



Approach and Hemodynamic Evaluation of Shocks

Mazen Kherallah, MD, MHA, FCCP



Shock Definition

Question #1

Which of the following is necessary in the definition of shock?

- (a) A drop in the systolic blood pressure of less than 90 mm Hg
- (b) A drop in the mean arterial pressure of less than 60 mm Hg
- (c) A drop in the SBP of 40 mm Hg from baseline
- (d) A drop in the SBP of 20% from baseline
- (e) Any of the above

Question #2

- Which of the following is necessary in the definition of shock?
- (a) Hypotension
- (b) Tissue hypoxia
- (c) Use of pressors
- (d) Multiple organ dysfunction

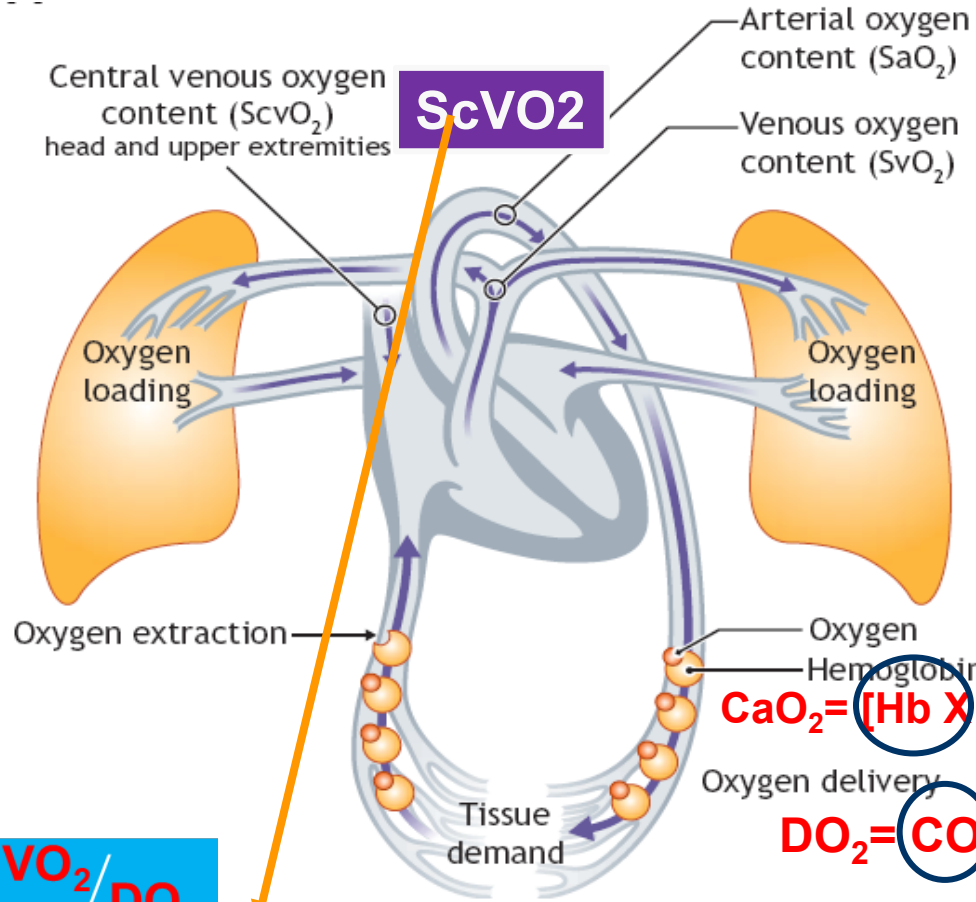
Shock

- Profound and widespread reduction in the effective delivery of oxygen leading to first reversible, and then if prolonged, to irreversible **cellular hypoxia** and organ dysfunction” **Kumar and Parrillo**
- Leads to Multiple Organ Dysfunction Syndrome (MODS)



Pathophysiology

OXYGENATION



$$CaO_2 = [Hb \times 1.34 \times SaO_2] + 0.003 \times PaO_2$$

$$DO_2 = CO \times [CaO_2]$$

$$O_{2ER} = 100 \times VO_2 / DO_2$$

$$VO_2 = CO \times [CaO_2 - CvO_2]$$

Pathophysiology

Oxygen delivery

DO₂

Oxygen uptake

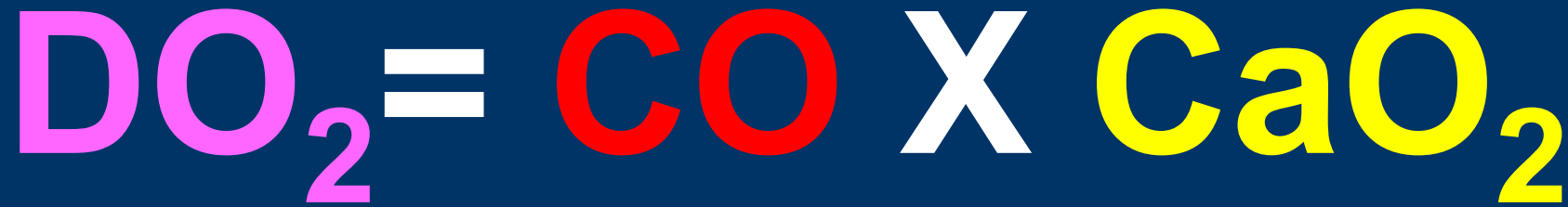
VO₂

VO₂

DO₂

Oxygen extraction ratio

Oxygen Delivery



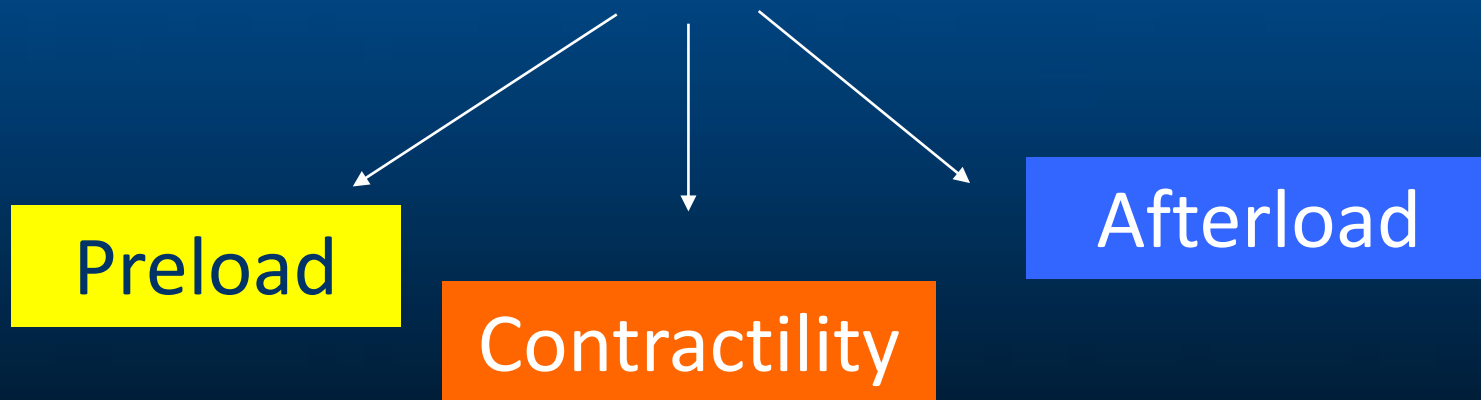
Oxygen Content (CaO_2)

$$[(1.3 \times \text{Hg} \times \text{SaO}_2) + (0.003 \times \text{PaO}_2)]$$

- Hemoglobin concentration
- SaO_2
- Cardiac output
- PaO_2 (minimal)

Cardiac Output

$$CO = SV \times HR$$



Determinants of Oxygen Delivery

O₂ Capacity

O₂ Binding

O₂ Dissolved

Contractility

Afterload

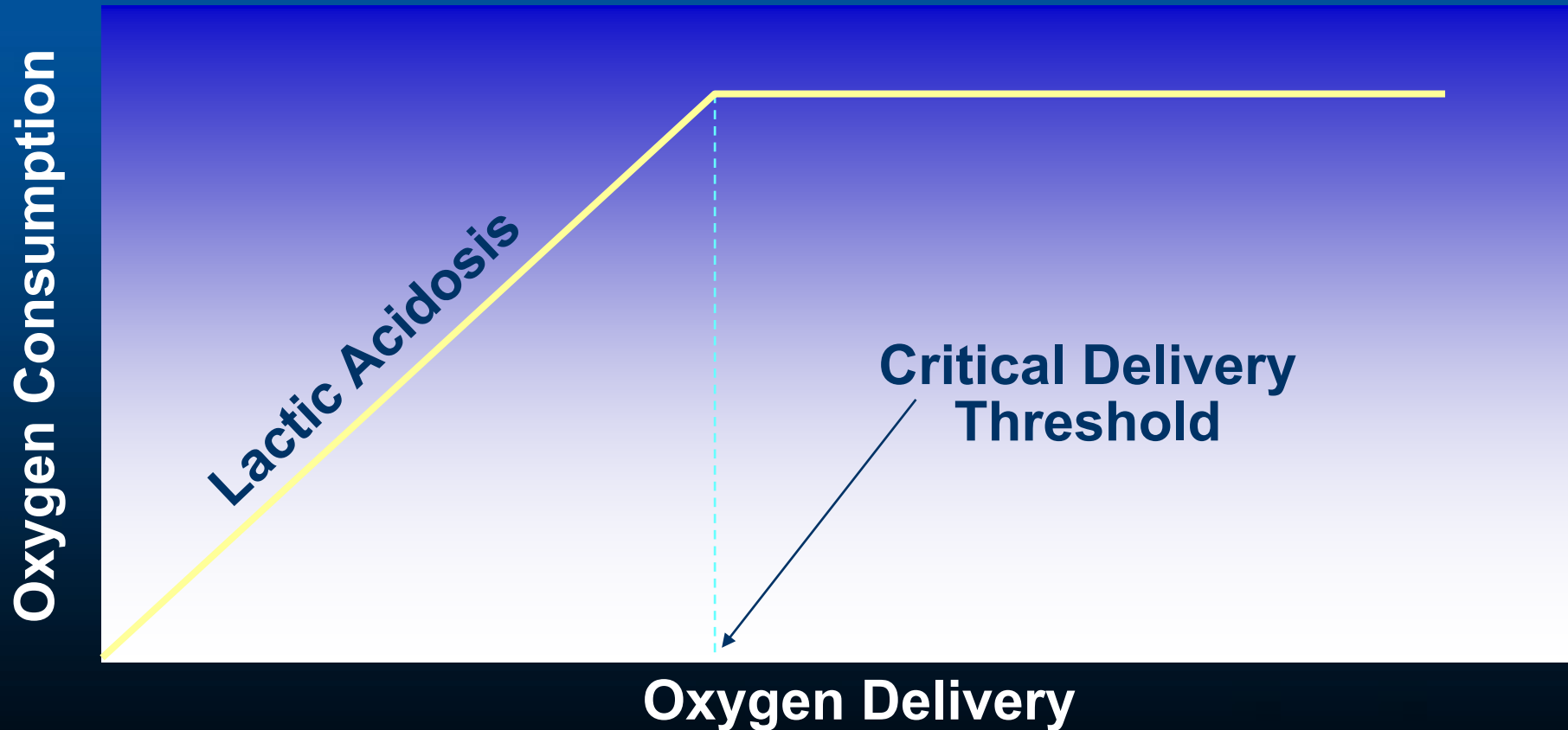
Preload

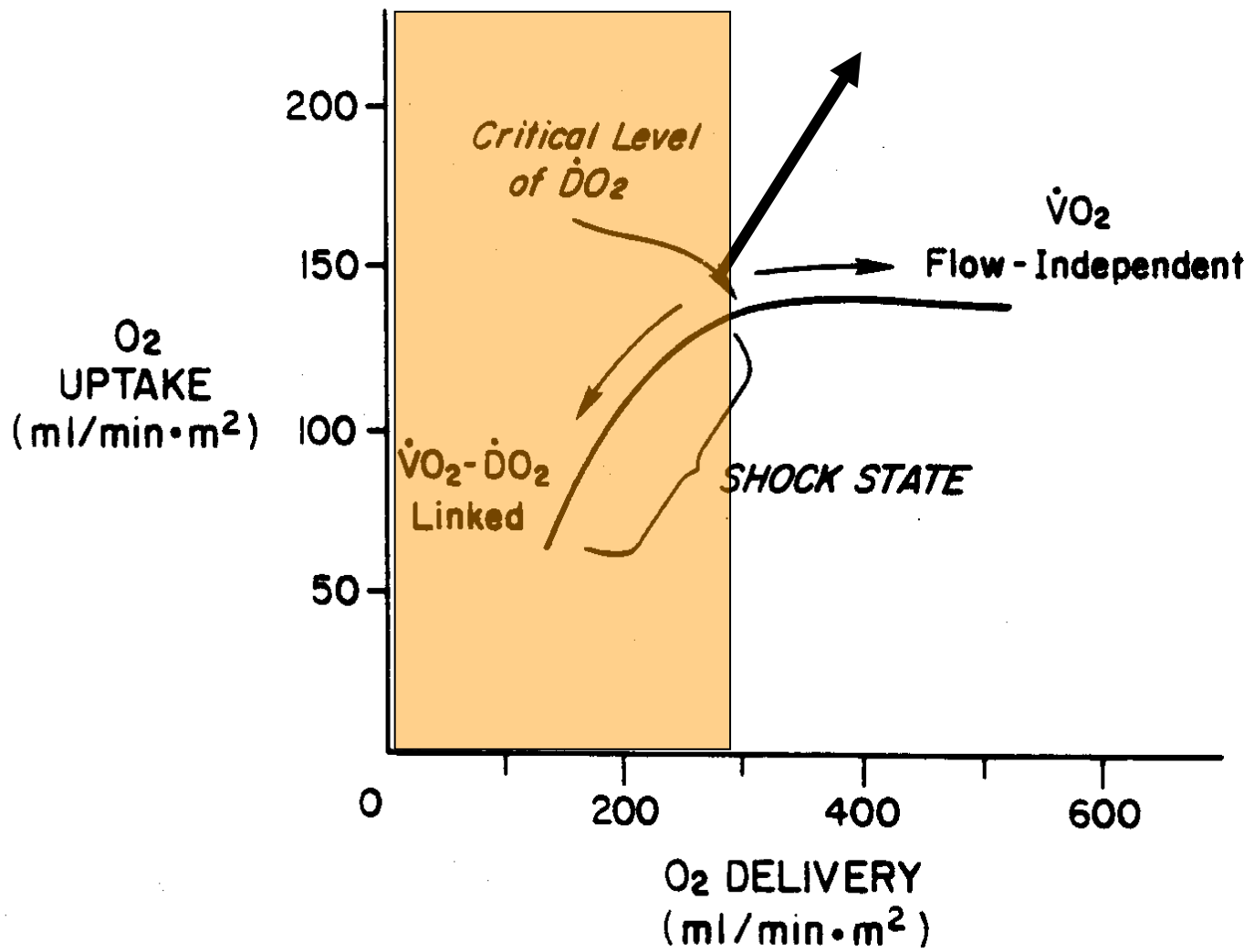
$$CaO_2 = (1.34 \times Hg \times SaO_2) + (0.003 \times PaO_2)$$

