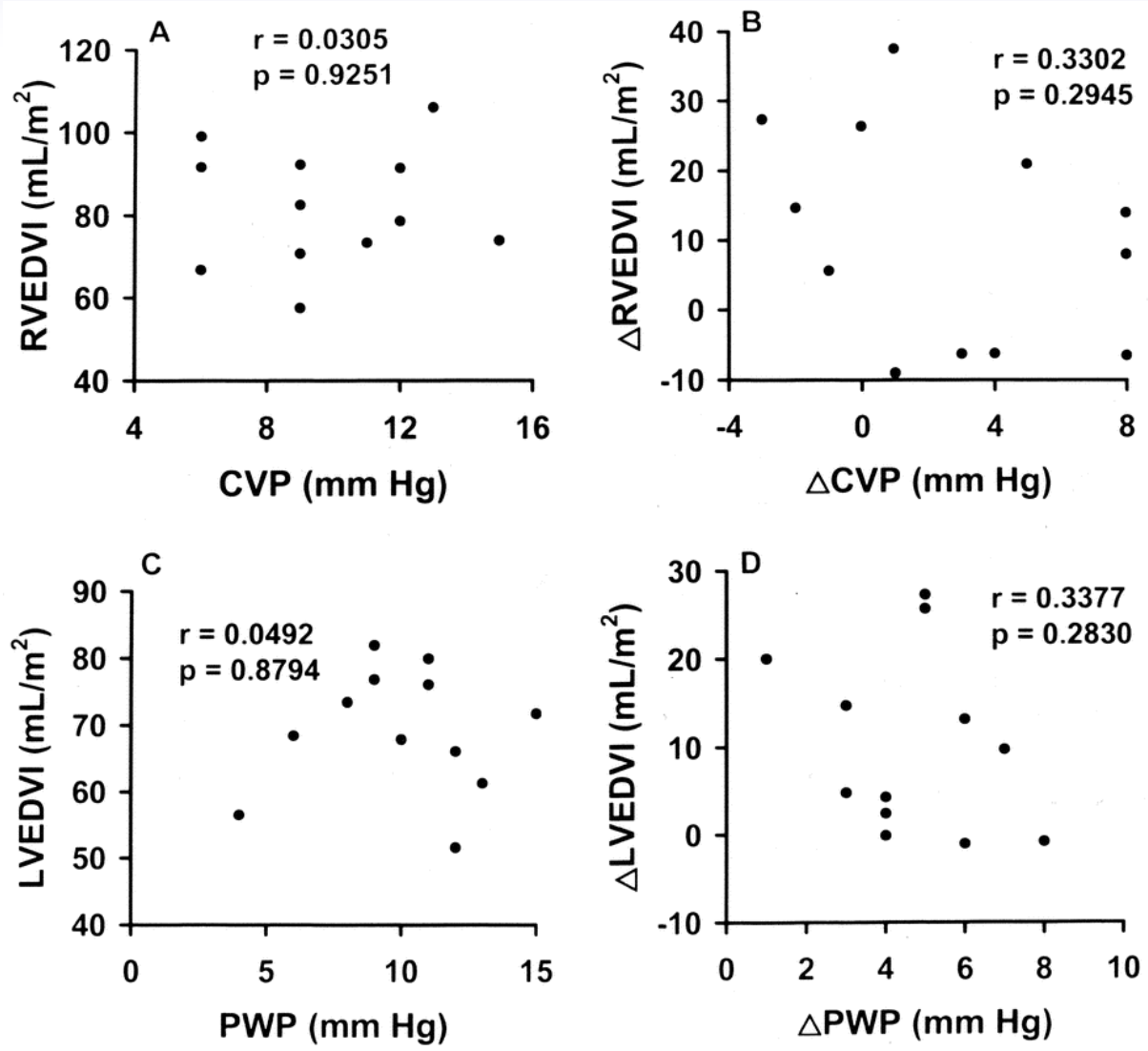
LVEDP

LAP

PAOP



CVP and PAOP



