

# Shock Talk: Recognition, Classification, and Treatment of Shock

Joseph Polit, DVM

Emergency & Critical Care Resident  
Cape Cod Vet Specialists



Cape cod vet Specialists

# Outline

- What is shock
- Classifications of shock
- Pathophysiology of shock
- Conditions with shock
- Clinical signs of shock
- Diagnostics
- Monitoring
- Treatment



<https://www.idlememe.com/shocked-meme-12/>

# Objectives

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- Define shock
- Understand the different classifications of shock
- Be able to identify shock
- Be able to treat shock efficiently and appropriately

# What is shock



<https://www.cliniciansbrief.com/article/treating-septic-shock>



# Why Do We Care?

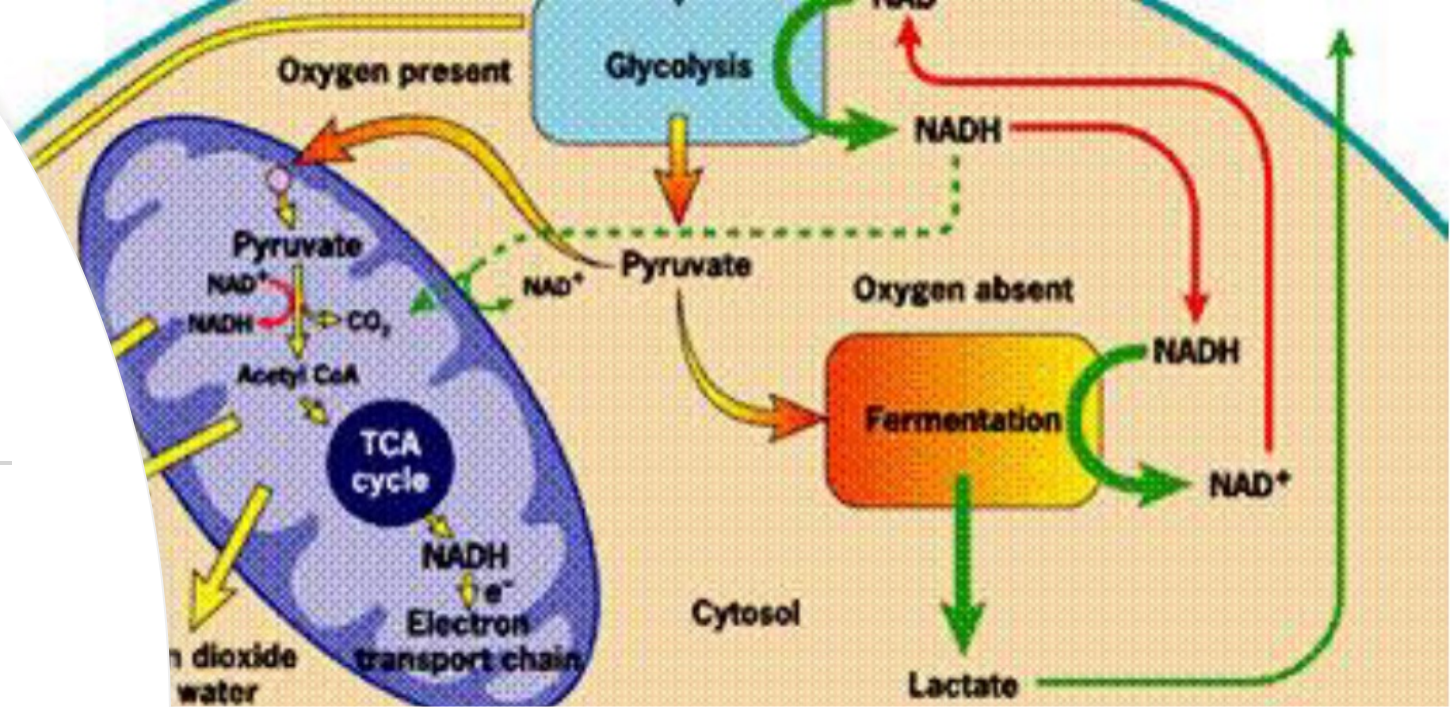
- Shock plays a role in fatal illnesses and is part of the final common pathway of cardiopulmonary arrest.
- Early recognition and appropriate treatment of shock can reverse the sequelae of shock and improve outcomes

## Time to Treatment and Mortality during Mandated Emergency Care for Sepsis

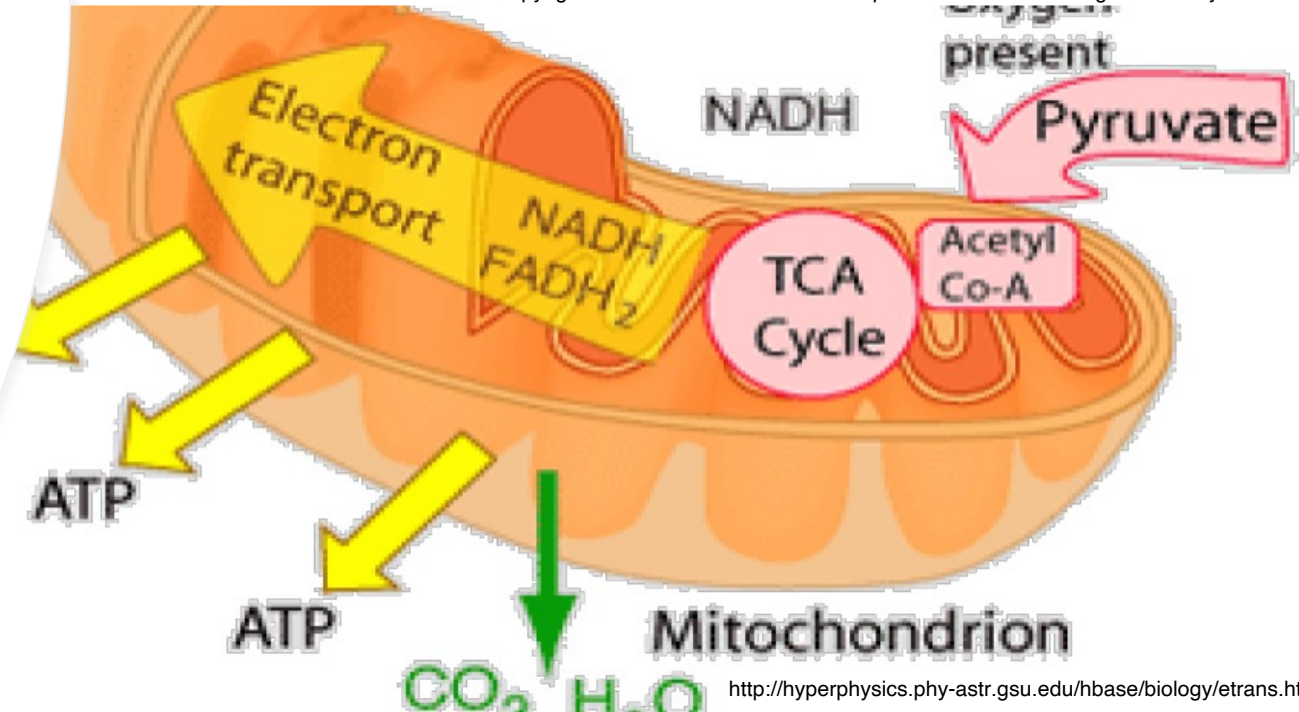
[Christopher W. Seymour](#), M.D., [Foster Gesten](#), M.D., [Hallie C. Prescott](#), M.D., [Marcus E. Friedrich](#), M.D., [Theodore J. Iwashyna](#), M.D., Ph.D., [Gary S. Phillips](#), M.A.S., [Stanley Lemeshow](#), Ph.D., [Tiffany Osborn](#), M.D., M.P.H., [Kathleen M. Terry](#), Ph.D., and [Mitchell M. Levy](#), M.D.

# What Is Shock ?

- Inadequate cellular energy production
- Oxygen or glucose
- Usually due to inadequate oxygen delivery



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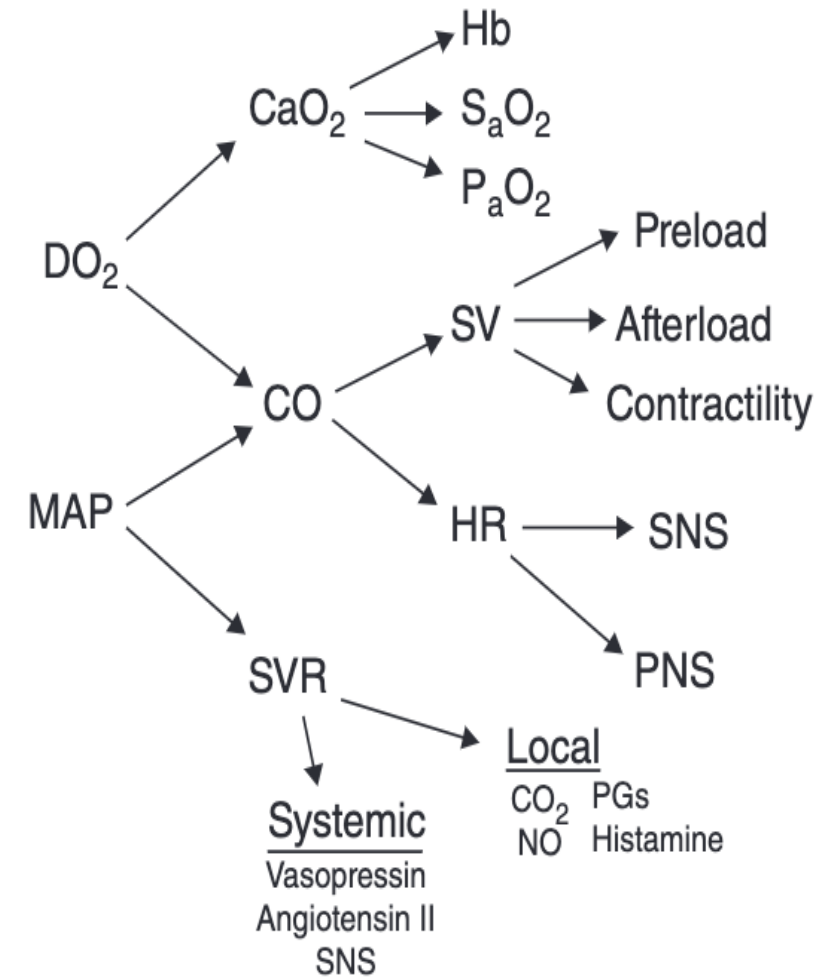