X

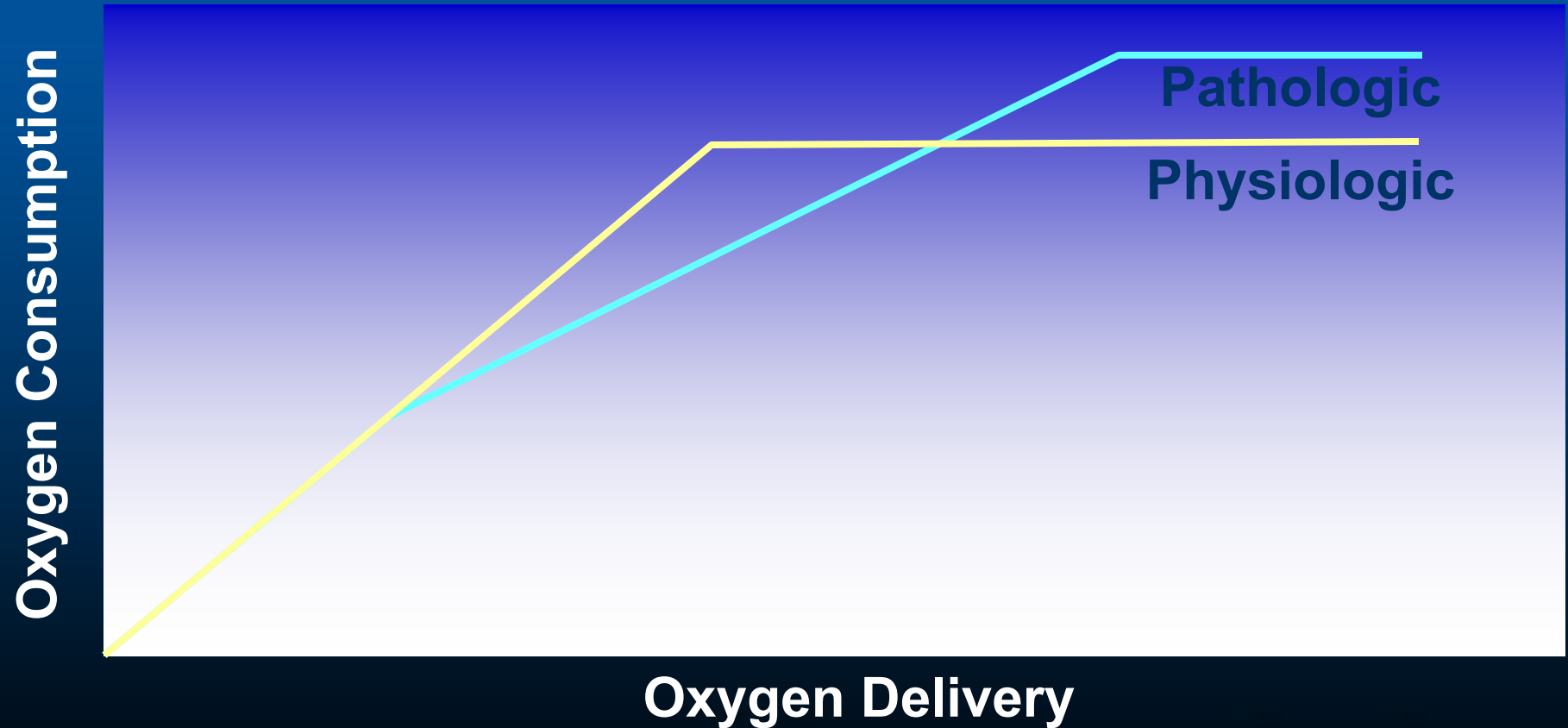
$$CO = SV \times HR$$

Physiologic Oxygen Supply Dependency





Pathologic Oxygen Supply Dependency



Pathophysiology

- Most forms of shocks

↓ **DO₂**

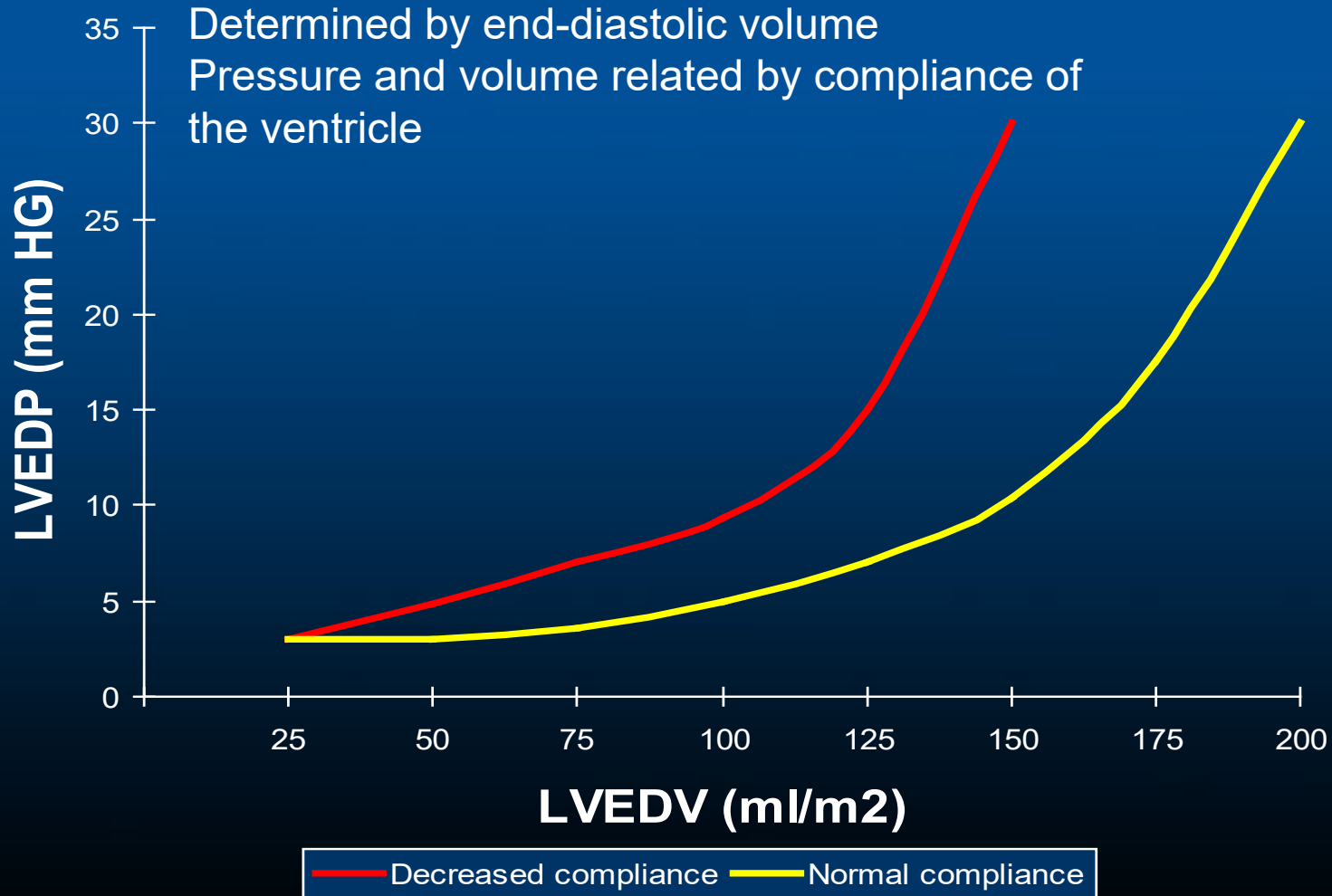
- Septic shock

↓ **VO₂**

Question #3

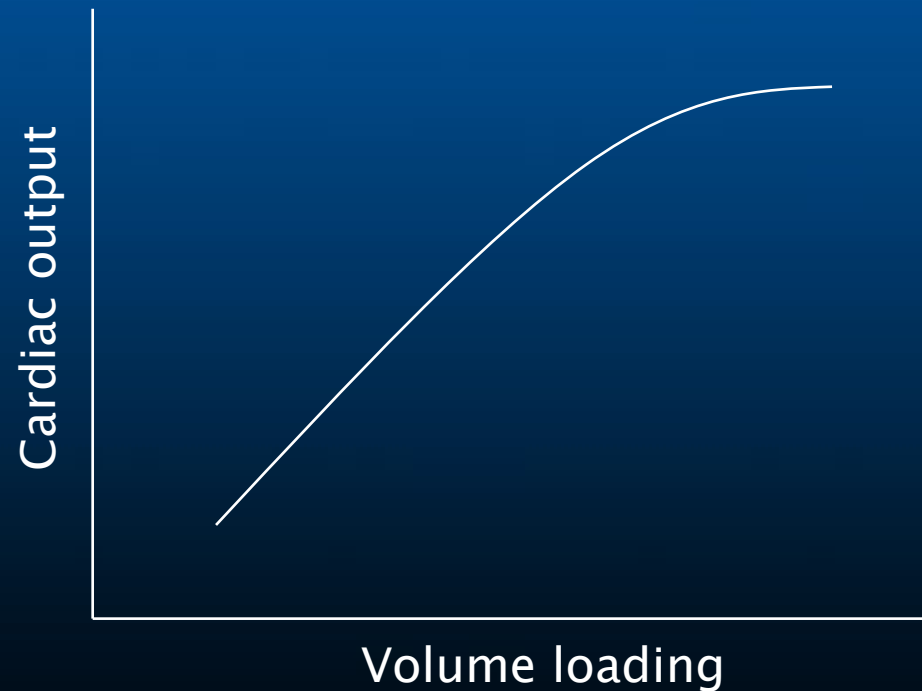
- Which of the following is not an important determinant of oxygen delivery?
- (a) Hemoglobin level
- (b) Cardiac output
- (c) pO_2
- (d) SaO_2

Left ventricular end-diastolic pressure versus left ventricular end-diastolic volume

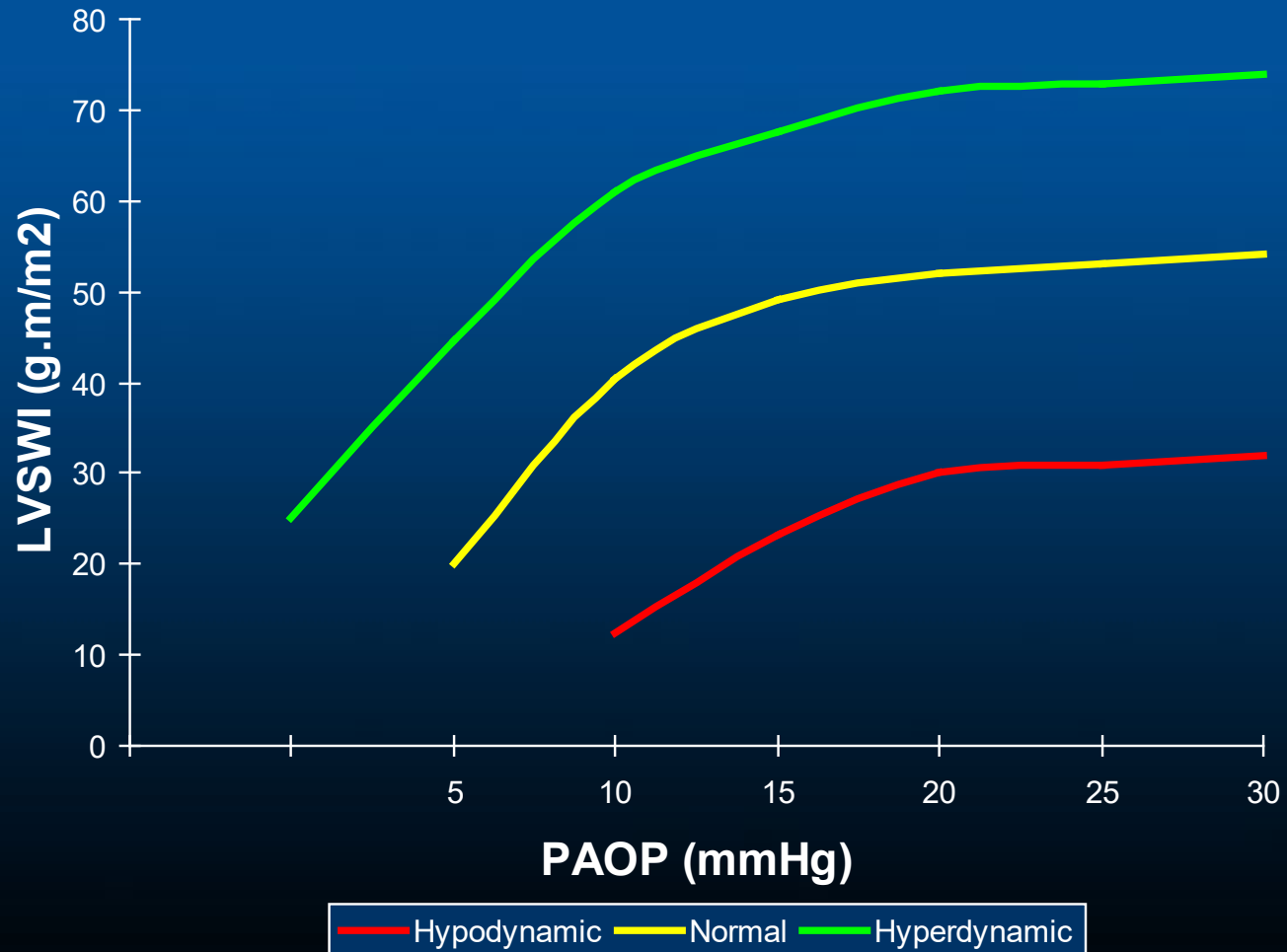


Cardiac Output

- Sterling relationship



Clinical Adaptation of the Sterling Myocardial Function Curves



Global Hemodynamic Relationships

$$MAP = CO \times SVR$$

$$HR \times SV$$

Preload

Contractility

Afterload

Question #4

- Which of the following can cause low preload?
- (a) High PEEP
- (b) Tension pneumothorax
- (c) Third spacing
- (d) Positive pressure ventilation
- (e) All of the above