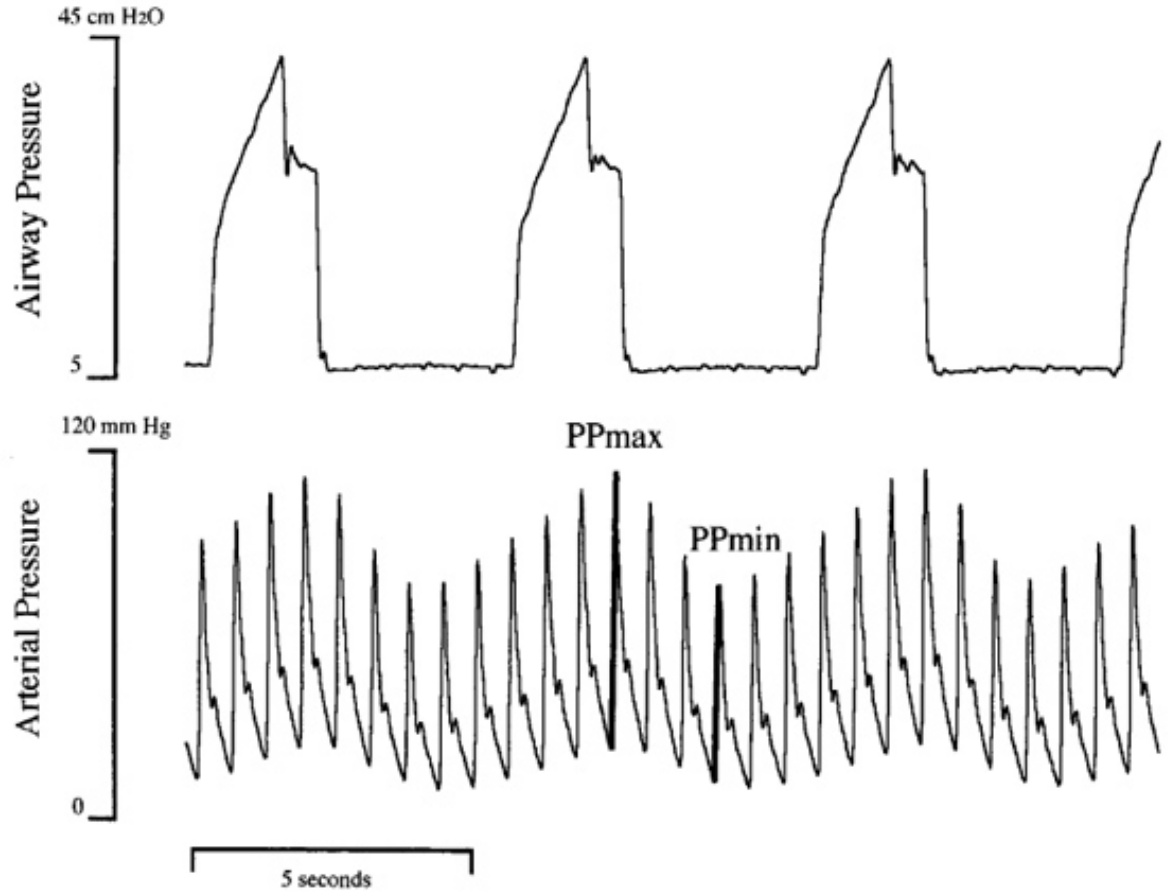
Kumar, et al. *CCM*, 2004.