<http://hyperphysics.phy-astr.gsu.edu/hbase/biology/etrans.html>

# Delivery of Oxygen

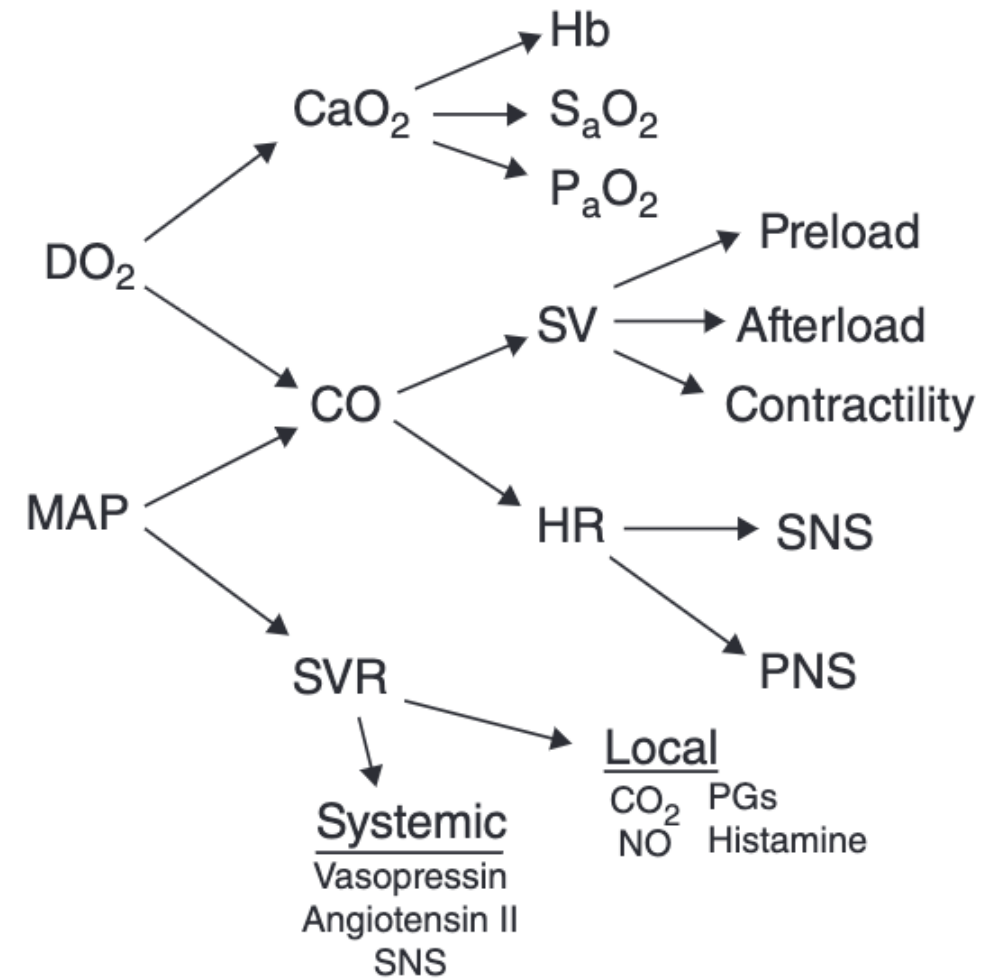
$$DO_2 = CO \times CaO_2$$

$$DO_2 = (HR \times SV) \times [(1.34 \times Hb \times SaO_2) + (PaO_2 \times 0.003)]$$