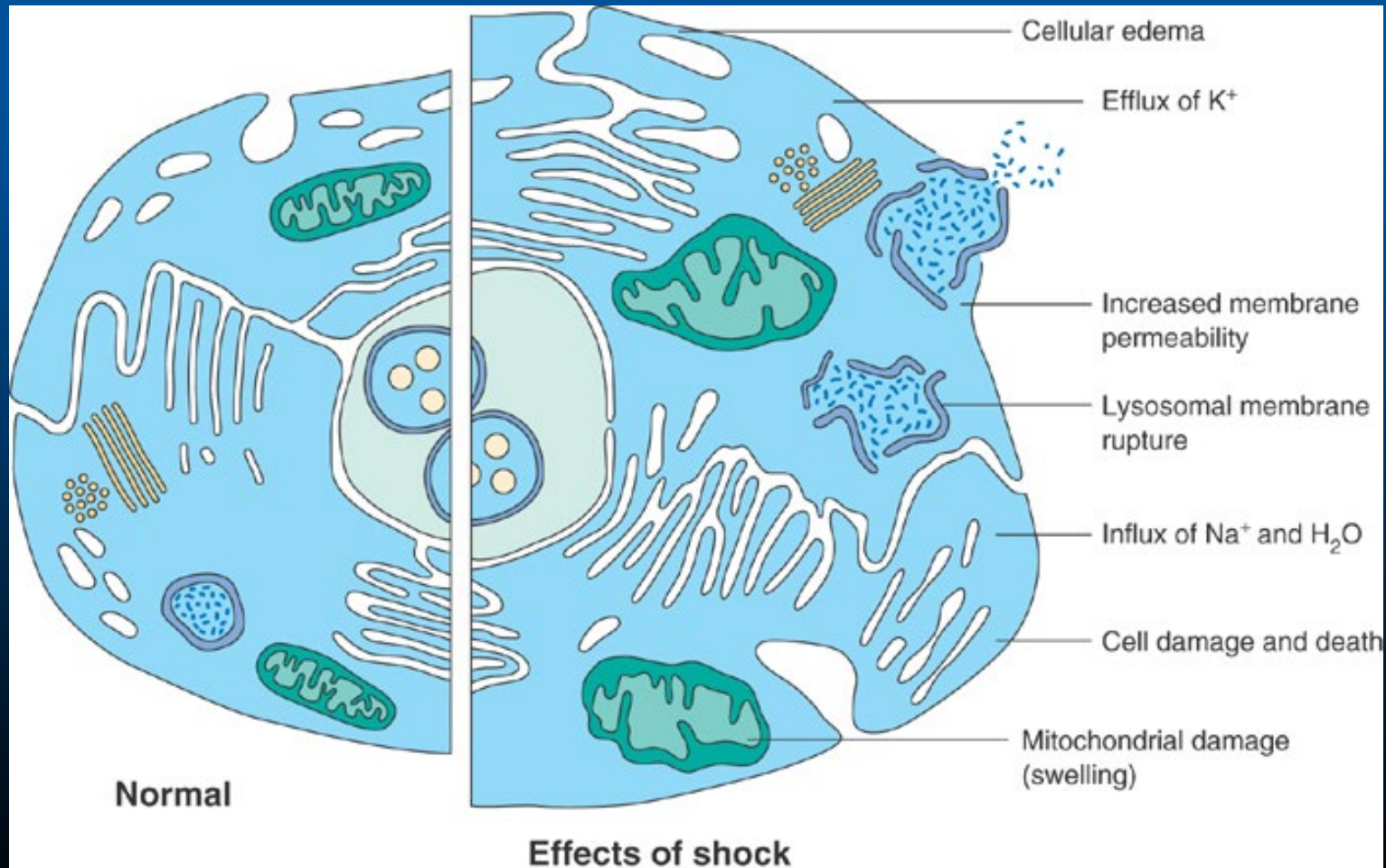


**Common Histopathology Associated
with
Tissue Hypoperfusion and Shock?**

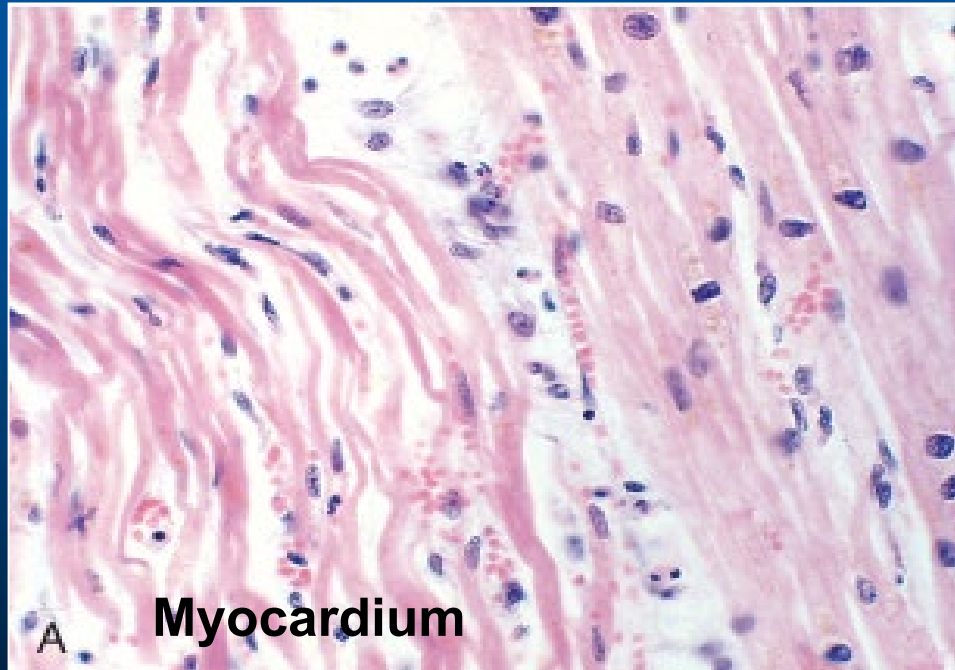
Pathophysiology

- Inadequate/ineffective DO_2 leads to anaerobic metabolism
- Large/prolonged oxygen deficit causes decrease of high-energy phosphates stores
- Membrane depolarization, intracellular edema, loss of membrane integrity and ultimately cell death

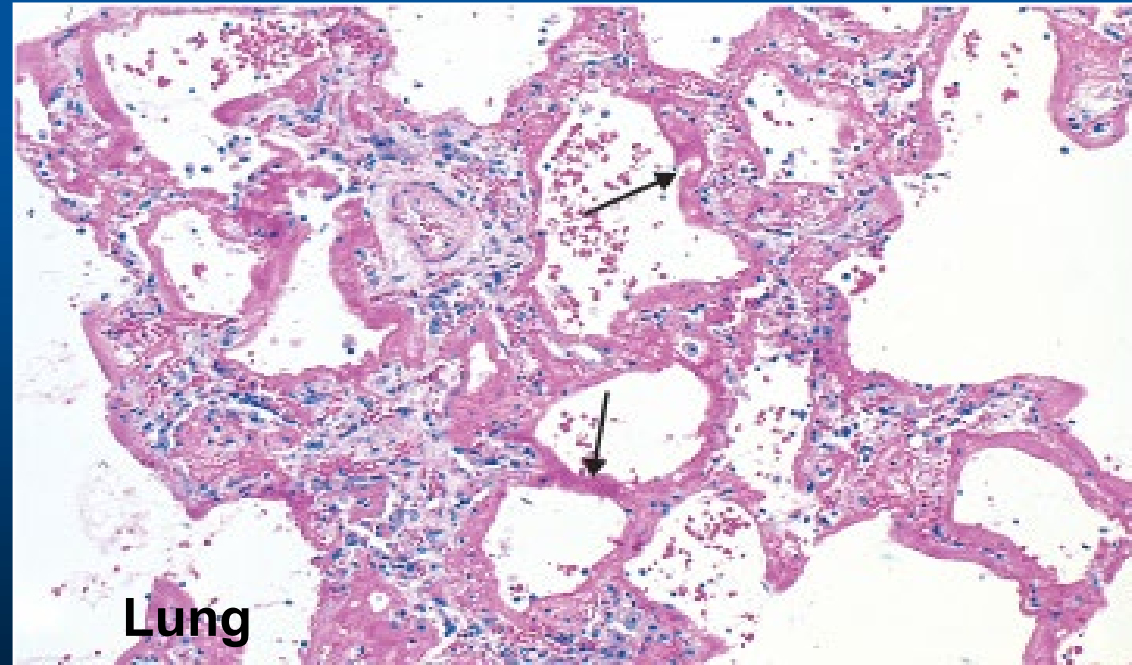
Effects of Shock at Cellular Level



Histopathology of Tissue Hypoperfusion Associated with Shock



- Coagulative necrosis**
- Contraction bands**
- Edema**
- Neutrophil infiltrate**

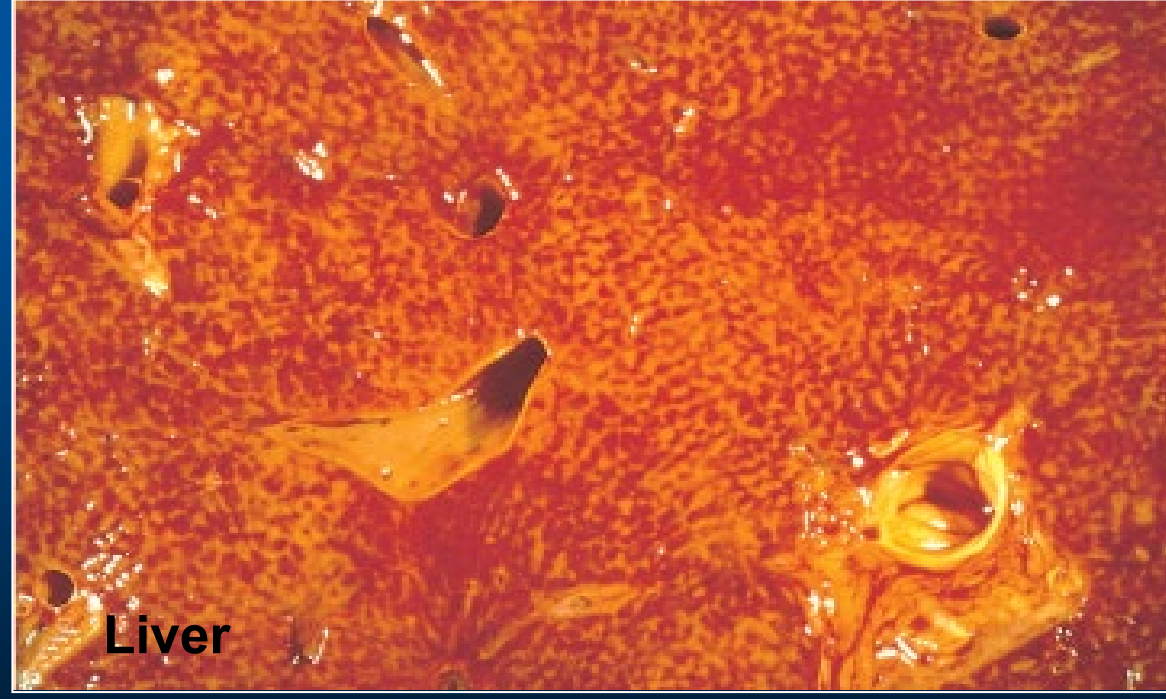


- Diffuse alveolar damage**
- Exudate, atelectasis**
- Edema**
- Hyaline membrane**