Functional Hemodynamic Monitoring

2-3 heart beats later

Positive pressure ventilation changes LV output

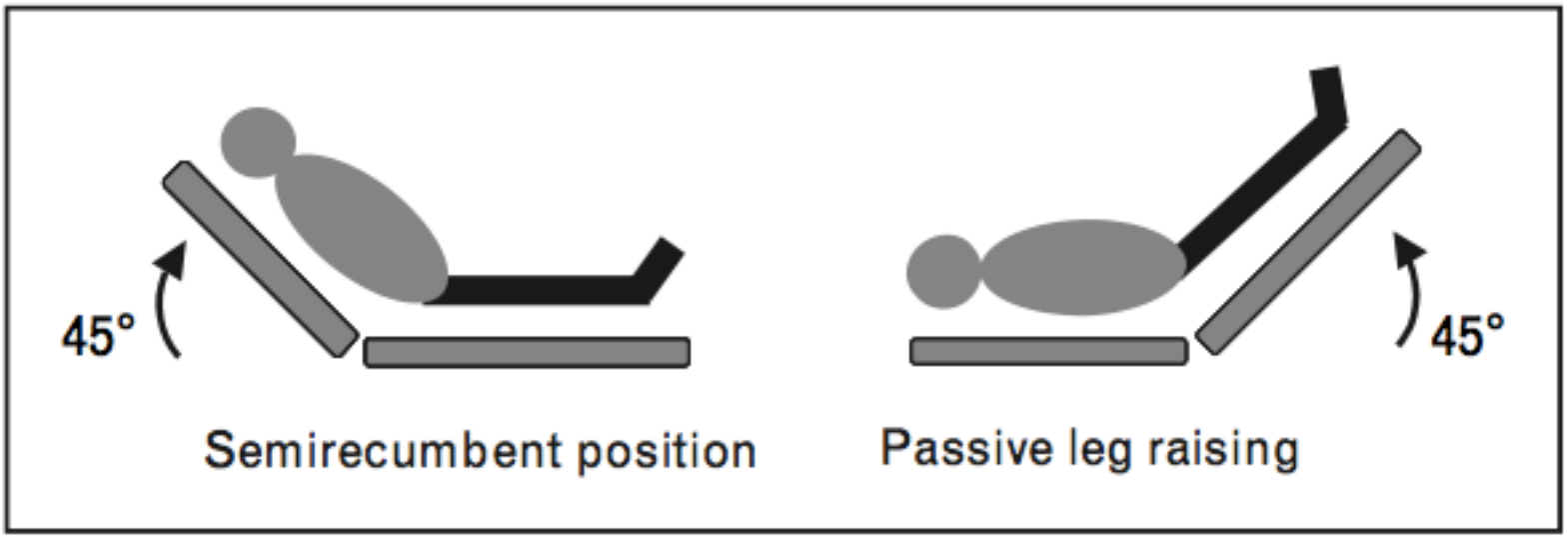
Resp variation in pulse pressure



Limitations: spontaneous breathing, arrhythmias.

Michard and Teboul. *Crit care*, 2000.