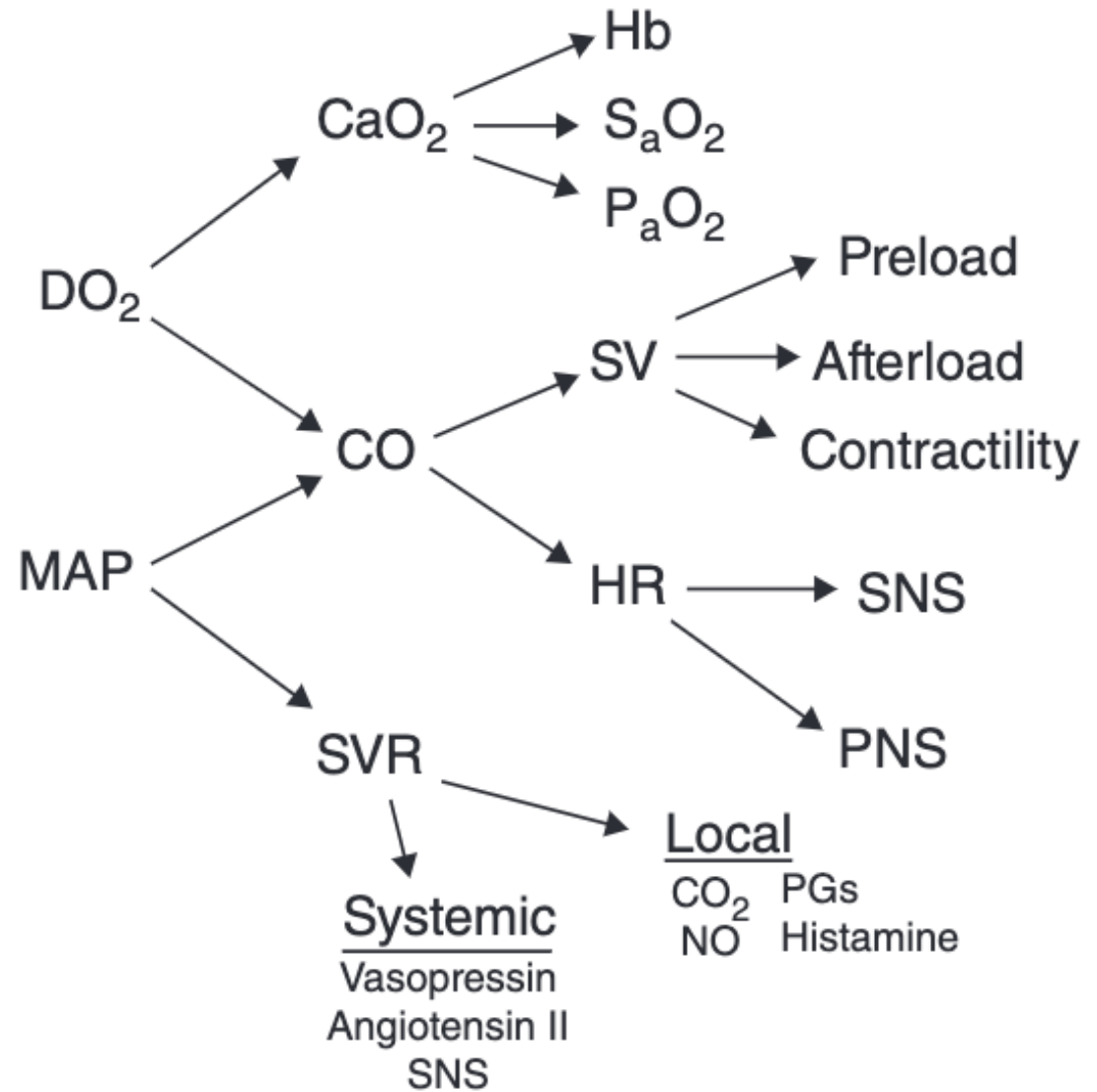
# Defects of Oxygen Delivery

$$DO_2 = CO \times CaO_2$$





# Why Does Shock Occur?



# Classifications of shock

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Hypovolemic

Distributive

Cardiogenic

Neurogenic

Hypoxemic

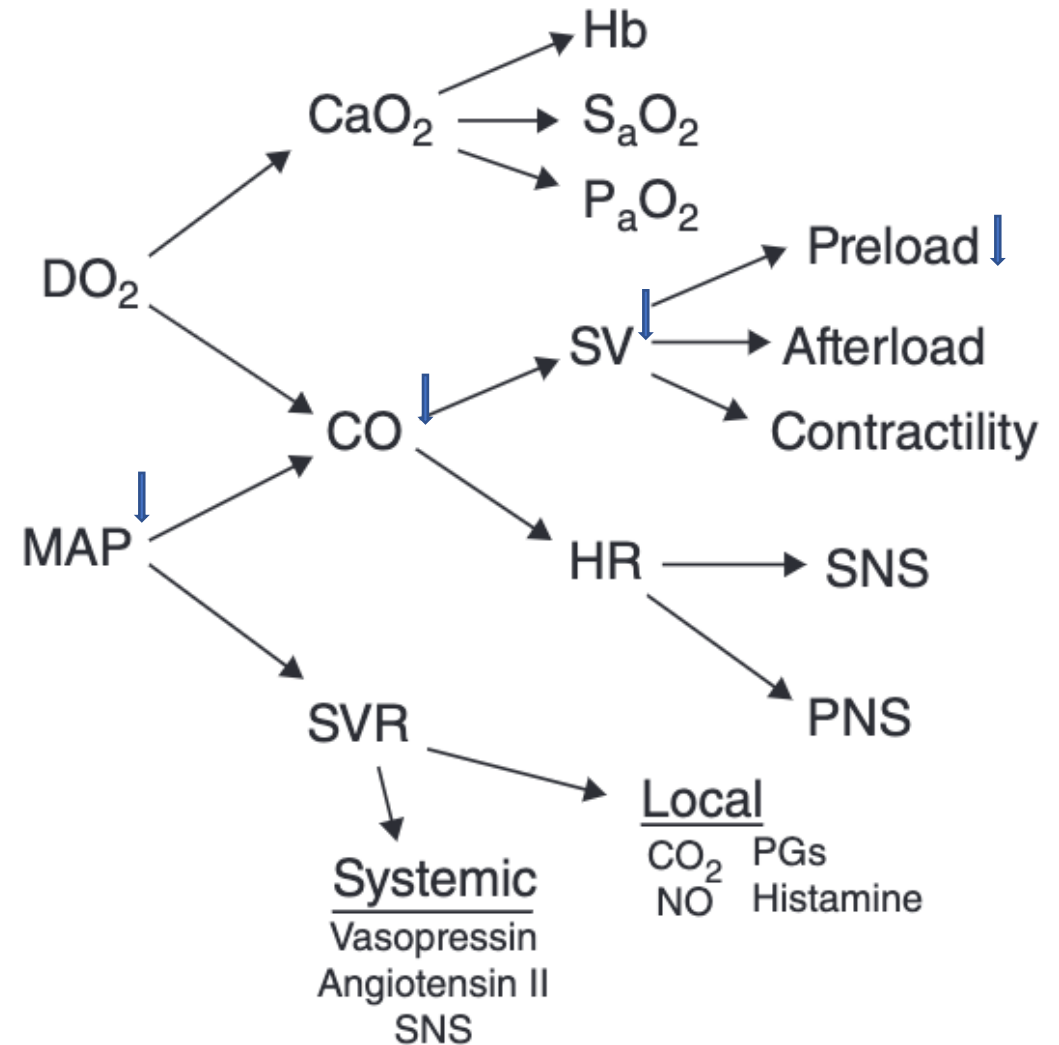
Metabolic



<https://www.dvm360.com/view/recognizing-and-treating-shock-cats>

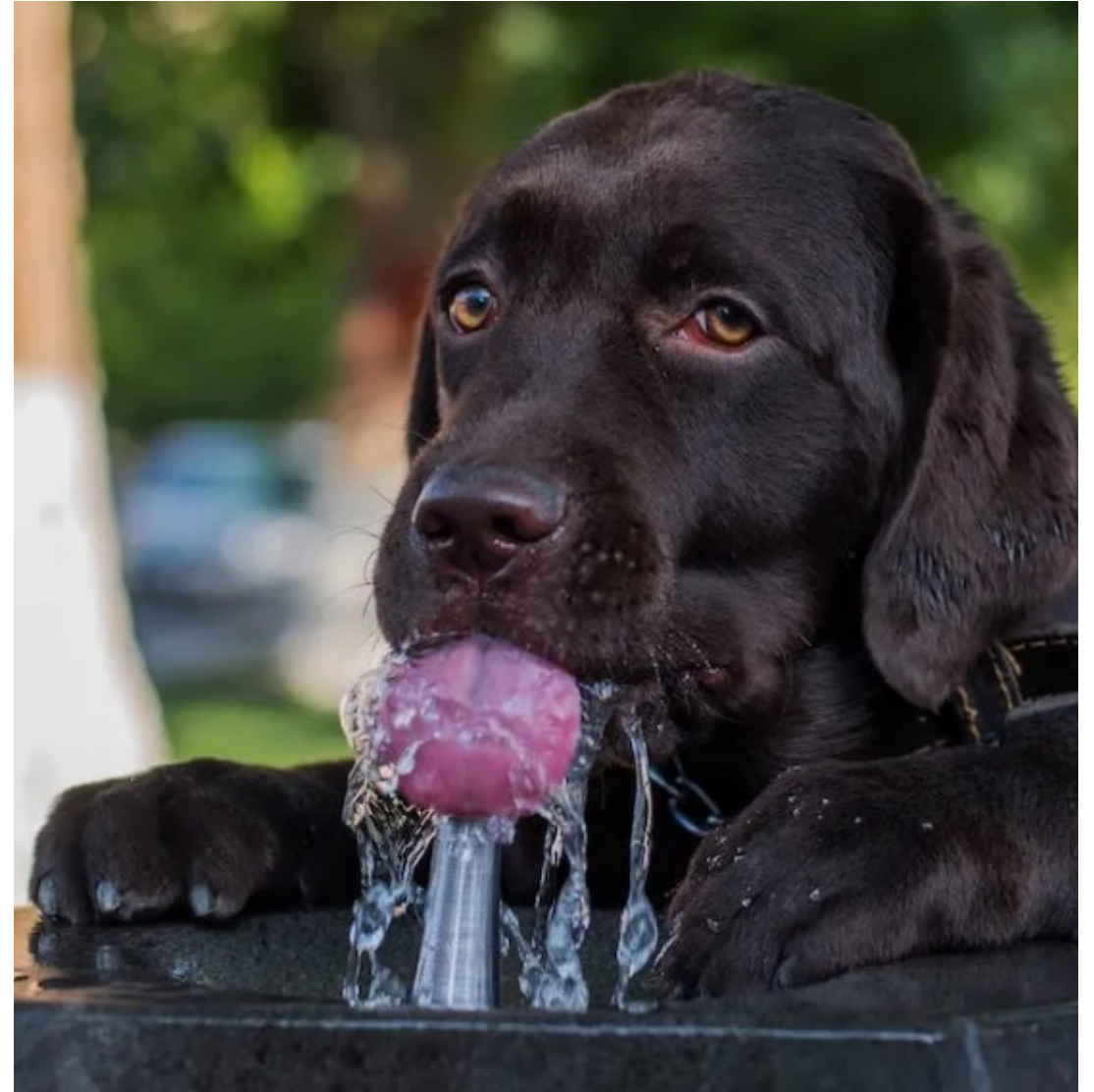
# Classifications of shock

- Hypovolemic shock
  - The most common cause of shock in veterinary patients
- Hemorrhagic; blood loss
- Non hemorrhagic; severe burns, diarrhea, third spacing, dehydration
- May overlap with other classifications of shock



# Dehydration ≠ Hypovolemia

- Dehydration is a decrease in interstitial and intracellular fluid compartments
- Hypovolemia is a decrease in intravascular volume
- Hemoconcentration is an increase in the relative number of red blood cells

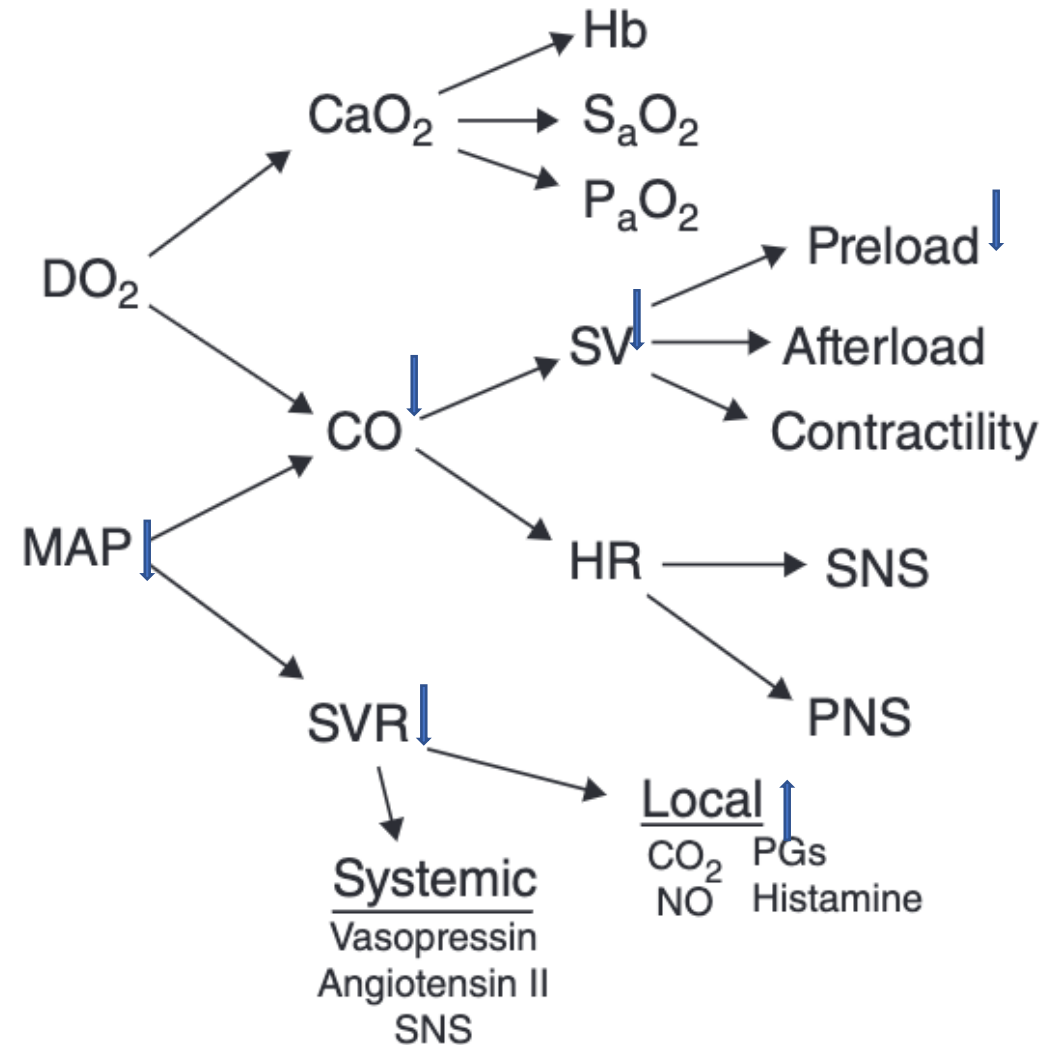


<https://dogfriendlymcr.com/how-to-get-your-dog-to-drink-water-in-4-steps/>



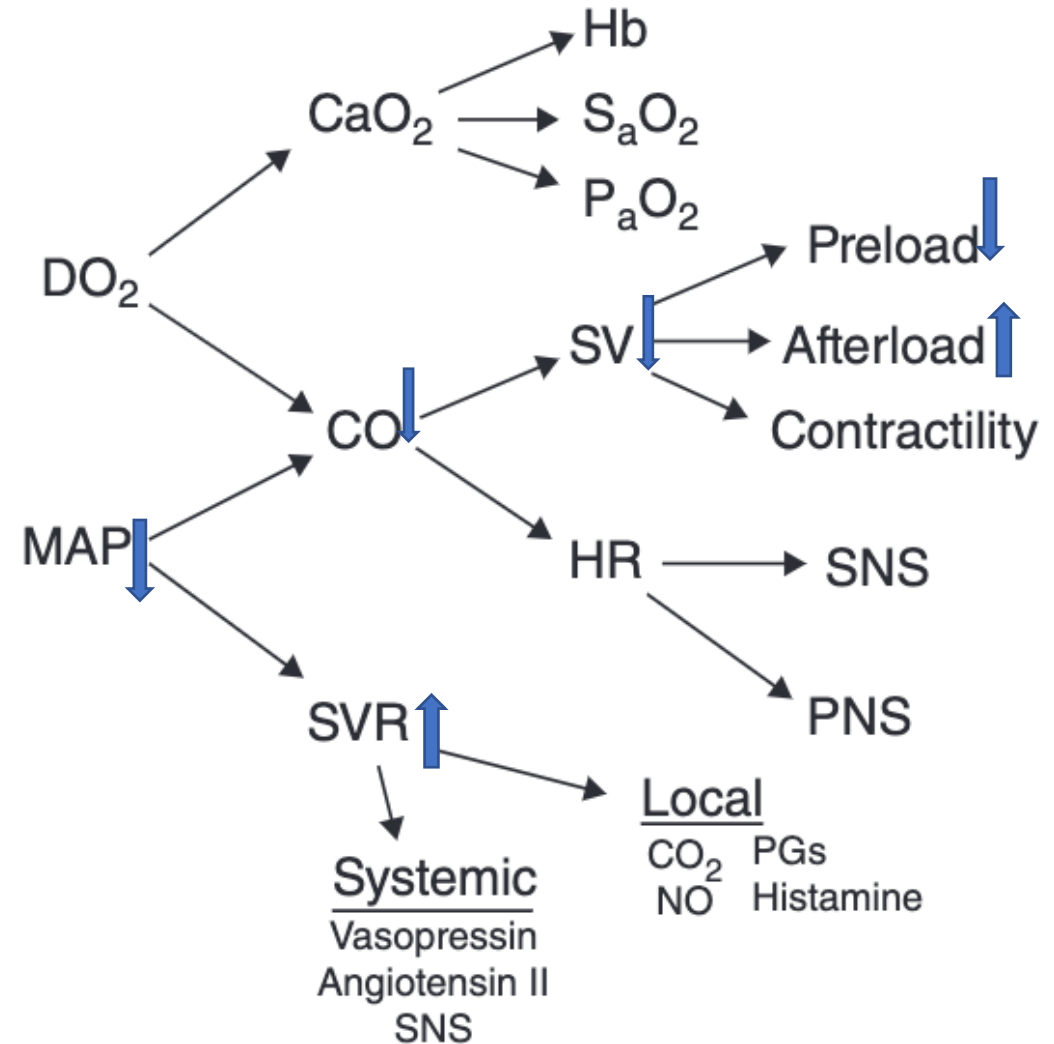
# Classifications of shock

- Distributive shock
  - Often a result of inappropriate vasodilation resulting in decreased venous flow
  - Reduction in blood flow limits oxygen delivery to the tissues and results in a tissue oxygen debt
  - Sepsis, obstruction (HWDz, thrombus, GDV), anaphylaxis