Histopathology of Tissue Hypoperfusion Associated with Shock

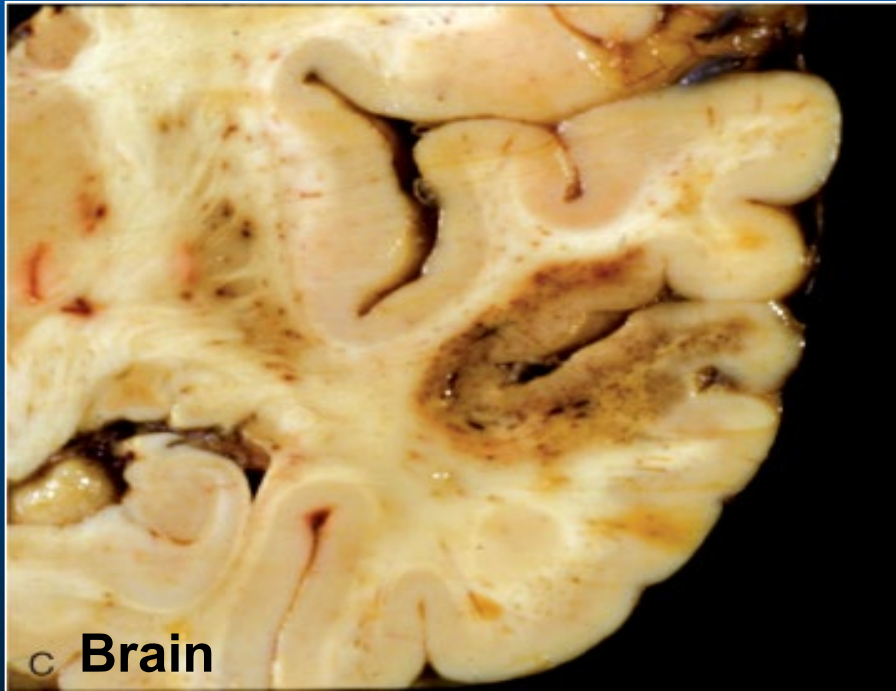


Mucosal infarction
Hemorrhagic mucosa
Epithelium absent

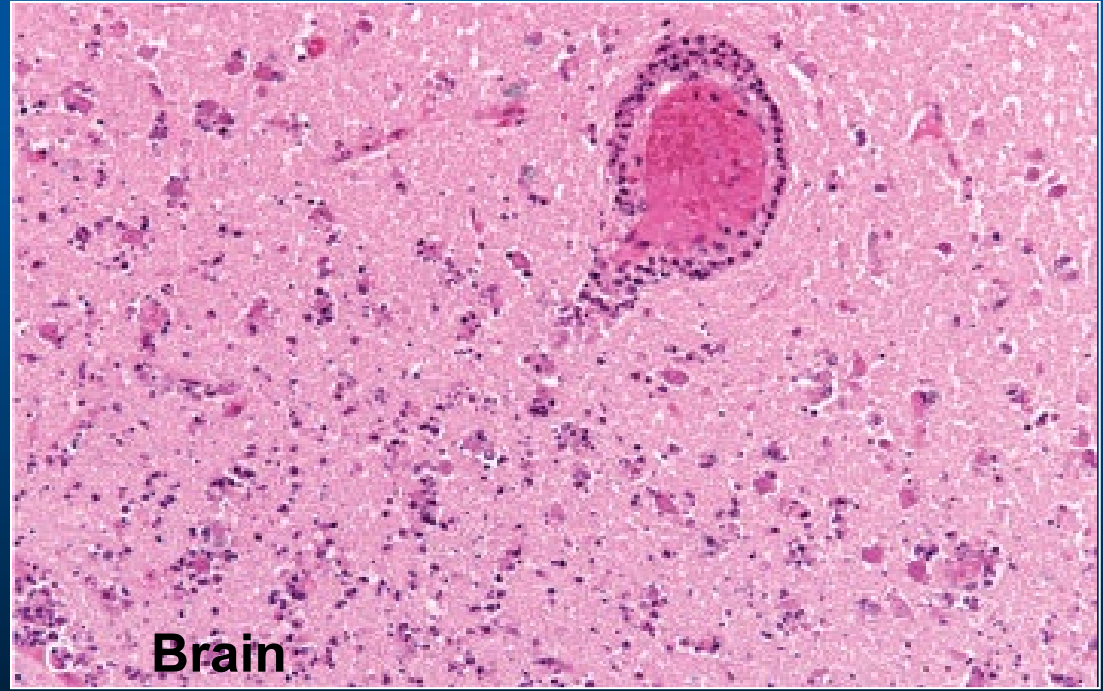


Centrilobular hemorrhagic necrosis
Nutmeg appearance

Histopathology of Tissue Hypoperfusion Associated with Shock

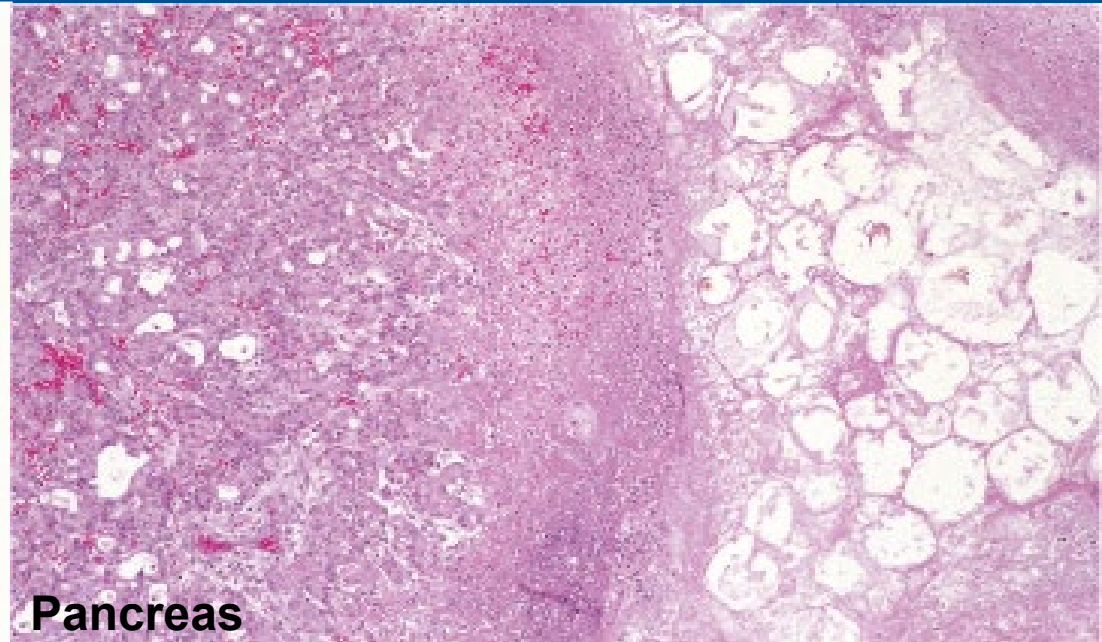
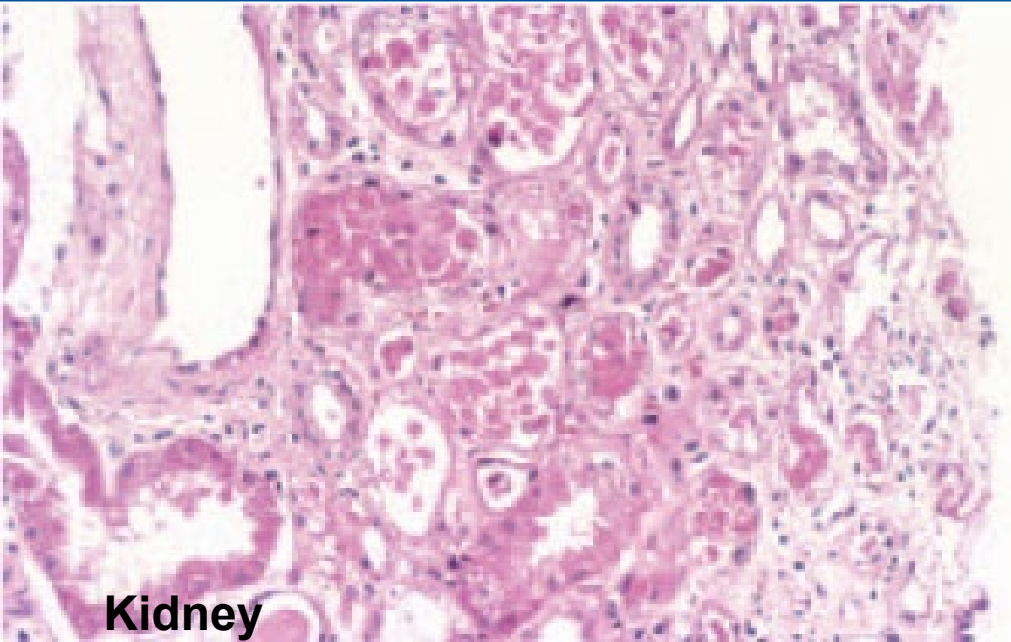


Bland infarct
Punctate hemorrhages



Eosinophilia and shrinkage of neurons
Neutrophil infiltration

Histopathology of Tissue Hypoperfusion Associated with Shock



Kidney

Pancreas

Tubular cells, necrotic
Detached from basement membrane
Swollen, vacuolated

Fat necrosis
Parenchymal necrosis

Incidence of Ischemic Histopathology in Patients Dying with Shock

	Hypovolemic n = 102 (%)	Septic n = 93 (%)	Cardiogenic n = 197 (%)
Heart	37	17	100
Lung	55	65	10
Kidney	25	18	11
Liver	46	30	56
Intestine	9	26	16
Pancreas	7	6	3
Brain	6	3	4

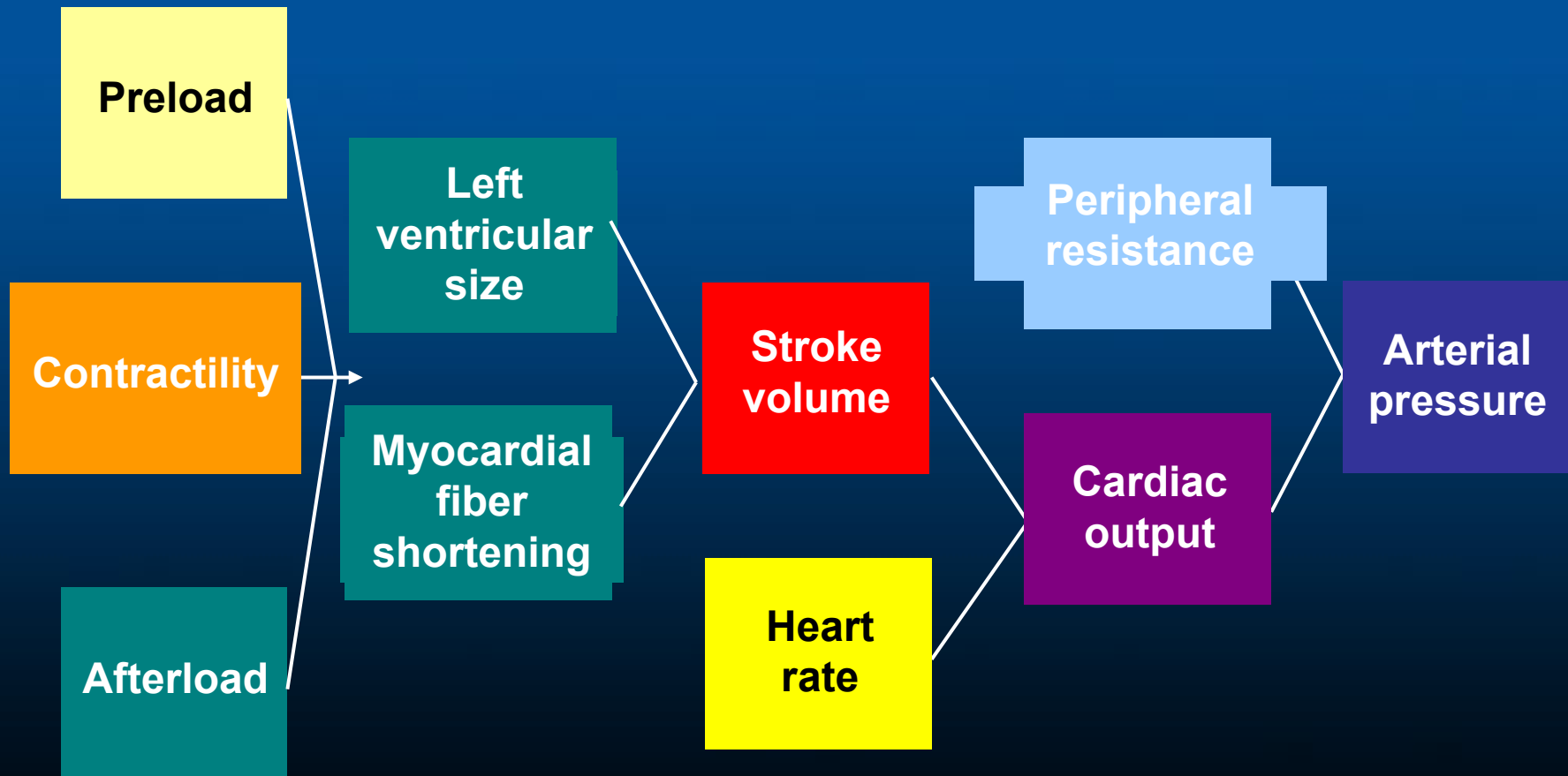


Shock Syndromes

Shocks

- ✦ **Cardiogenic shock** - a major component of the the mortality associated with cardiovascular disease (the #1 cause of U.S. deaths)
- ✦ **Hypovolemic shock** - the major contributor to early mortality from trauma (the #1 cause of death in those < 45 years of age)
- ✦ **Septic shock** - the most common cause of death in American ICUs (the 13th leading cause of death overall in US)