Passive Leg Raising



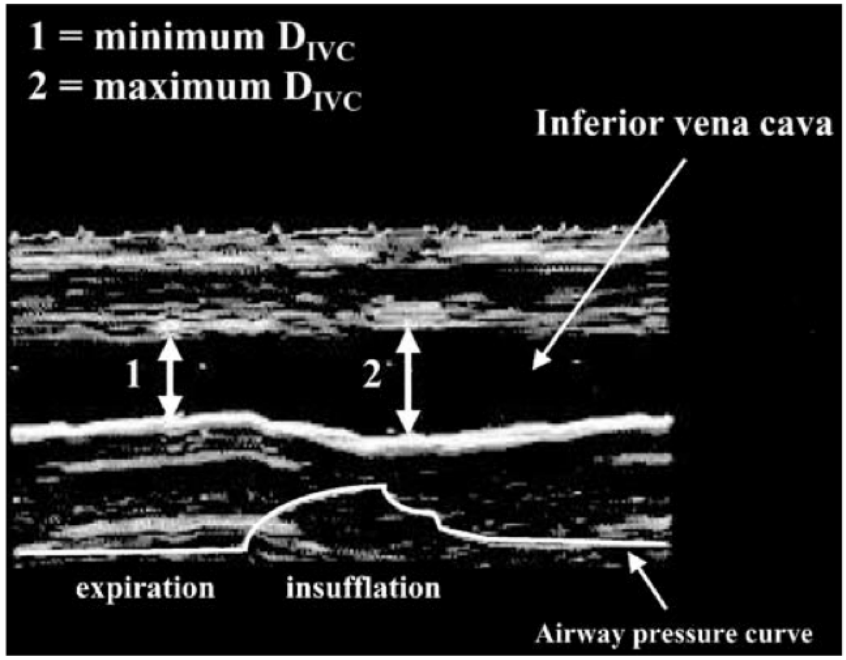
Passive Leg Raising

Variable	Area Under the Curve	p vs. 0.500	Best Cut-Off Value
Compliance of the respiratory system >30 cm H_2O/mL (n = 26)			
Pulse pressure variation at baseline	0.98 ± 0.03	<.0001	12%
Passive leg-raising–induced changes in CI	0.91 ± 0.06	<.0001	10%
End-expiratory occlusion-induced changes in CI	0.97 ± 0.03	<.0001	5%
Global end-diastolic volume index at baseline	0.69 ± 0.11[a]	.090	—
Compliance of respiratory system ≤30 cm H_2O/mL (n = 28)			
Pulse pressure variation at baseline	0.69 ± 0.10	.04	4%
Passive leg-raising–induced changes in CI	0.94 ± 0.05[a]	<.0001	10%
End-expiratory occlusion-induced changes in CI	0.93 ± 0.05[a]	<.0001	5%
Global end-diastolic volume index at baseline	0.48 ± 0.11[a]	.980	—

Monnet, et al. *CCM*, 2012.

Preload Echo

- Distensibility index
  - $\frac{\text{Max-min } D_{IVC}}{\text{Min } D_{IVC}} \times 100\%$
- Collapsibility index
  - $\frac{\text{Max-min } D_{IVC}}{\text{Max } D_{IVC}} \times 100\%$
- Resp variability index
  - $\Delta D_{IVC} = \frac{\text{Max-min } D_{IVC}}{\text{Mean } D_{IVC}} \times 100\%$



Feissel, et al. *Intensive Care Med*, 2004.