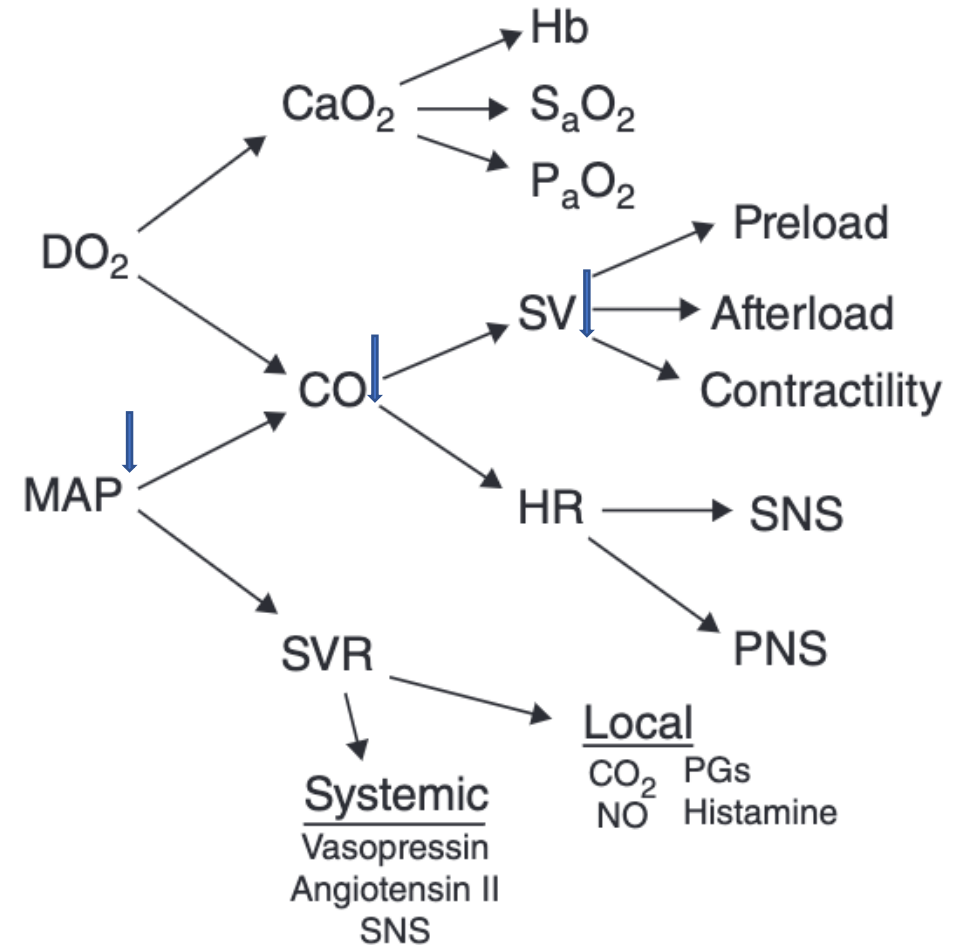
# Classifications of Shock

- Obstructive Shock
  - Heart can pump well, but the output is decreased due to an obstruction
  - GDV, tension pneumothorax, pericardial tamponade, high end positive pressure ventilation



# Classifications of shock

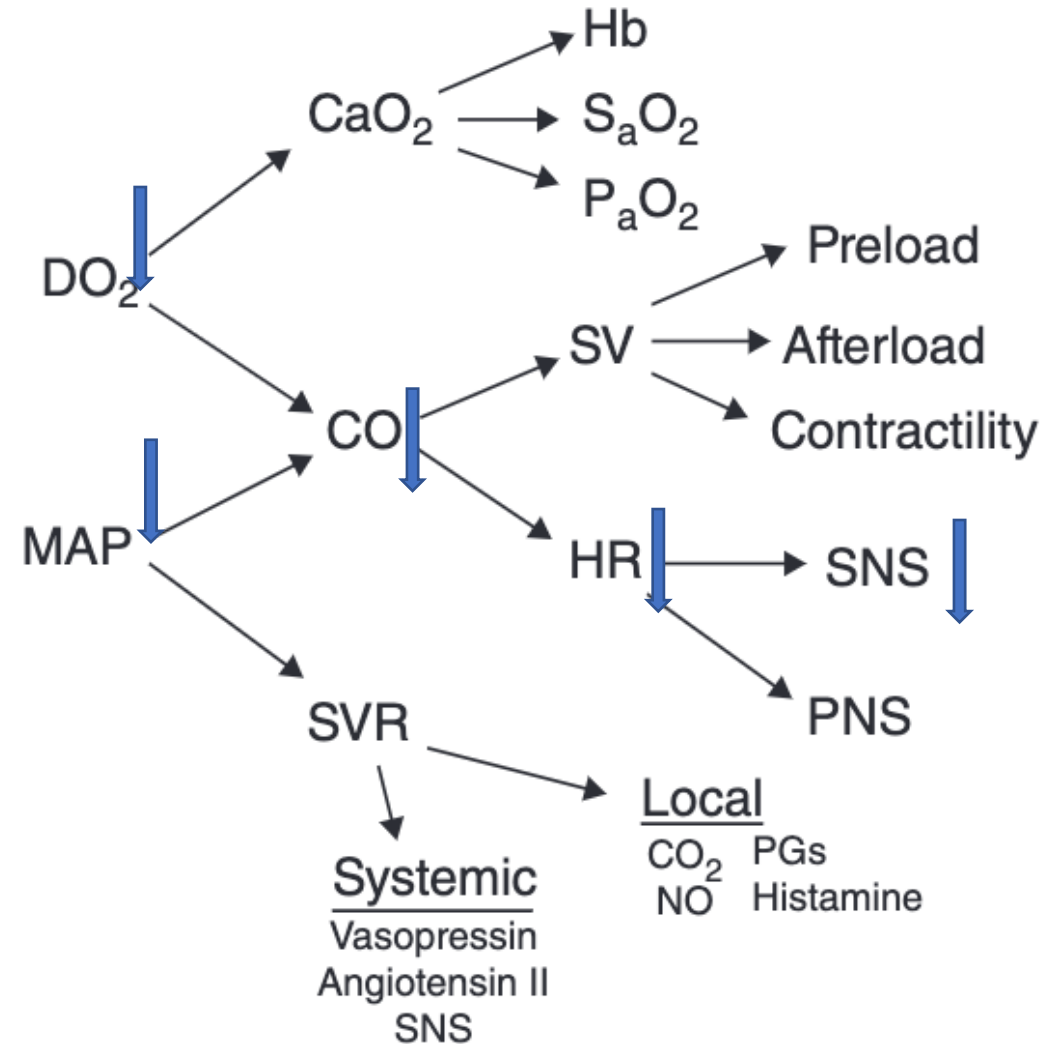
- Cardiogenic shock
  - primarily a disorder of cardiac function in the form of a critical reduction of the heart's pumping capacity
  - Systolic failure; CHF, DCM, arrhythmias, drugs, ischemia
  - Diastolic failure; HCM, RCM, tamponade,



# Classifications of shock

- Neurogenic shock

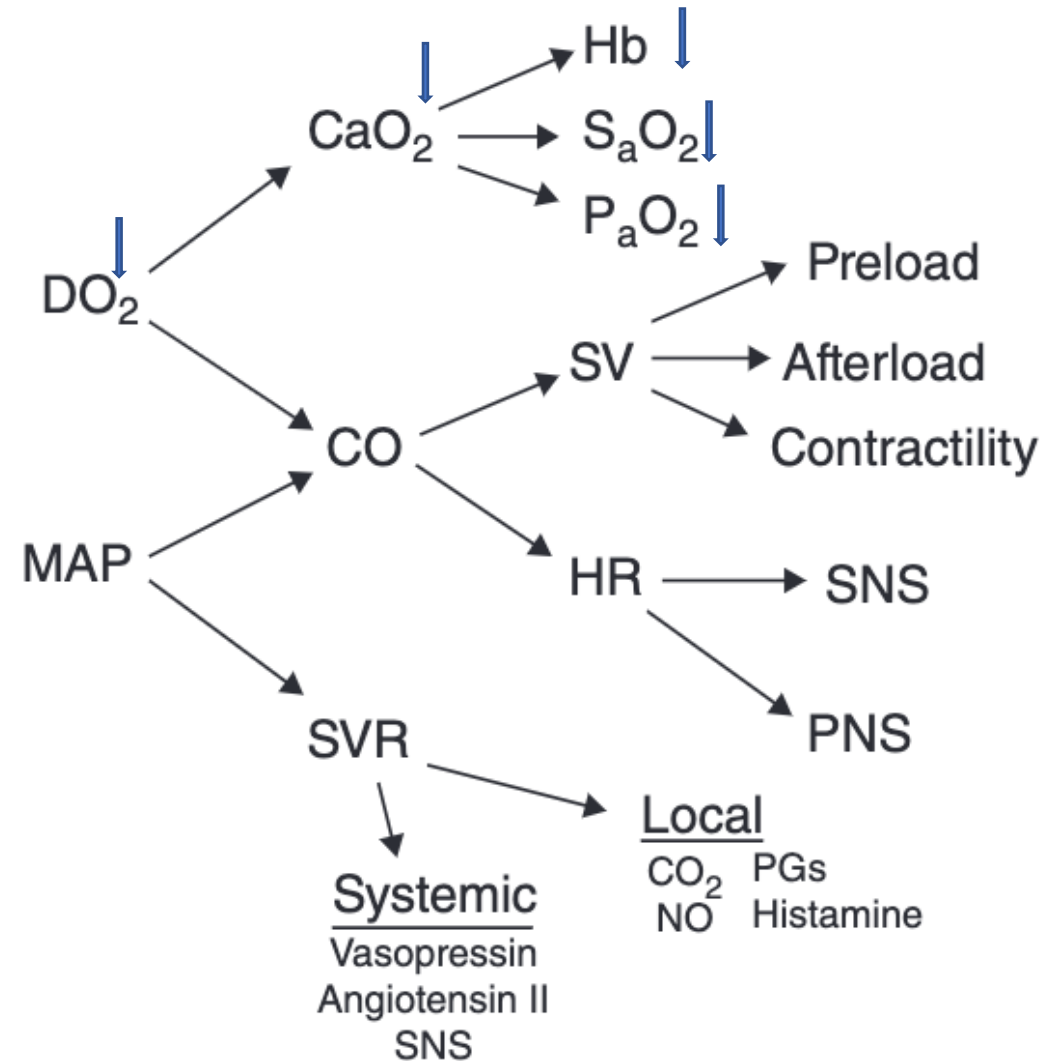
- Direct injury to the centers for circulatory regulation
- Altered afferents to the circulatory center
- Interruption of the descending connection to the spinal cord,