Cardiac Performance



Case 1

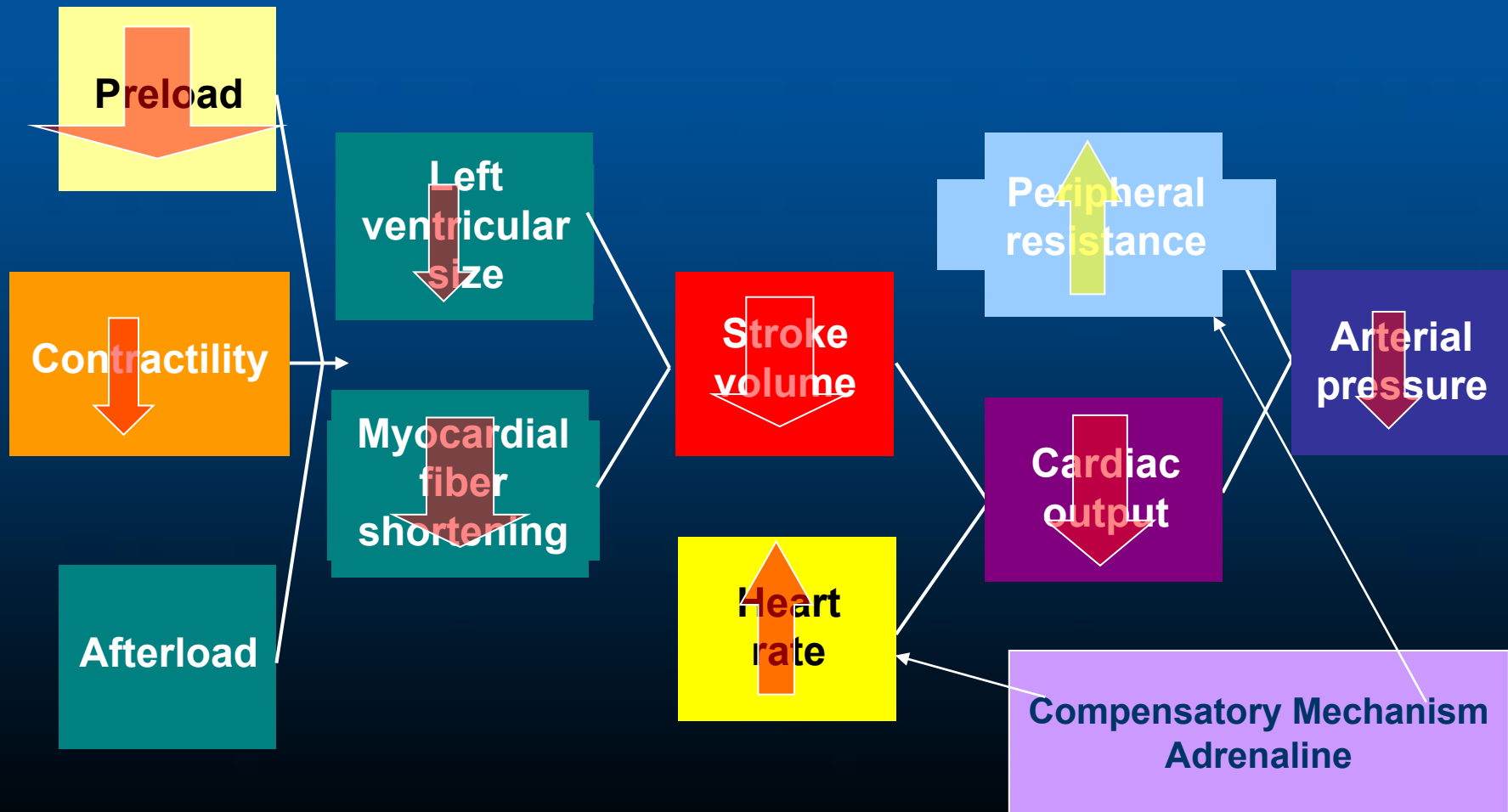
- 34 year old involved in a motor vehicle accident arrived to emergency room with blood pressure of 70/45 and heart rate of 142/min



Question #5

- Which of the following is typical of hypovolemic shock?
- (a) High SVR
- (b) High cardiac output
- (c) High oxygen delivery
- (d) Normal wedge pressure

Hypovolemic Shock



Hypovolemic Shock Hemodynamics

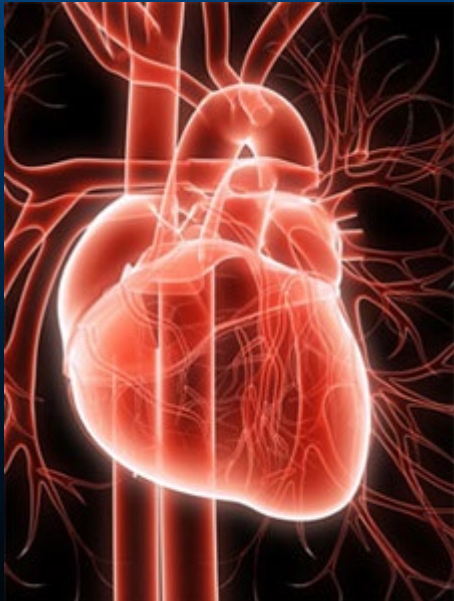
	CO	SVR	PWP	EDV
Hypovolemic	↓	↑	↓	↓
Cardiogenic	↓	↑	↑	↑
Obstructive				
afterload	↓	↑↑	↑	↑
preload	↓	↑	↑	↓
Distributive				
pre-resusc	↓	↑	↓	↓
post-resusc	↑	↓	↑	↑

Hypovolemic Shock

- ✦ Hemorrhagic
 - Trauma
 - Gastrointestinal
 - Retroperitoneal
- ✦ Fluid depletion (nonhemorrhagic)
 - External fluid loss
 - Dehydration
 - Vomiting
 - Diarrhea
 - Polyuria
 - Interstitial fluid redistribution
 - Thermal injury
 - Trauma
 - Anaphylaxis
- ✦ Increased vascular capacitance (venodilatation)
 - Sepsis
 - Anaphylaxis
 - Toxins/drugs

Case 2

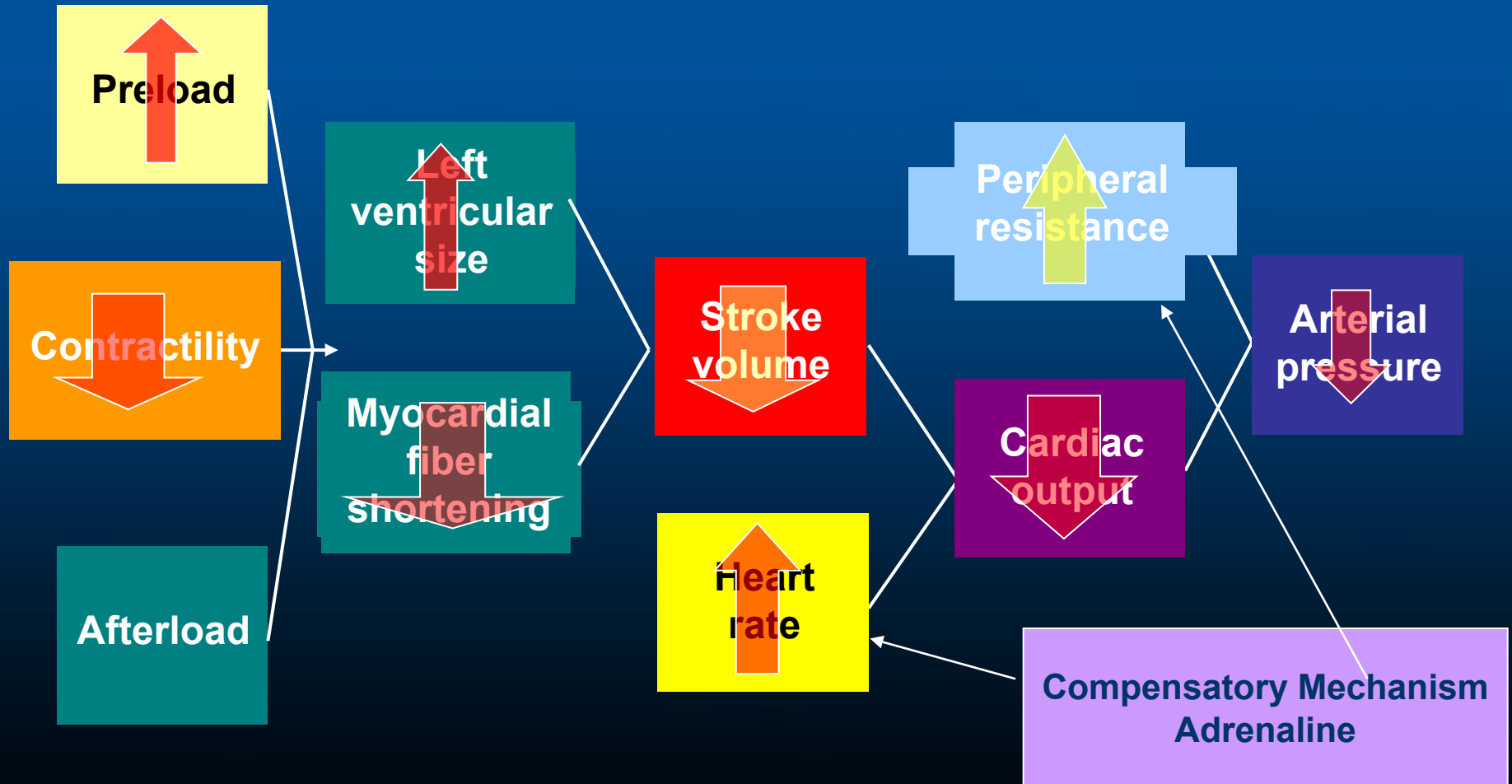
- 54 year old with acute onset chest pain arrived to emergency room with blood pressure of 70/50 and heart rate of 140/min



Question #5

- Which of the following is typical of cardiogenic shock?
- (a) Low SVR
- (b) High cardiac output
- (c) Low oxygen delivery
- (d) Low wedge pressure

Cardiogenic Shock



Cardiogenic Shock Hemodynamics

	CO	SVR	PWP	EDV
Hypovolemic	↓	↑	↓	↓
Cardiogenic	↓	↑	↑	↑
Obstructive				
afterload	↓	↑↑	↑	↑
preload	↓	↑	↑	↓
Distributive				
pre-resusc	↓	↑	↓	↓
post-resusc	↑	↓	↑	↑

Cardiogenic Shock

- ✦ Myopathic
 - Myocardial infarction (hibernating & stunned myocardium)
- ✦ Right ventricle
- ✦ Myocardial contusion (trauma)
- ✦ Myocarditis
- ✦ Cardiomyopathy
- ✦ Septic myocardial depression
- ✦ Pharmacologic
 - Anthracycline cardiotoxicity
 - Calcium channel blockers
- ✦ Mechanical
 - Valvular failure (stenotic or regurgitant)
 - Hypertrophic cardiomyopathy
 - Ventricular septal defect
- ✦ Arrhythmic
 - Bradycardia
 - Tachycardia

Case 3

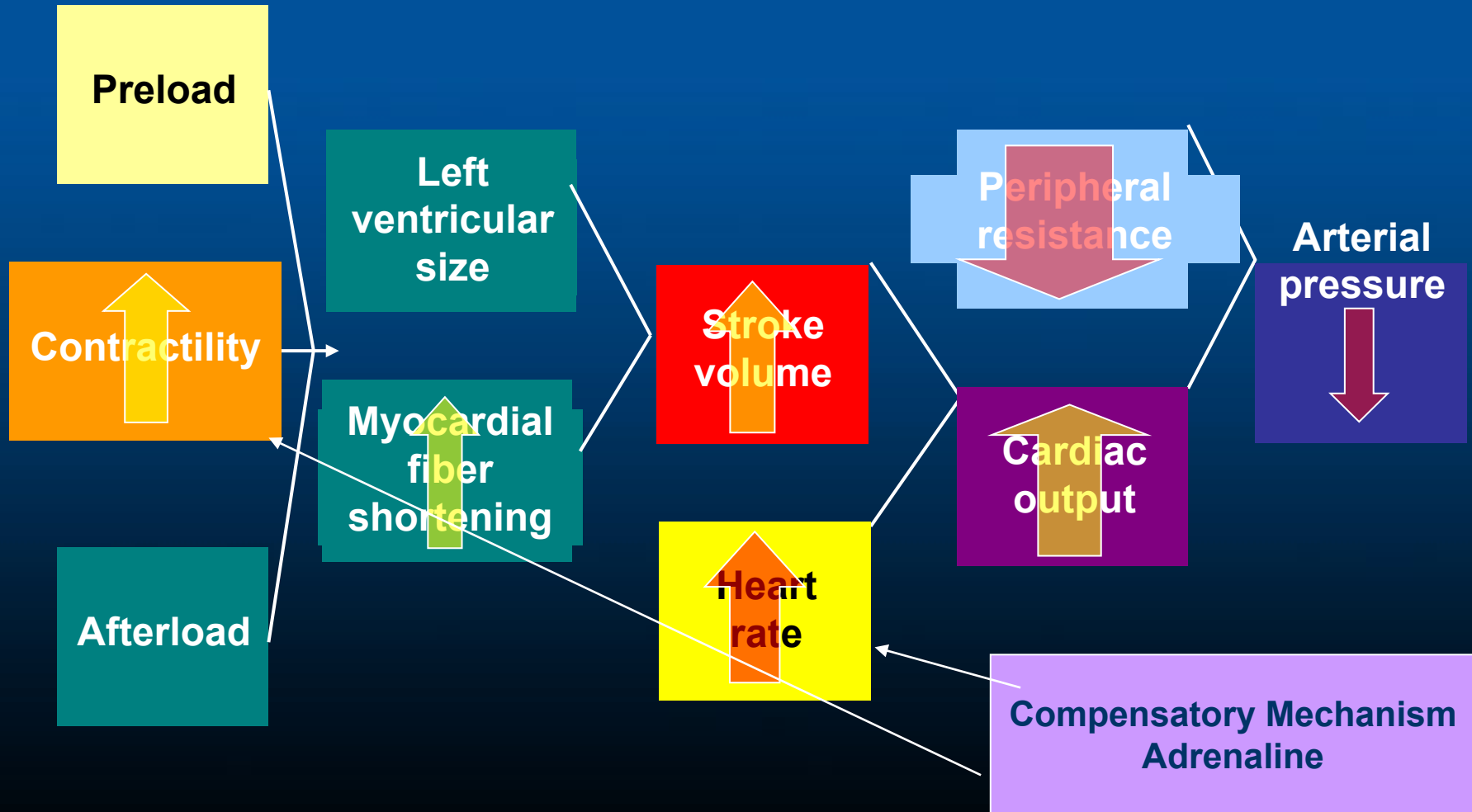
- 67 year old with fever, chills, SOB, and ugly looking abdominal wound arrived to emergency room with blood pressure of 70/30 and heart rate of 135/min