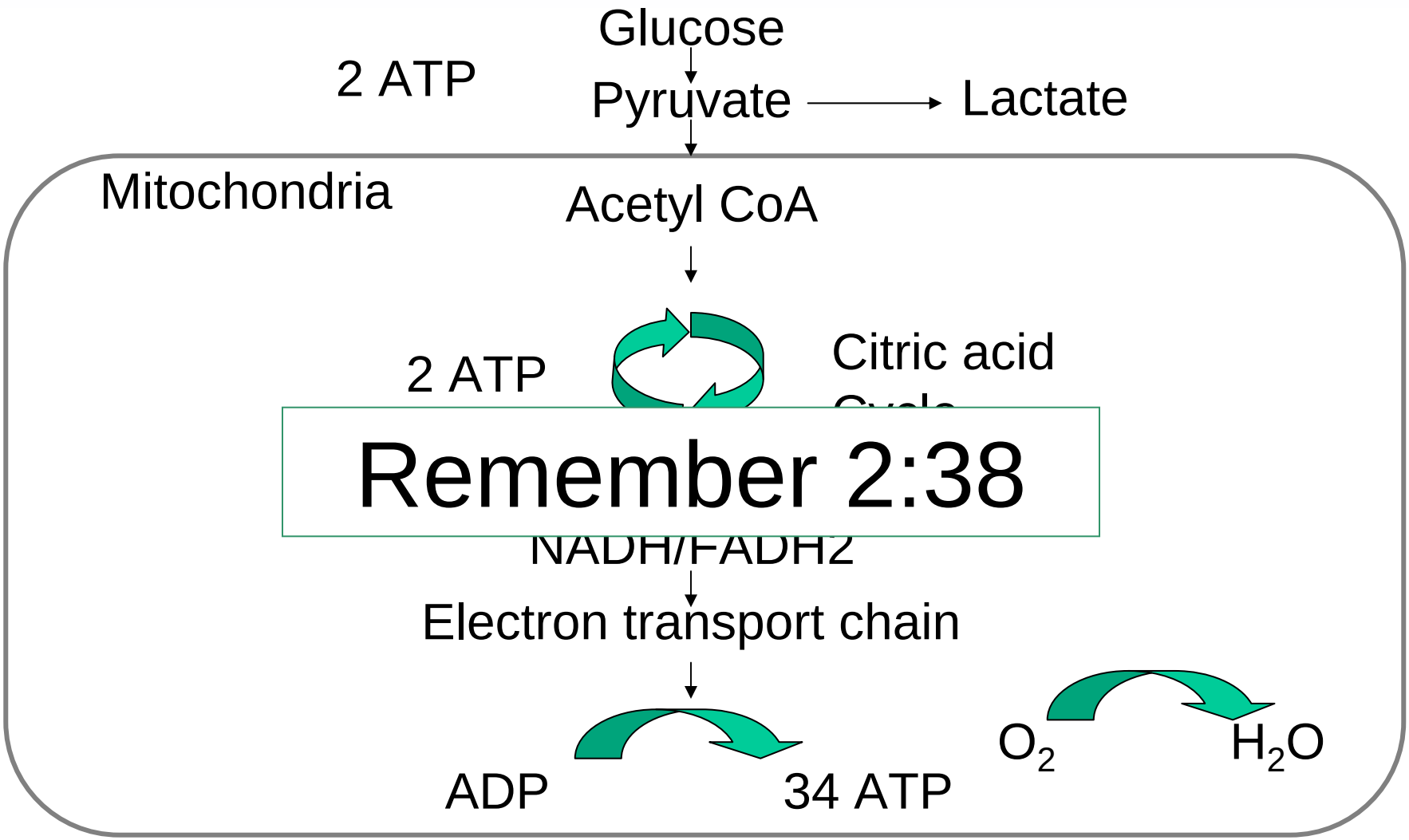
Mixed venous oxygen - SvO2

- **Decrease SvO_2**
  - Decrease DO_2
    - Hb, O_2 sat, cardiac output
  - Increase O_2 demands
    - Fever, sepsis, exercise
  - Normal >65%
  - Critical value ~40%

- **Resuscitation endpoint for sepsis and cardiogenic shock**

- **Sepsis -> maldistribution of blood flow**
  - SvO_2 normal with tissue dysoxia still present

Oxidative Metabolism



Base Deficit

Definition

- Amount of base needed to normalize pH with normal PCO_2

Limitations

- Administration of bicarbonate
- Alcohol intoxication
- Hyperchloremic metabolic acidosis
- Seizures
- Pre-existing acidosis