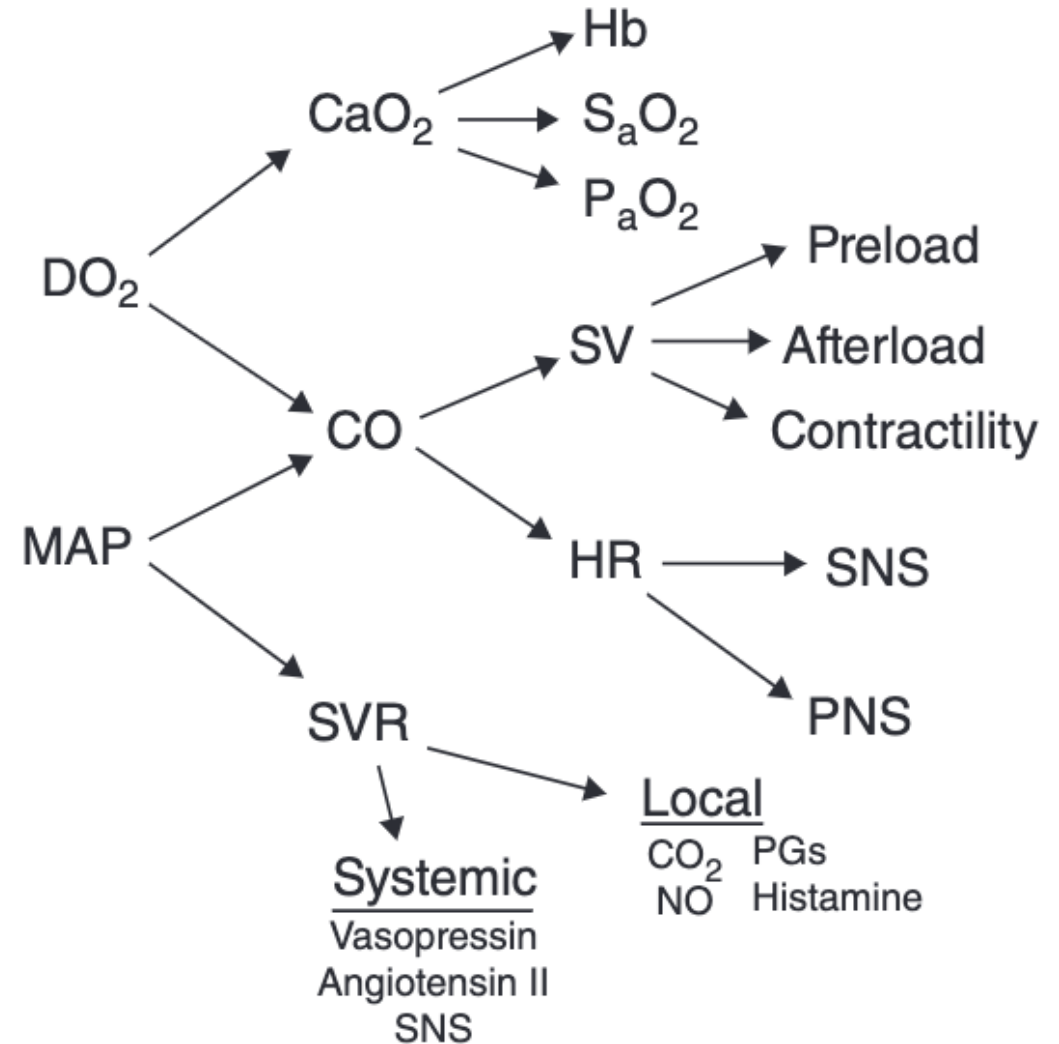
# Classifications of shock

- Hypoxemic shock
  - Decrease in oxygen content in arterial blood
  - Anemia, severe pulmonary disease
  - CO toxicity, methemoglobinemia



# Classifications of shock

- Metabolic shock
  - Have adequate circulation and arterial oxygen content,
  - Inadequate energy substrate, or energy generating capability
  - Hypoglycemia, cyanide toxicity, mitochondrial dysfunction, cytopathic hypoxia



# Case 1

- 10 year old male neutered golden presented for lethargy and collapse. On presentation patient is quiet and tachypneic. Initial physical exam revealed pale mucus membranes, CRT >2, HR of 160, with a palpable fluid wave. The patient also has normal to cool limbs, normal to weak pulses with a blood pressure of 70. You place a catheter and are only able to obtain a pcv/ts; 20/4.
- How would you classify this patient?



## Case 2

- 3 year old male neutered golden presented with a one week history of vomiting, anorexia and lethargy. Over the last 12 hours the patients lethargy has progressed. On presentation the patient is dull to obtunded. Temp 104, HR 160, panting, CRT <1, Hyperemic MM, with warm limbs but weak pulses. Patient has abdominal discomfort. Blood pressure of 50.
- How would you classify this patient?



<https://www.cliniciansbrief.com/article/quiz-mucous-membrane-evaluation-dogs>



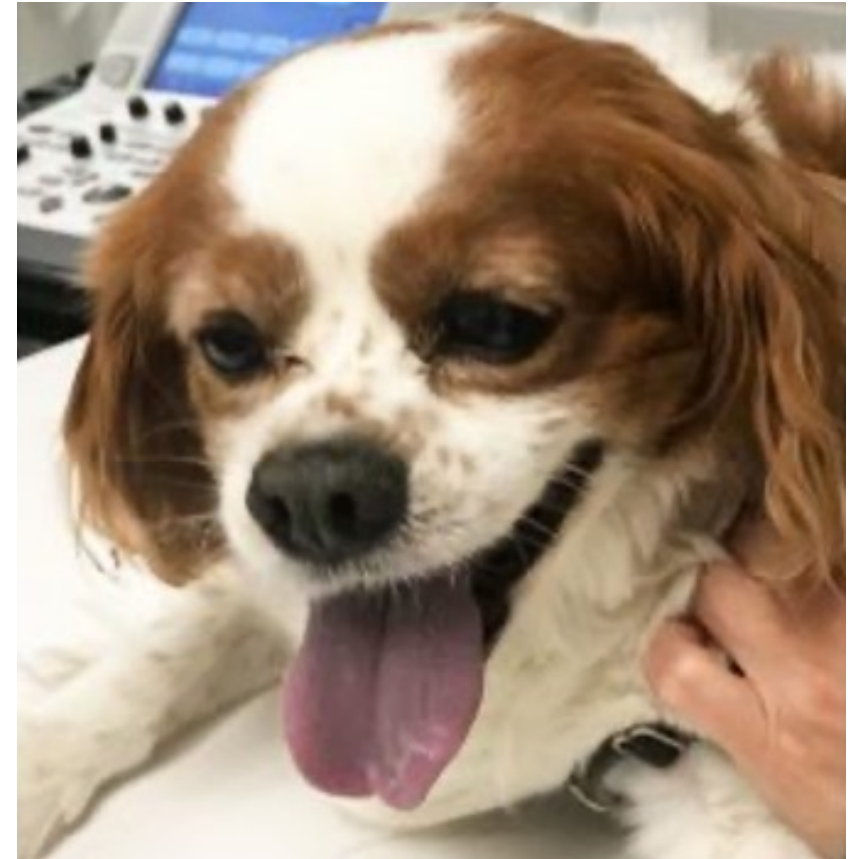
<https://todaysveterinarynurse.com/emergency-medicine-critical-care/shock-an-overview/>



# Case 3

---

- 8 year old male neutered Cavalier presented for hyporexia, and progressive tachypnea. On presentation the patient was anxious, RR 60, HR 150, and cyanotic mucus membranes. Physical exam revealed bilateral crackles, fair to weak pulses and a grade 4/6 murmur. Unable to obtain blood pressure because patient was in distress
- How would you classify this patient?



# Pathophysiology of Shock



<https://rhodes2safety.com/canine-tip-of-the-day-shock/>

# Compensation of Shock

- Increase in sympathetic activity and decrease in parasympathetic activity
  - Constriction of arterioles leading to an increase in systemic vascular resistance
  - Constriction of large capacitance venules and veins
  - Marked increase in heart rate

## Compensated

- Decreased venous return
  - Decreased stroke volume
  - Decreased aortic and carotid arterial wall stretch
- Increased sympathetic nervous system tone
  - Increased cardiac inotropy, chronotropy, lusitropy
  - Release of catecholamines from adrenal medulla
  - Peripheral arteriolar vasoconstriction
  - Cerebral and coronary arteriolar vasodilation
  - Venoconstriction
  - Splenic contraction
- Supply-dependent oxygen consumption
  - Hyperlactatemia
  - Increased cellular hydrogen ion production
  - Peripheral chemoreceptor stimulation
  - Local arteriolar vasoconstriction
  - Increased ventilatory drive
- Stimulation of renin-angiotensin-aldosterone system
  - Increased angiotensin II
  - Peripheral vasoconstriction
  - Maintenance of glomerular filtration rate
  - Increased aldosterone
  - Increased renal sodium reabsorption
- Increased antidiuretic hormone
  - Peripheral vasoconstriction
  - Increased renal water reabsorption
  - Increased thirst
- Decreased intravascular hydrostatic pressure
  - Fluid movement from interstitial space

# Compensation of Shock Con't

- Maintain vital organs with adequate oxygen
  - Maintaining mean circulatory pressures
  - Maximize cardiac performance
  - Redistribute perfusion
  - Optimize oxygen unloading



# Conditions With Shock



<https://wagwalking.com/treatment/heatstroke-treatments>



# Systemic Inflammatory Response

**TABLE 6.10** SIRS Criteria for Dogs, Cats, and People

Modified from Silverstein DS, Otto CM: Sepsis. In Greene CE, editor: *Infectious diseases of the dog and cat*, ed 4, St Louis, 2012, Elsevier.