Question #6

- Which of the following is not typical of sepsis?
- (a) Low SVR
- (b) High cardiac output
- (c) Low oxygen delivery
- (d) Low wedge pressure

Distributive Shock



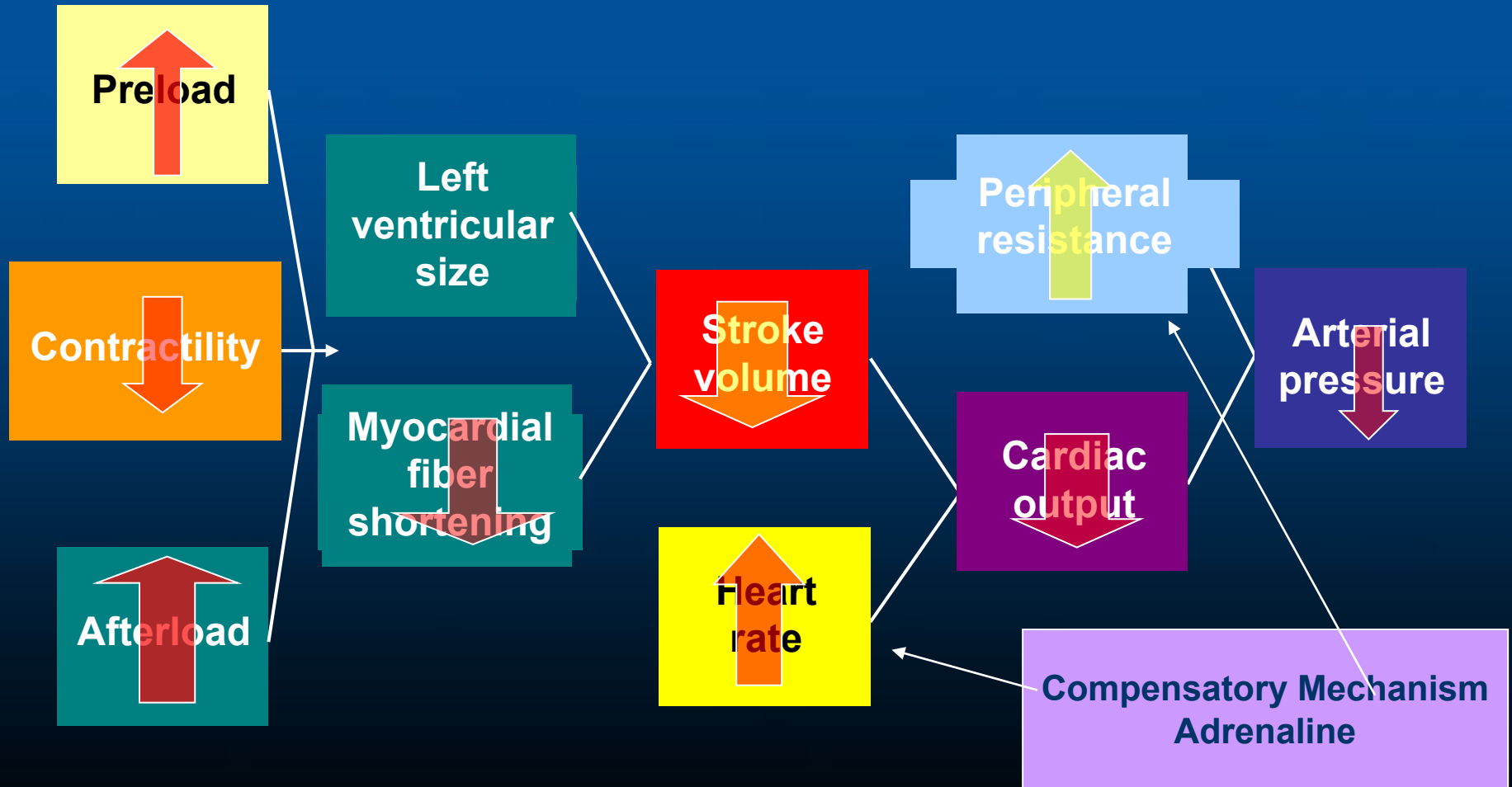
Distributive Hemodynamics

	CO	SVR	PWP	EDV
Hypovolemic	↓	↑	↓	↓
Cardiogenic	↓	↑	↑	↑
Obstructive				
afterload	↓	↑↑	↑	↑
preload	↓	↑	↑	↓
Distributive				
pre-resusc	↓	↑	↓	↓
post-resusc	↑	↓	↑	↑

Distributive Shock

- ◆ Septic (bacterial, fungal, viral, rickettsial)
- ◆ Toxic shock syndrome
- ◆ Anaphylactic, anaphylactoid
- ◆ Neurogenic (spinal shock)
- ◆ Endocrinologic
 - Adrenal crisis
 - Thyroid storm
- ◆ Toxic (e.g., nitroprusside, bretylium)

Obstructive Shock



Obstructive Shock Hemodynamics

	CO	SVR	PWP	EDV
Hypovolemic	↓	↑	↓	↓
Cardiogenic	↓	↑	↑	↑
Obstructive				
afterload	↓	↑↑	↑	↑↓
preload	↓	↑	↑	↓
Distributive				
pre-resusc	↓	↑↓	↓	↓
post-resusc	↑	↓	↑	↑

Extracardiac Obstructive Shock

- ✦ Impaired diastolic filling (decreased ventricular preload)
 - Direct venous obstruction (vena cava)
 - Intrathoracic obstructive tumors
 - Increased intrathoracic pressure
 - Tension pneumothorax
 - Mechanical ventilation (with excessive pressure or volume depletion)
 - Asthma
 - Decreased cardiac compliance
 - Constrictive pericarditis
 - Cardiac tamponade
- ✦ Impaired systolic contraction (increased ventricular afterload)
 - Right ventricle
 - Pulmonary embolus (massive)
 - Acute pulmonary hypertension
 - Left ventricle
 - Aortic dissection



Shock Evaluation and Monitoring

Symptoms of Shock

General Symptoms

- Anxiety /Nervousness
- Dizziness
- Weakness
- Faintness
- Nausea & Vomiting
- Thirst
- Confusion
- Decreased UO

Specific Symptoms

- Diarrhoea
- Chest Pain
- Fevers / Rigors
- SOB

Signs of Shock

Pale

Cold & Clammy

Sweating

Cyanosis

Tachycardia

Tachypnoea

Confused / Agitated

Unconscious

Hypotensive/Oliguric

Stridor / SOB

Capillary Refill



Skin Mottling



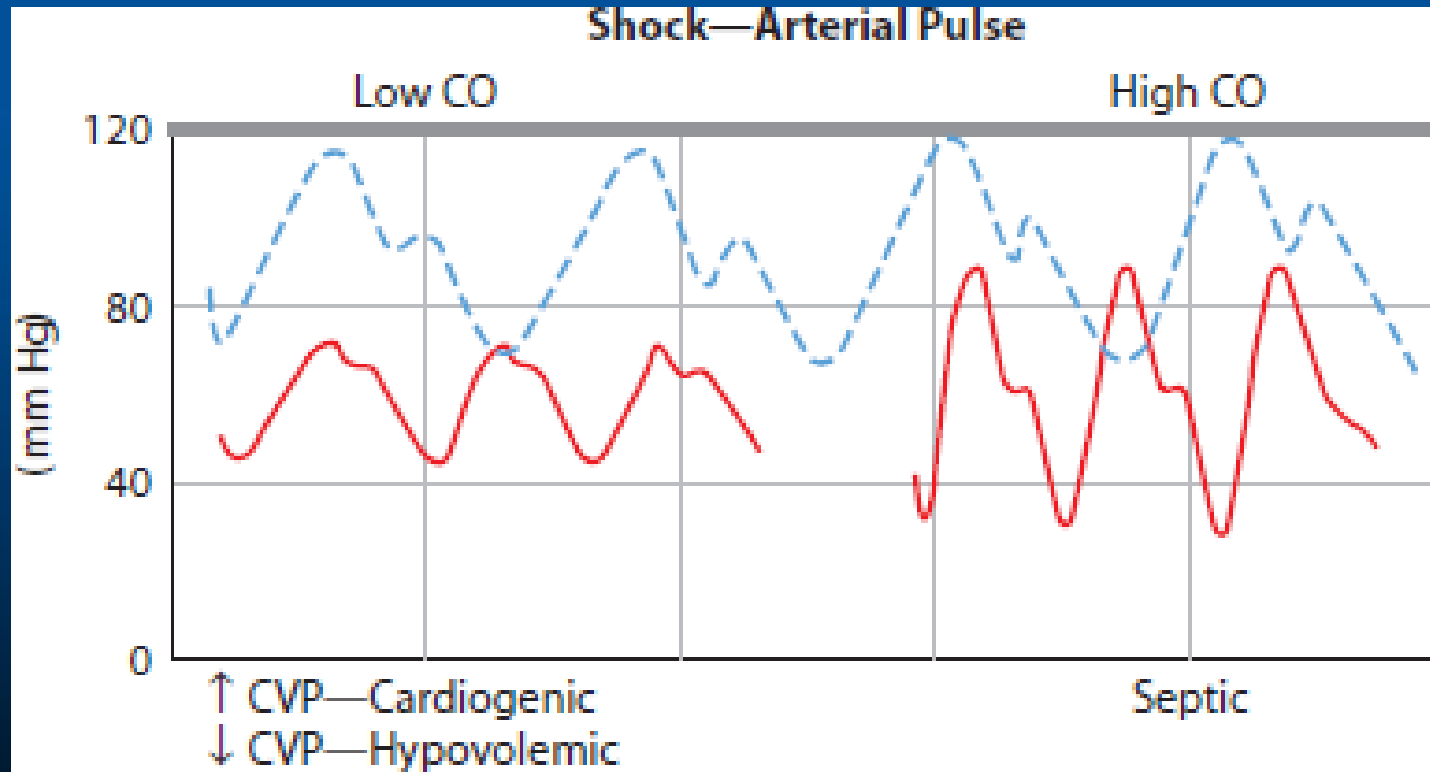
Skin Mottling



Unable to produce Tachycardia

- Limited cardiac response to catecholamine stimulation: elderly
- Autonomic dysfunction: DM
- Concurrent use of beta-adrenergic blocking agents
- The presence of a pacemaker

Arterial Pulse in Shocks



Source: Jesse B. Hall, Gregory A. Schmidt, John P. Kress: *Principles of Critical Care*, 4th Edition: www.accessmedicine.com
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Classification of Hemorrhagic Shock

	Class I	Class II	Class III	Class IV
Blood loss (ml)	Up to 750	750-1500	1500-2000	>2000
Blood loss (%)	Up to 15%	15-30%	30-40%	>40%
Pulse rate	<100	>100	>120	>140
Blood pressure	Normal	Normal	Decreased	Decreased
Pulse pressure	Normal	Decreased	Decreased	Decreased
Respiratory rate	14-20	20-30	30-40	>35
Urine output (ml/h)	>30	20-30	5-15	Negligible
CNS/mental status	Slightly anxious	Mildly anxious	Anxious/confused	Confused/lethargic
Fluid replacement	Crystalloid	Crystalloid	Crystalloid/blood	Crystalloid/Blood

Diagnosis and Evaluation

- Primary diagnosis - tachycardia, tachypnea, oliguria, encephalopathy (confusion), peripheral hypoperfusion (mottled, poor capillary refill vs. hyperemic and warm), hypotension
- Differential DX:
 - JVP - hypovolemic vs. cardiogenic
 - Left S3, S4, new murmurs – cardiogenic
 - Right heart failure - PE, tamponade
 - Pulsus paradoxus, Kussmaul's sign – tamponade
 - Fever, rigors, infection focus - septic
 - Poor skin turgor and dry mucous membranes: hypovolemic

A Clinical Approach to Shock Diagnosis and Management

Initial Therapeutic Steps

- ✦ Admit to intensive care unit (ICU)
- ✦ Venous access (1 or 2 large-bore catheters)
- ✦ Central venous catheter
- ✦ Arterial catheter
- ✦ EKG monitoring
- ✦ Pulse oximetry
- ✦ Urine output monitoring
- ✦ Hemodynamic support (MAP < 60 mmHg)
 - Fluid challenge
 - Vasopressors for severe shock unresponsive to fluids

Diagnosis and Evaluation

Laboratory

- Hgb, WBC, platelets
- PT/PTT
- Electrolytes, arterial blood gases
- BUN, Cr
- Ca, Mg
- **Serum lactate**
- ECG

A Clinical Approach to Shock Diagnosis and Management

Initial Diagnostic Steps

- CXR
- Abdominal views*
- CT scan abdomen or chest*
- Echocardiogram*
- Pulmonary perfusion scan*