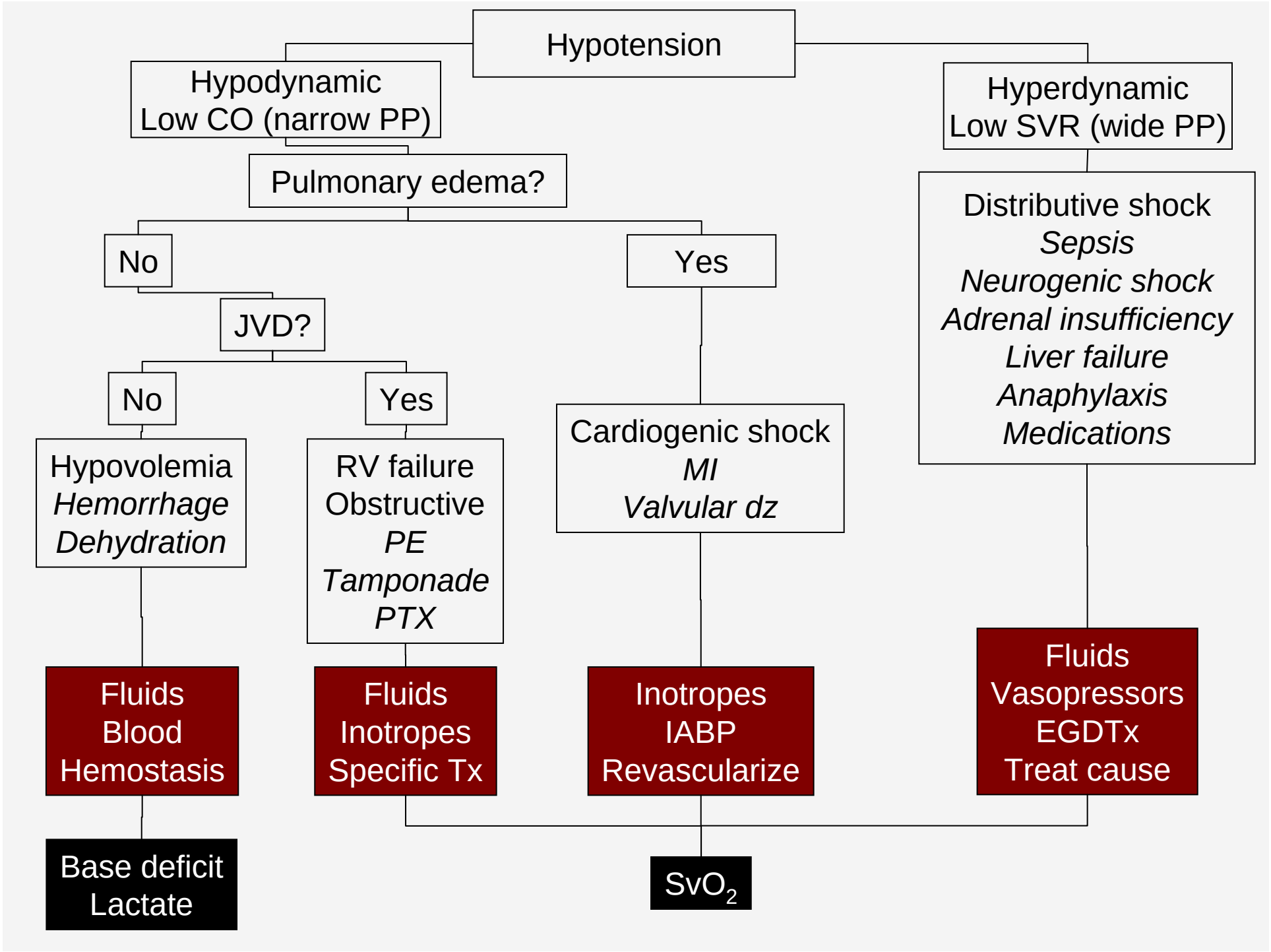
Lactate

- **Excess production**
  - Anaerobic metabolism
  - Initial level and time to clearance useful
- **Decreased metabolism (liver, kidney)**
- **Washout during reperfusion**
- **Sepsis**
  - Increase flux of alanine from muscle
  - Decreased PDH activity
  - Decreased hepatic clearance
  - Dysfunctional mitochondrial respiration

Near Infrared Spectroscopy

- **Measurements**
  - PO_2
  - PCO_2
  - pH
  - O_2 saturation of hemoglobin
  - Tissue oxyhemoglobin coupling to cytochrome *a,a3* redox
    - Mitochondrial O_2

- **Location**
  - Muscle
  - Stomach
  - Bowel
  - Liver


Hypotension
Hypodynamic
Low CO (narrow PP)
Hyperdynamic
Low SVR (wide PP)
Pulmonary edema?
No
Yes
JVD?
Distributive shock
Sepsis
Neurogenic shock
Adrenal insufficiency
Liver failure
Anaphylaxis
Medications
No
Yes
Hypovolemia
Hemorrhage
Dehydration
RV failure
Obstructive
PE
Tamponade
PTX
Cardiogenic shock
MI
Valvular dz
Fluids
Blood
Hemostasis
Fluids
Inotropes
Specific Tx
Inotropes
IABP
Revascularize
Fluids
Vasopressors
EGDTx
Treat cause
Base deficit
Lactate
SvO2

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