SIRS CRITERIA	CATS	DOGS	PEOPLE
Temperature	<37.8°C, >40.0°C	>39.2°C, <37.2°C	>38.0°C, <36.0°C
	>103.5°F, <100°F	>102.6°F, <99°F	>100.4°F, <96.8°F
Heart rate	>225, <140 beats/min	>140	>90
Respiratory rate	>40 breaths/min	>30	>20
White blood cell count	>19,500 <5000	>19,000 <6000	>12,000 <4000

- Systemic Inflammatory Response Syndrome (SIRS)
  - A widespread systemic response to an infectious or non-infectious insult
  - Imbalance between pro and anti inflammatory mediators
- Criteria for diagnosis
  - Abnormal temperature (fever or hypothermia)
  - Abnormal heart rate (tachycardia or bradycardia)
  - Tachypnea
  - Leukocytosis or leukopenia

# Sepsis

- Sepsis
  - Clinical syndrome of systemic inflammation in response to an infection
- Septic shock
  - Acute circulatory failure and persistent arterial hypotension, despite adequate volume resuscitation

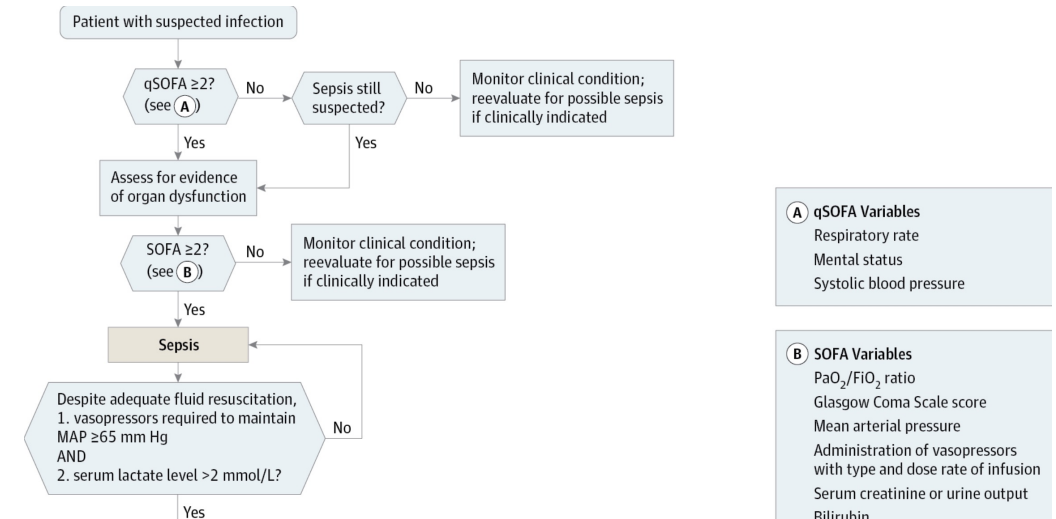


Table 1. Sequential [Sepsis-Related] Organ Failure Assessment Score<sup>a</sup>

	Score				
System	0	1	2	3	4
Respiration					
PaO <sub>2</sub> /FiO <sub>2</sub> , mm Hg (kPa)	≥400 (53.3)	<400 (53.3)	<300 (40)	<200 (26.7) with respiratory support	<100 (13.3) with respiratory support
Coagulation					
Platelets, ×10 <sup>3</sup> /μL	≥150	<150	<100	<50	<20
Liver					
Bilirubin, mg/dL (μmol/L)	<1.2 (20)	1.2-1.9 (20-32)	2.0-5.9 (33-101)	6.0-11.9 (102-204)	>12.0 (204)
Cardiovascular					
MAP ≥70 mm Hg	MAP ≥70 mm Hg	MAP <70 mm Hg	Dopamine <5 or dobutamine (any dose) <sup>b</sup>	Dopamine 5.1-15 or epinephrine ≤0.1 or norepinephrine ≤0.1 <sup>b</sup>	Dopamine >15 or epinephrine >0.1 or norepinephrine >0.1 <sup>b</sup>
Central nervous system					
Glasgow Coma Scale score <sup>c</sup>	15	13-14	10-12	6-9	<6
Renal					
Creatinine, mg/dL (μmol/L)	<1.2 (110)	1.2-1.9 (110-170)	2.0-3.4 (171-299)	3.5-4.9 (300-440)	>5.0 (440)
Urine output, mL/d				<500	<200

Singer M, Deutschman CS, Seymour CW, et al. The Third International Consensus Definitions for Sepsis and Septic Shock (Sepsis-3). *JAMA*. 2016;315(8):801–810. doi:10.1001/jama.2016.0287

## Sepsis Con't

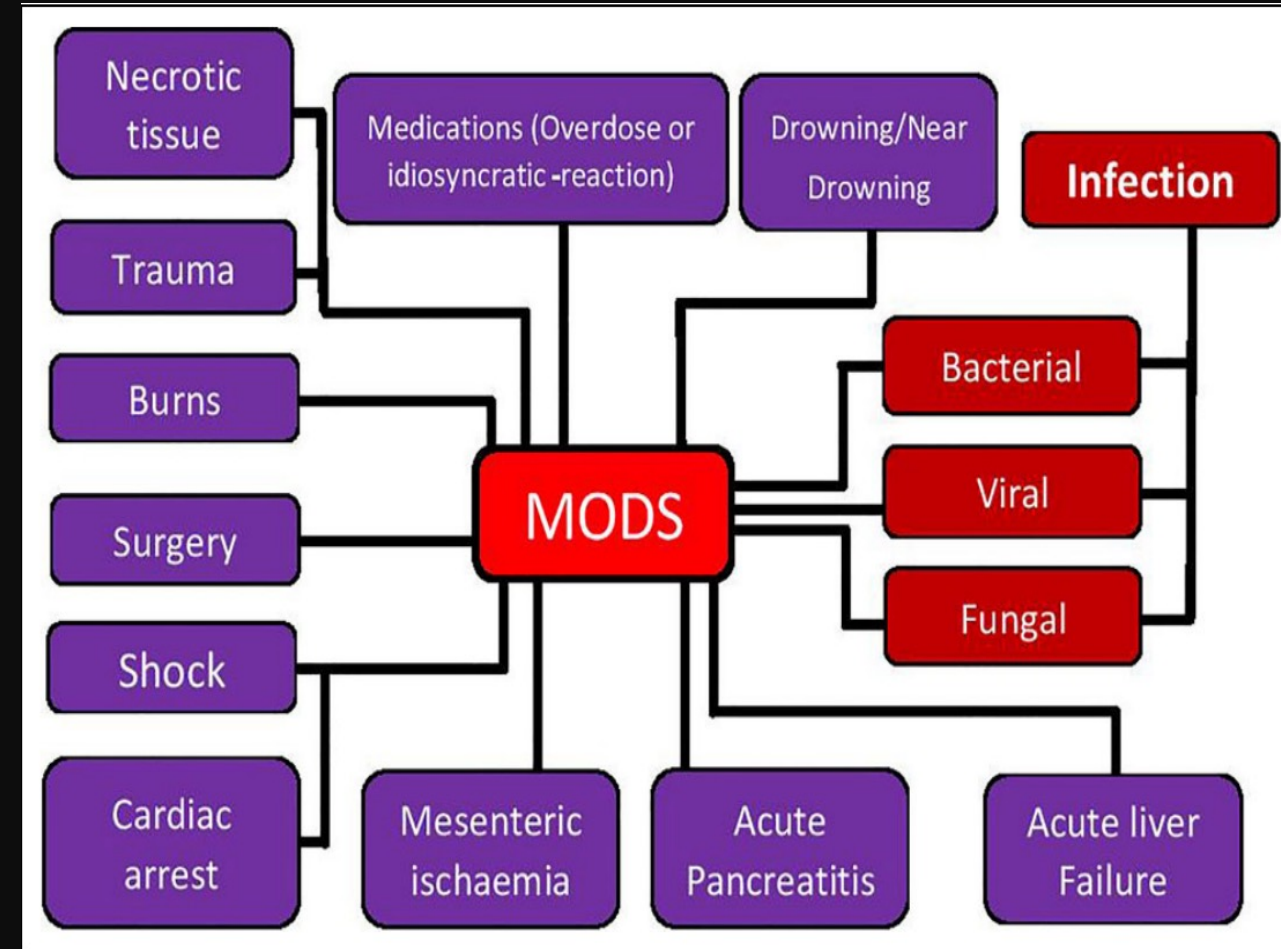
**Table 91-4 Septic Foci in Cats and Dogs and Pathogens Involved**<sup>4,19,21,22,40-45,89-92</sup>

Site	Disease Examples	Dogs (%)	Cats (%)	Pathogens
Peritoneal cavity	GI perforation	35%-36% <sup>2,4,8</sup>	47% <sup>10</sup>	Coagulase-negative <i>Staphylococcus</i> spp, <i>Enterococcus</i> spp, B-hemolytic <i>Streptococcus</i> spp, <i>Escherichia coli</i> , <i>Klebsiella</i> spp, <i>Enterobacter</i> spp, <i>Pasteurella</i> spp, <i>Corynebacterium</i> spp <sup>4,40,42,43</sup>
Pulmonary parenchymal, pleural	Pneumonia	20% <sup>4,41</sup>	24% (pyothorax) + 14% (pneumonia) <sup>21</sup>	B-hemolytic <i>Streptococcus</i> spp, <i>E. coli</i> , <i>Bordetella bronchiseptica</i> , <i>Staphylococcus</i> spp, <i>E. coli</i> , <i>Klebsiella</i> spp, <i>Pseudomonas</i> spp, <i>Enterococcus faecalis</i> , <i>Acinetobacter</i> spp, <i>Pasteurella</i> spp <sup>4,44</sup>
Gastrointestinal	Enteritis, bacterial translocation	4%	5% <sup>21</sup>	<i>E. coli</i> <sup>21</sup>
Reproductive	Pyometra Prostatitis	25% <sup>4,6</sup>		Group G <i>Streptococcus</i> spp, <i>Enterococcus</i> spp, B-hemolytic <i>Streptococcus</i> spp, <i>E. coli</i> , <i>Klebsiella</i> spp <sup>4</sup>
Urinary tract	Pyelonephritis Bacterial cystitis	4%-10% <sup>4</sup>	8%, <sup>22</sup> 7% <sup>21</sup>	B-hemolytic <i>Streptococcus</i> spp, <i>E. coli</i> , <i>Acinetobacter</i> spp, <i>Enterococcus</i> spp <sup>4,22</sup>
Soft tissue, bone	Trauma, osteomyelitis, bite wounds	29%	16%, <sup>22</sup> 3% (osteomyelitis) + 3% (bite wounds) <sup>21</sup> ; 3%-50% <sup>6,21,22</sup>	<i>E. coli</i> , <i>Enterobacter</i> spp <sup>4</sup>
Cardiovascular	Endocarditis		14% <sup>21</sup>	<i>Staphylococcus lugdunensis</i> , <i>Bartonella</i> spp, <i>S. aureus</i> , <i>E. faecalis</i> , <i>Granulicatella</i> spp, <i>Streptococcus</i> spp, <i>Brucella</i> spp <sup>45</sup>

Modified from Silverstein DS, Otto CM: Sepsis. In Greene CE, editor: *Infectious diseases of the dog and cat*, ed 4. St Louis, 2012, Elsevier.