* When indicated

Vasoactive Agent Receptor Activity

Agent	a1	a2	b1	b2	Dopa
Dobutamine	+	+	++++	++	0
Dopamine	++/+++	?	++++	++	++++
Epinephrine	++++	++++	++++	+++	0
Norepinephrine	+++	+++	+ / +++	0	0
Phenylephrine	++/+++	+	?	0	0

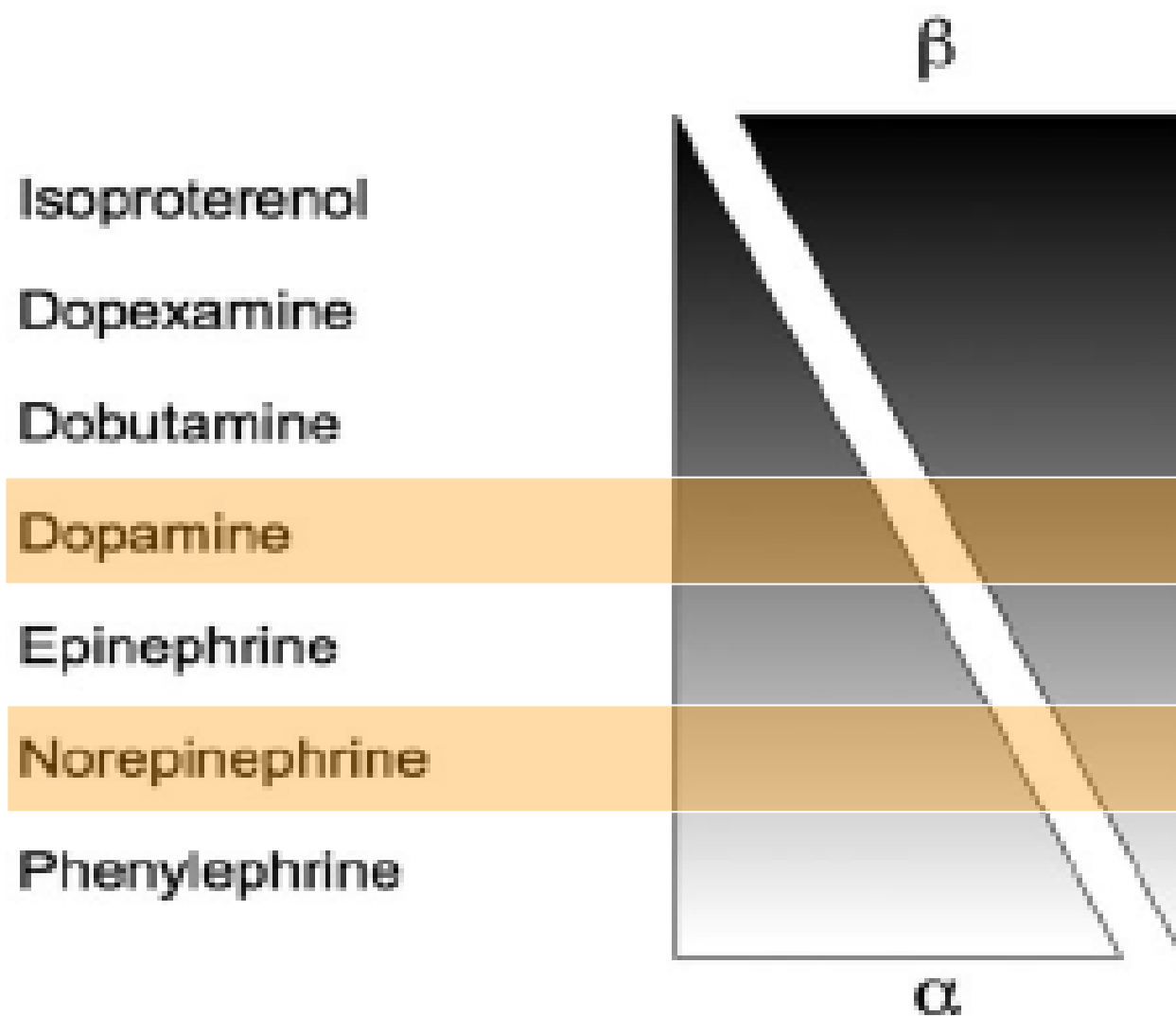
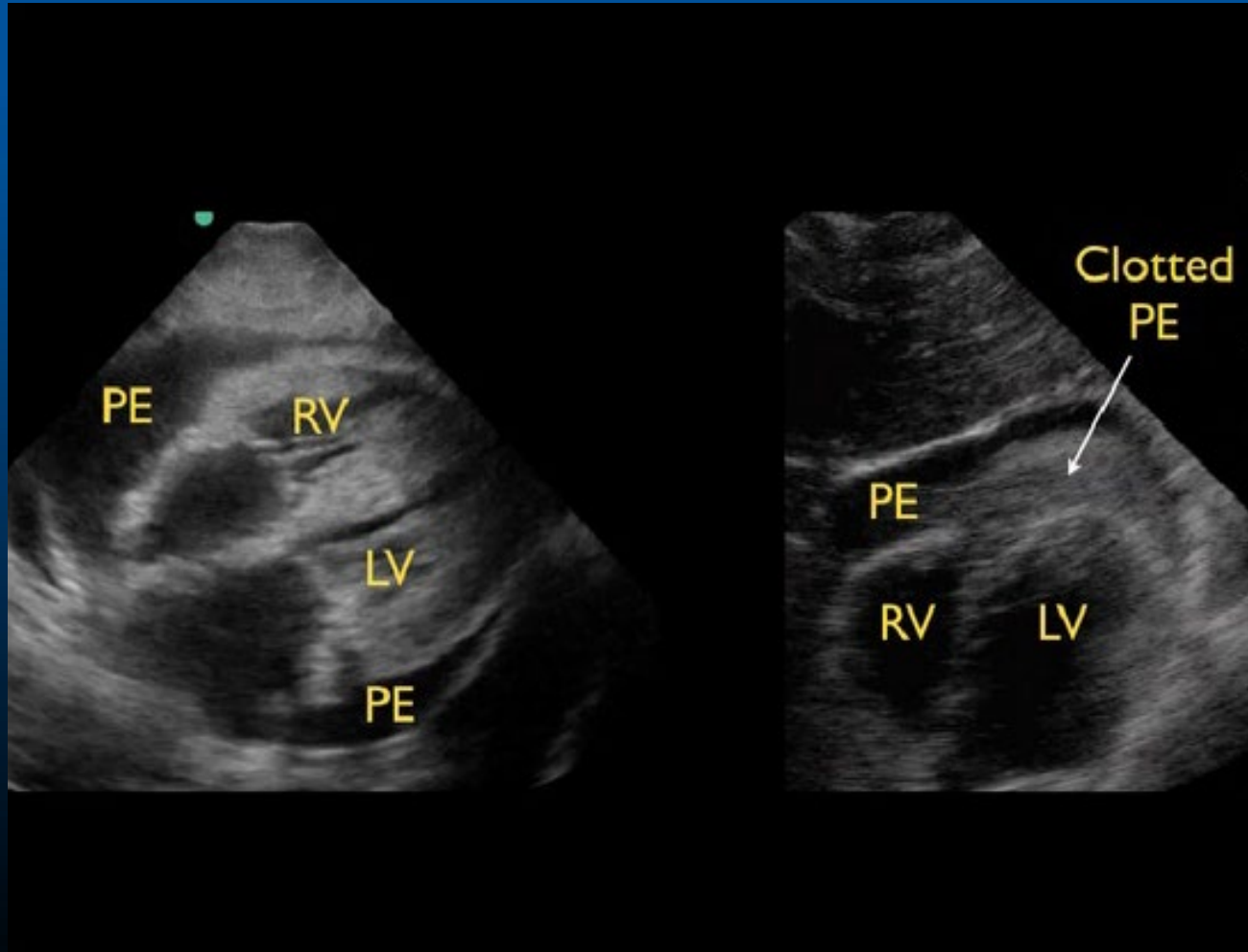
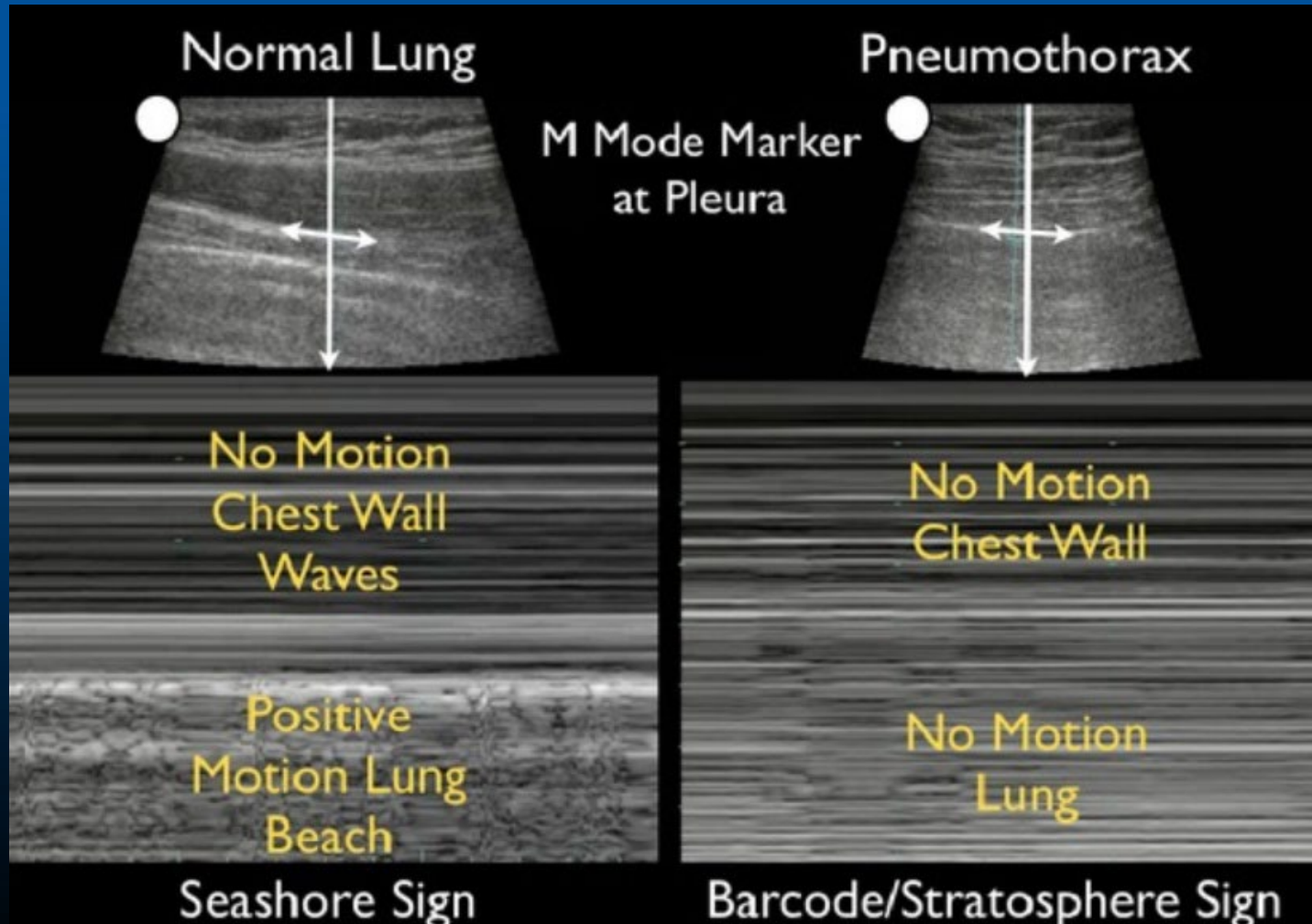


FIGURE 1. α -adrenergic and β -adrenergic effects of vasoactive catecholamines.

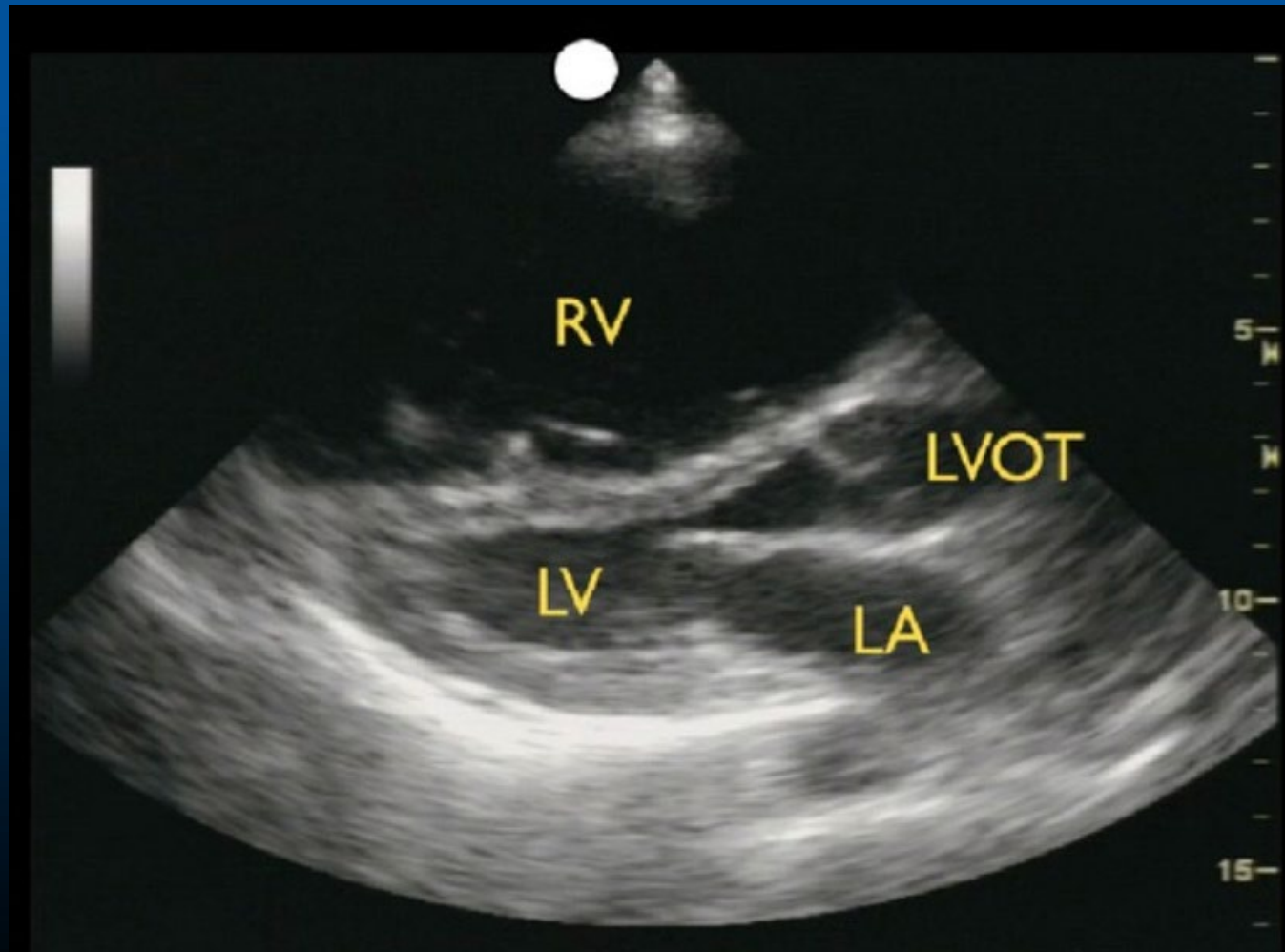
Obstructive Shock



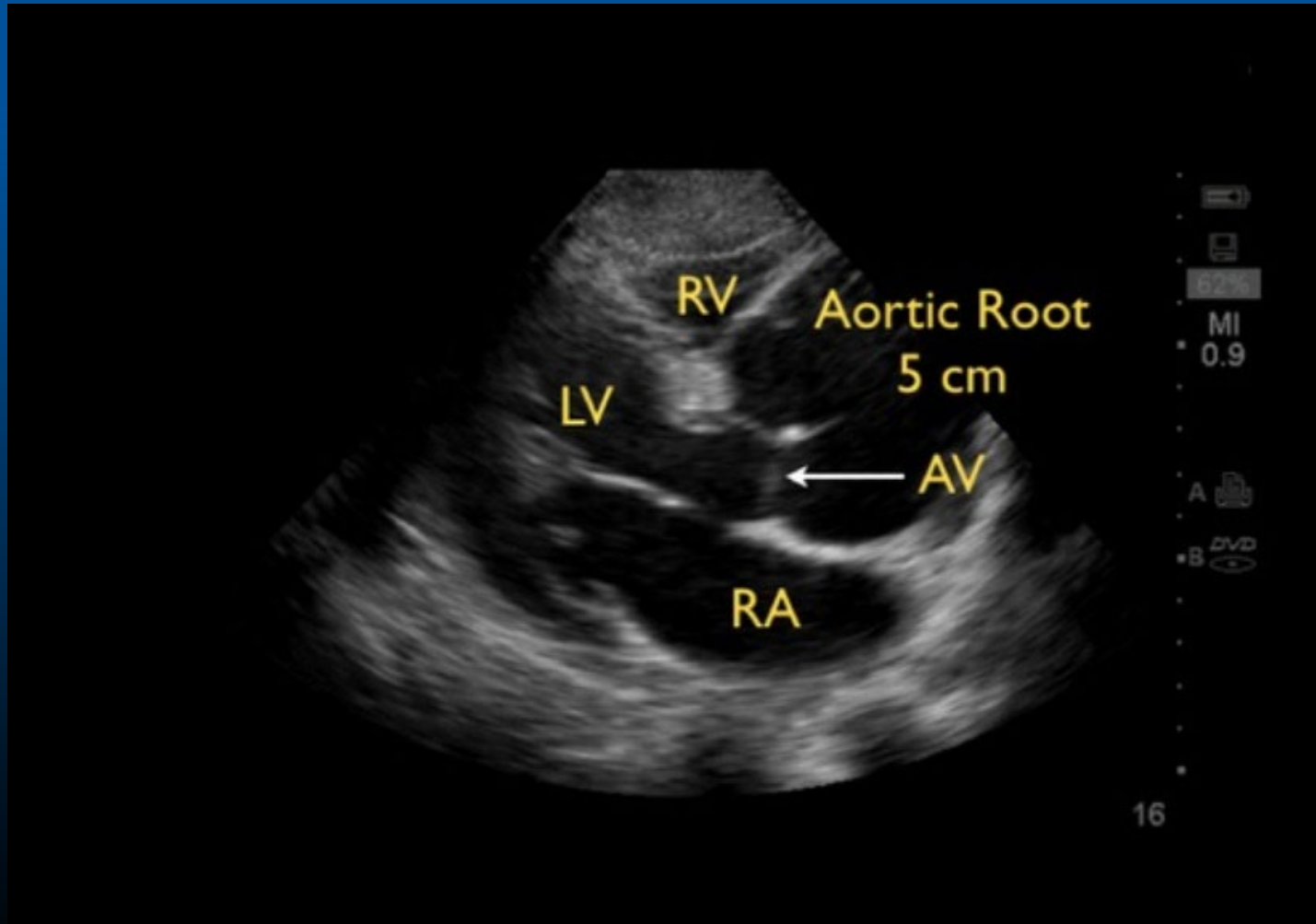
Obstructive Shock



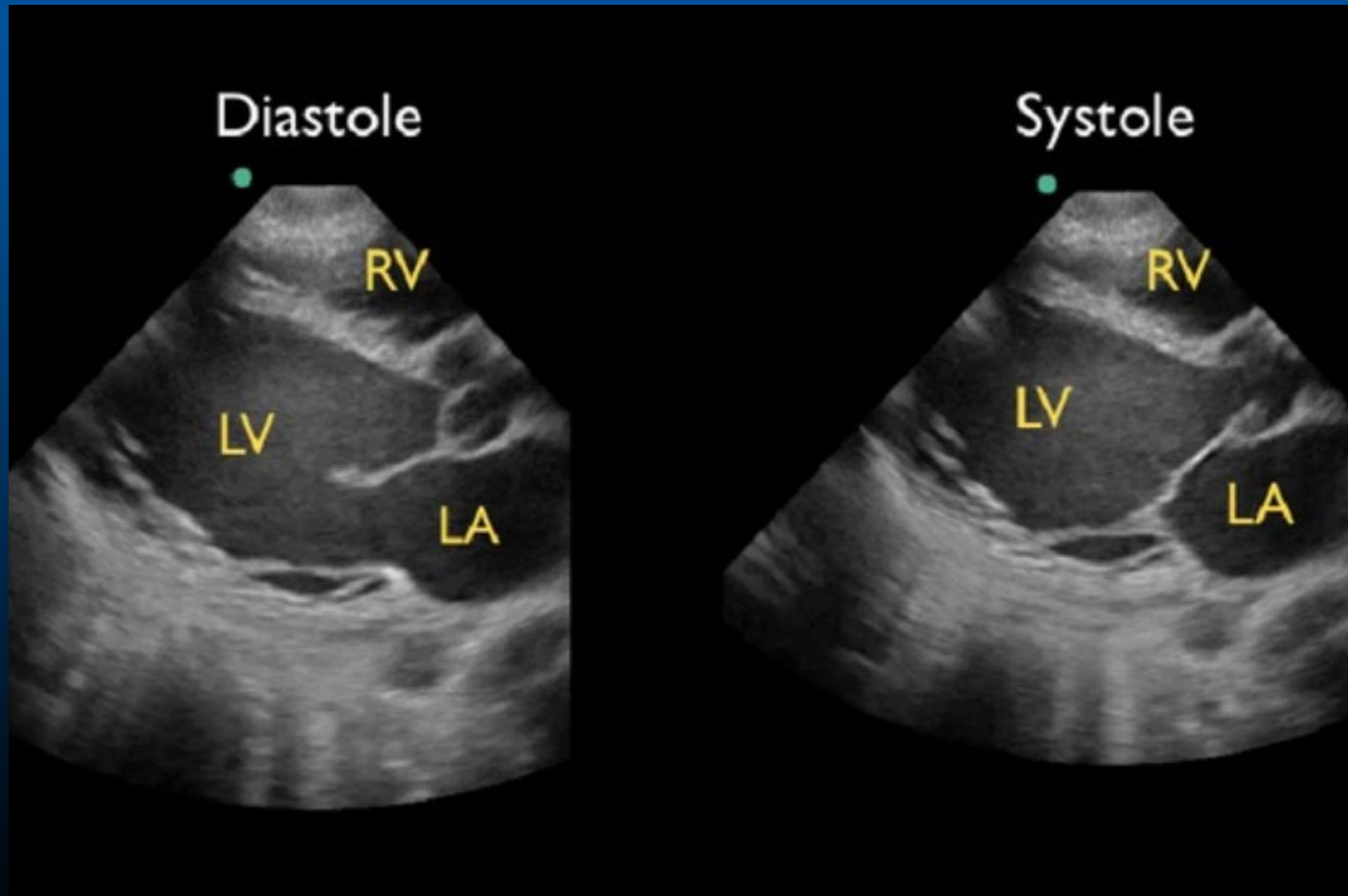
Obstructive Shock



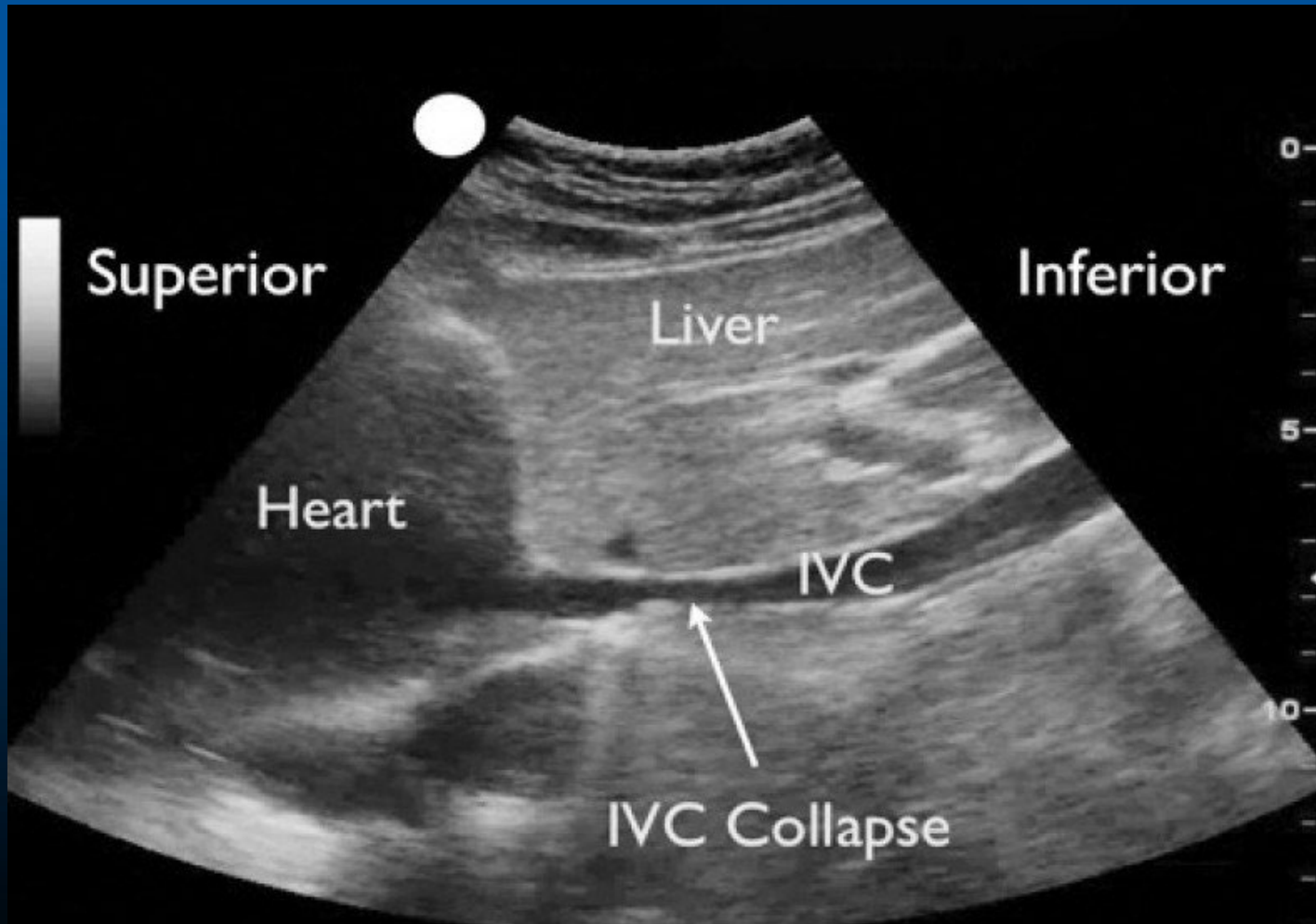
Aortic Arch Dissection



Cardiogenic Shock



Hypovolemic Shock



A black and white photograph showing a close-up of an adult's hand gently holding a baby's hand. The adult's hand is positioned on the right, with the thumb and index finger supporting the baby's hand from underneath. The baby's hand is on the left, with fingers slightly curled. The background is dark, making the hands stand out. The overall mood is tender and protective.

Thank You

There are two great days in a person's life . The day we are born and the day we discover why .