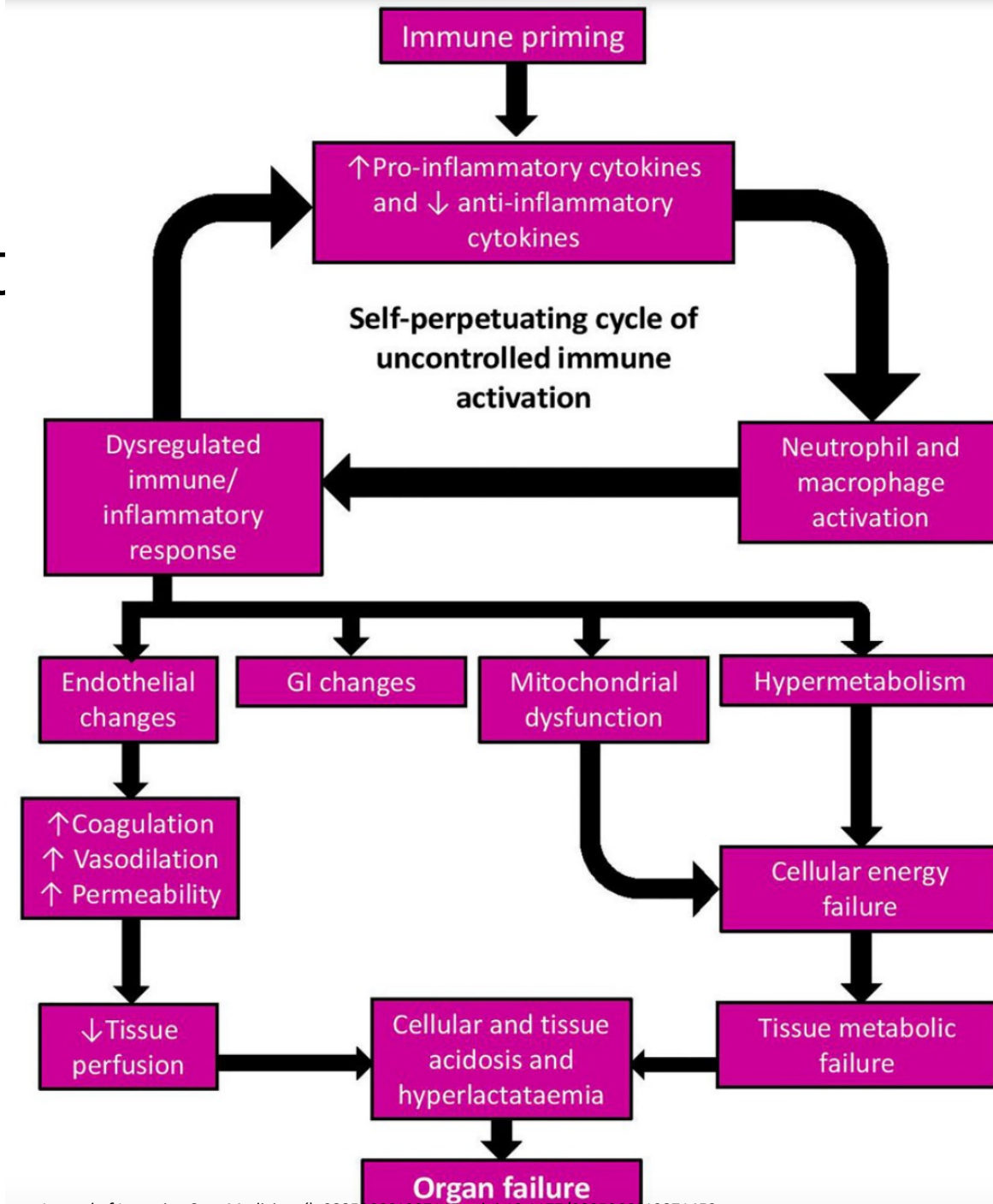
# Multiple Organ System Dysfunction Syndrome

- The acute and potentially reversible dysfunction of 2 or more organ systems that is triggered by multiple different and clinically diverse factors
- Diversity of triggers
- Infectious and noninfectious



# Multiple Organ System Dysfunction Syndrome Con't

- Dysregulated disproportional activation of neutrophils and macrophages
- Mitochondrial changes
- Endothelial changes
- Epithelial changes
- Coagulation changes
- Neuroendocrine changes





# Multiple Organ Dysfunction Syndrome Con't

- Multiple Organ Dysfunction Syndrome
  - Renal dysfunction (rise in [Creatinine] > 0.5mg/dL)
  - Cardiovascular dysfunction (myocardial dysfunction or requirement for pressors)
  - Respiratory dysfunction (requirement of oxygen or mechanical ventilation)
  - Hepatic dysfunction (T. bili >0.5mg/dL)
  - Coagulation dysfunction, DIC (thrombocytopenia, prolonged PT, PTT, etc.)
  - Gastrointestinal dysfunction (vomiting, regurgitation, ileus, constipation, diarrhea)
  - Endothelial dysfunction (vascular leak with edema formation and low albumin)

# Additional conditions to Shock

- Coagulopathy
- Mitochondrial dysfunction
- Microcirculatory dysfunction



# Clinical Signs of Shock

# Identifying Shock

- **Physical exam is going to be your most important tool!**
- Perfusion parameters
  - MM color
  - Capillary refill time
  - Heart rate
  - Pulse quality
  - Temperature
  - Mentation
  - Blood pressure



# Clinical Signs of Shock

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- physical exam findings associated with shock:
  - Tachycardia
  - Tachypnea
  - Pale mucus membranes (MM) with delayed capillary refill time (CRT)
  - Brick red MM with brisk CRT (e.g. < 1 second) in early septic shock
  - Cool limbs
  - Weak arterial pulses (sometimes bounding in early septic shock)
  - Reduced level of consciousness
  - Hypotension
  - Fever or hypothermia







**Sepsis**



ERIN MOONEY, BVSC DACVECC

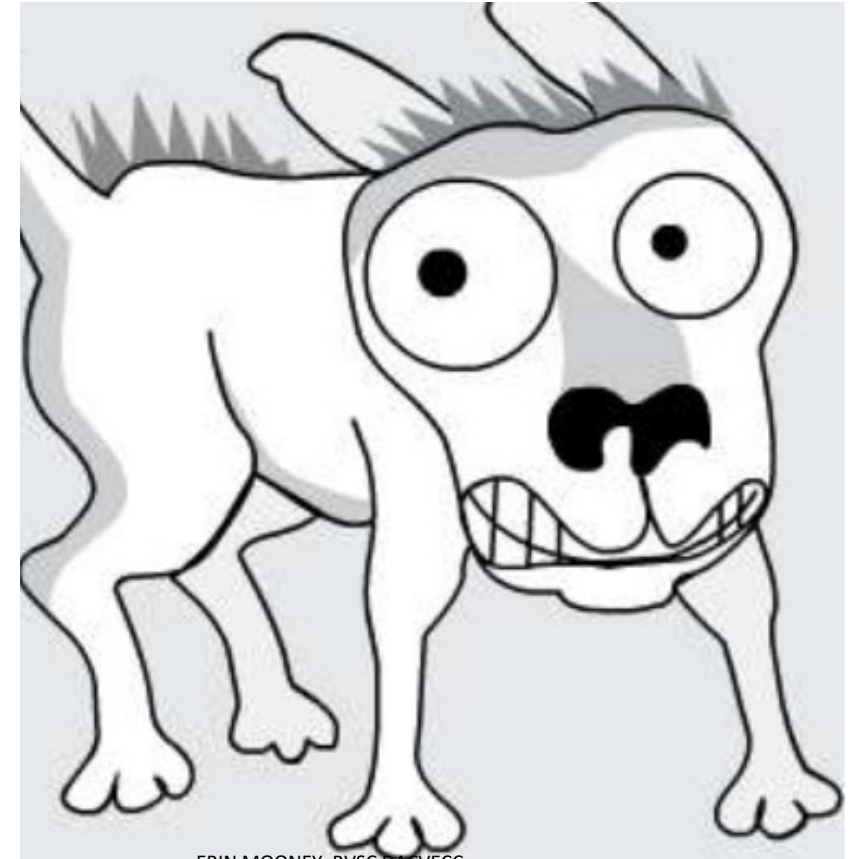


**Hypovolaemia**

# Phases of Shock

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- Compensatory phase
  - Mildly increased HR, RR
  - Normal pulse quality
  - Normal –increased pulse pressure
  - Hyperemic MM, CRT <1
  - Mildly depressed mentation
  - Normal temperature
  - Normal blood pressure
  - Normal urine output

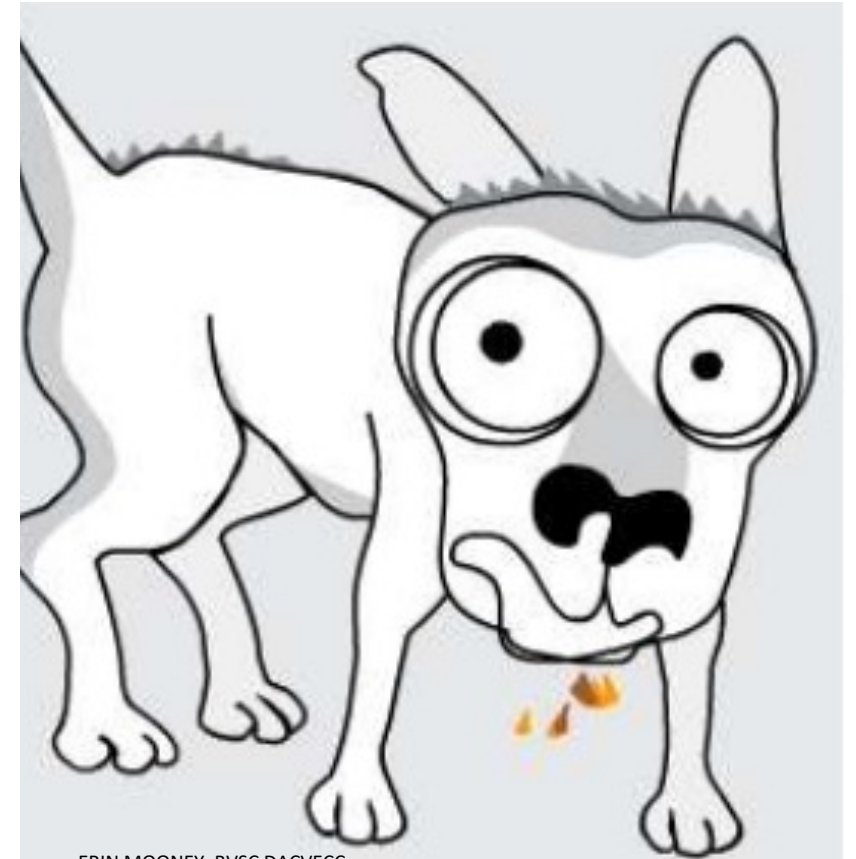


ERIN MOONEY, BVSC DACVECC

# Phases of Shock Con't

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- Early decompensated
  - Tachycardia
  - Tachypnea
  - Weak pulse quality, cool limbs
  - Normal to decreased pulse pressure
  - Pale MM, CRT >2 sec
  - Depressed to obtunded mentation
  - Hypothermia
  - Hypotension
  - Hyperglycemia
  - Petechiae, Ecchymosis

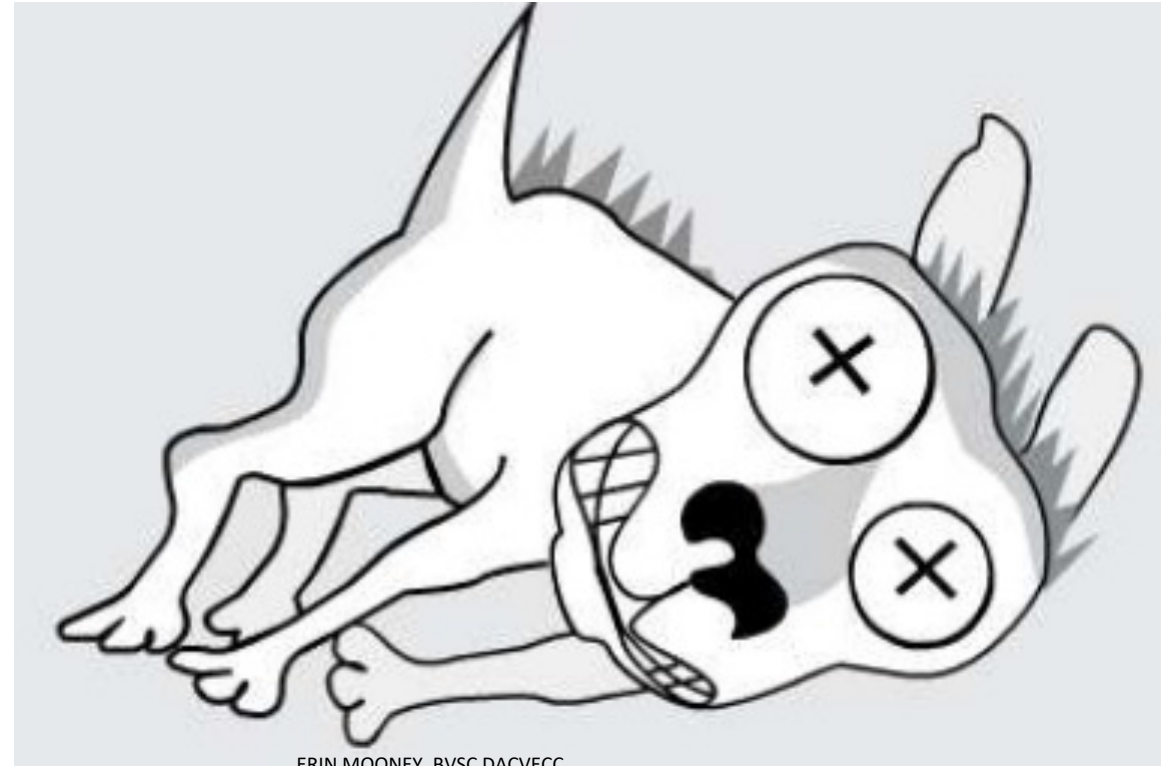


ERIN MOONEY, BVSC DACVECC

# Phases of Shock Con't

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- Late decompensated
  - Tachycardia/bradycardia
  - Tachypnea/hypopnea
  - Weak or absent pulses
  - Pale to cyanotic MM, absent CRT
  - Comatose mentation
  - Severely hypothermic
  - Severely hypotensive
  - Normal to decreased glucose



ERIN MOONEY, BVSC DACVECC

	COMPENSATORY	EARLY DECOMPENSATORY	LATE DECOMPENSATORY
Heart rate	Mildly increased	Tachycardia	Tachycardia/bradycardia
Respiratory rate	Mildly increased	Tachypnea	Tachypnea/hypopnea
Pulse quality	Normal	Weak	Weak or absent
Pulse pressure	Normal to increased	Normal to decreased	Decreased
Mucous membrane color	Hyperemic	Pale	Pale or cyanotic
Capillary refill time	<1s	>2s	Absent
Mentation	Mildly depressed	Depressed to obtunded	Stuporous or comatose
Temperature	Normal	Hypothermic	Severely hypothermic
Arterial pressure	Normal	Hypotensive	Severely hypotensive
Glucose	Increased	Increased	Normal or decreased

Modified from Silverstein DS, Otto CM: Sepsis. In Greene CE, editor: *Infectious diseases of the dog and cat*, ed 4. St Louis, 2012, Elsevier.



# Case 1

- 10 year old male neutered golden presented for lethargy and collapse. On presentation patient is quiet and tachypneic. Initial physical exam revealed pale mucus membranes, CRT >2, HR of 160, with a palpable fluid wave. The patient also has normal to cool limbs, normal to weak pulses with a blood pressure of 70. You place a catheter and are only able to obtain a pcv/ts; 20/4.
- Which stage of shock is this patient in



## Case 2

- 3 year old male neutered golden presented with a one week history of vomiting, anorexia and lethargy. Over the last 12 hours the patients lethargy has progressed. On presentation the patient is dull to obtunded. Temp 104, HR 160, panting, CRT <1, Hyperemic MM, with warm limbs but weak pulses. Patient has abdominal discomfort. Blood pressure of 50.
- Which stage of shock is this patient in



<https://www.cliniciansbrief.com/article/quiz-mucous-membrane-evaluation-dogs>



<https://todaysveterinarynurse.com/emergency-medicine-critical-care/shock-an-overview/>

# Case 3

---

- 8 year old male neutered Cavalier presented for hyporexia, and progressive tachypnea. On presentation the patient was anxious, RR 60, HR 150, and cyanotic mucus membranes. Physical exam revealed bilateral crackles, fair to weak pulses and a grade 4/6 murmur. Unable to obtain blood pressure because patient was in distress
- Which stage of shock is this patient in





# Clinical Signs of Cardiogenic Shock

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- Clinical signs associated with cardiogenic shock can
  - Cyanosis
  - Respiratory distress
  - Pulmonary crackles
  - Tachycardia
  - A cardiac murmur or gallop
  - Cardiac arrhythmias
  - weakness
  - Distended jugular veins and elevated CVP and/or pulmonary edema



# Emergent Diagnostic Evidence of Shock

- PCV/TS; anemic
- Hyperlactemia; marker of tissue perfusion
- Metabolic acidosis
  - Base excess
  - Decreased  $\text{HCO}_3$
- Urine specific gravity; renal function
- Blood pressure; hypotension
- PT/PTT; Coagulopathy - can lead to disseminated intravascular coagulation (DIC) or organ thrombosis



<https://www.psnetwork.org/14-show-me-the-evidence/>



# Emergent Diagnostic Evidence of Shock Con't

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- Shock Index
  - Heart rate divided by blood pressure
  - Allows quantification on severity of shock
  - Allows identification of derangements in perfusion status in the face of normal cardiovascular parameters
  - Shock index > 0.9 correlates with a higher mortality

$$\text{SHOCK INDEX} = \frac{\text{Heart rate}}{\text{Systolic BP}}$$

<https://www.linkedin.com/pulse/shock-index-veterinary-patients-shailen-jasani>

Evaluation of the shock index in dogs presenting as emergencies

[Adam E. Porter](#), DVM, [Elizabeth A. Rozanski](#), DVM, DACVIM, DACVECC, [Claire R. Sharp](#), BVMS, MS, DACVECC, [Kirsten L. Dixon](#), BS, CVT, [Lori Lyn Price](#), MAS, and [Scott P. Shaw](#), DVM, DACVECC

The background of the slide is a close-up photograph of a hand holding a stethoscope. Overlaid on this image is a network of white circular icons connected by thin white lines. The icons include a first aid kit, a pill, a virus, a microscope, an eye, a DNA helix, a computer monitor, a stethoscope, a plus sign, test tubes, a flask, a thermometer, and a magnifying glass. The word "Diagnostics" is centered in white text, with a white horizontal line underneath it.

# Diagnostics

# Diagnostics

- Initial diagnostics
  - Blood pressure
  - Lactate
  - Electrolytes
  - Blood glucose
  - Pulse ox
  - EKG
  - Heart rate
  - Respiratory rate
  - Temperature
  - Shock Index
- Complete diagnostics
  - CBC
  - CHEM
  - Arterial blood gas
  - Coags
  - Blood type
  - Urine analysis
  - Thoracic/abdominal radiographs
  - Abdominal ultrasound
  - Echocardiogram



# Monitoring



# Monitoring

- Tissue perfusion and oxygen delivery
  - Central venous pressure
    - Normal 0-5cm H<sub>2</sub>O
  - Mean arterial pressure
    - Normal 70-120mmhg
  - Urine production
    - 1ml/kg/hr



# Monitoring Con't

- Lactate
  - Measure of hypoperfusion and a product of anaerobic metabolism
  - Normal in adult dogs and cats is less than 2mmol/L
  - Used as a prognostic indicator and a guide for resuscitation
  - Should decrease by half every 1-2 hours

Type A		Type B			
Relative	Absolute	B1: Disease	B2: Drugs/Toxins	B3: Congenital	
Exercise <sup>§,+</sup>	Hypoperfusion <sup>§,+</sup>	Malignancy <sup>∞,B,*</sup>	Glucocorticoids <sup>∞,B,+</sup>	Epinephrine <sup>∞,B,+</sup>	MELAS*
Muscle tremors <sup>§</sup>	Severe anemia <sup>§</sup>	Diabetes mellitus <sup>∞,B,*</sup>	Acetylcholinesterase inhibitors <sup>§</sup>	Acetaminophen <sup>∞,B,*</sup>	Mitochondrial myopathy*
Shivering <sup>§</sup>	Severe hypoxemia <sup>§</sup>	Hepatic failure <sup>∞,B</sup>	Fructose <sup>∞</sup>	Salicylates <sup>∞,B,†,*</sup>	PDH deficiency <sup>B</sup>
Seizures <sup>§</sup>	Carbon monoxide <sup>§</sup>	Thiamine deficiency <sup>B,†</sup>	Xylitol <sup>∞</sup>	β-agonists <sup>∞,B,+</sup>	
Struggling <sup>§,+</sup>		Hyperthyroidism <sup>∞,B</sup>	Sorbitol <sup>∞</sup>	Cocaine <sup>§,∞,+</sup>	
		Microcirculatory dysfunction <sup>§</sup>	Glucose <sup>∞</sup>	Methylxanthines <sup>∞,+</sup>	
		Cytopathic hypoxia <sup>∞,B,+</sup>	Strychnine <sup>§</sup>	Cyanide*	
		Impaired gluconeogenesis <sup>✱</sup>	Biguanides*	Nitroprusside*	
		Alkalosis <sup>∞</sup>	Linezolid*	Ethylene glycol <sup>B,#</sup>	
		SIRS/Sepsis <sup>§,B,+,*</sup>	Isoniazid <sup>§</sup>	Methanol <sup>§,*,#</sup>	
		Pheochromocytoma <sup>∞,+</sup>	NRTIs*	Propylene glycol <sup>✱</sup>	
			Lactulose <sup>✱</sup>	Ethanol <sup>#</sup>	
			5-Fluorouracil <sup>†</sup>	Propofol*	

# Monitoring Con't

- Base excess
  - Measurement of total buffering capacity
  - Can be used a prognostic indicator

Base excess and lactate as prognostic indicators for patients admitted to intensive care

[I. Smith](#), [P. Kumar](#), [S. Molloy](#), [A. Rhodes](#), [P. J. Newman](#), [R. M. Grounds](#) & [E. D. Bennett](#)

# Monitoring Con't

- Cardiac output
  - Pulmonary arterial catheter (Swan-Ganz catheter)
- Mixed venous oxygen saturation and Central Venous oxygen saturation
  - Assess global tissue oxygenation
  - Low ScVO<sub>2</sub> from decreased oxygen delivery or increased oxygen consumption

## **Early goal-directed therapy in the treatment of severe sepsis and septic shock**

E Rivers <sup>1</sup>, B Nguyen, S Havstad, J Ressler, A Muzzin, B Knoblich, E Peterson, M Tomlanovich;  
Early Goal-Directed Therapy Collaborative Group

# Treatment



# Treatment of Shock

“Shock is a dynamic, multisystemic disorder. Animals with shock change rapidly, and thus therapy is not “a set of specific things to do in each case” but rather is dictated by serial monitoring of patient parameters and assessing response to treatment”

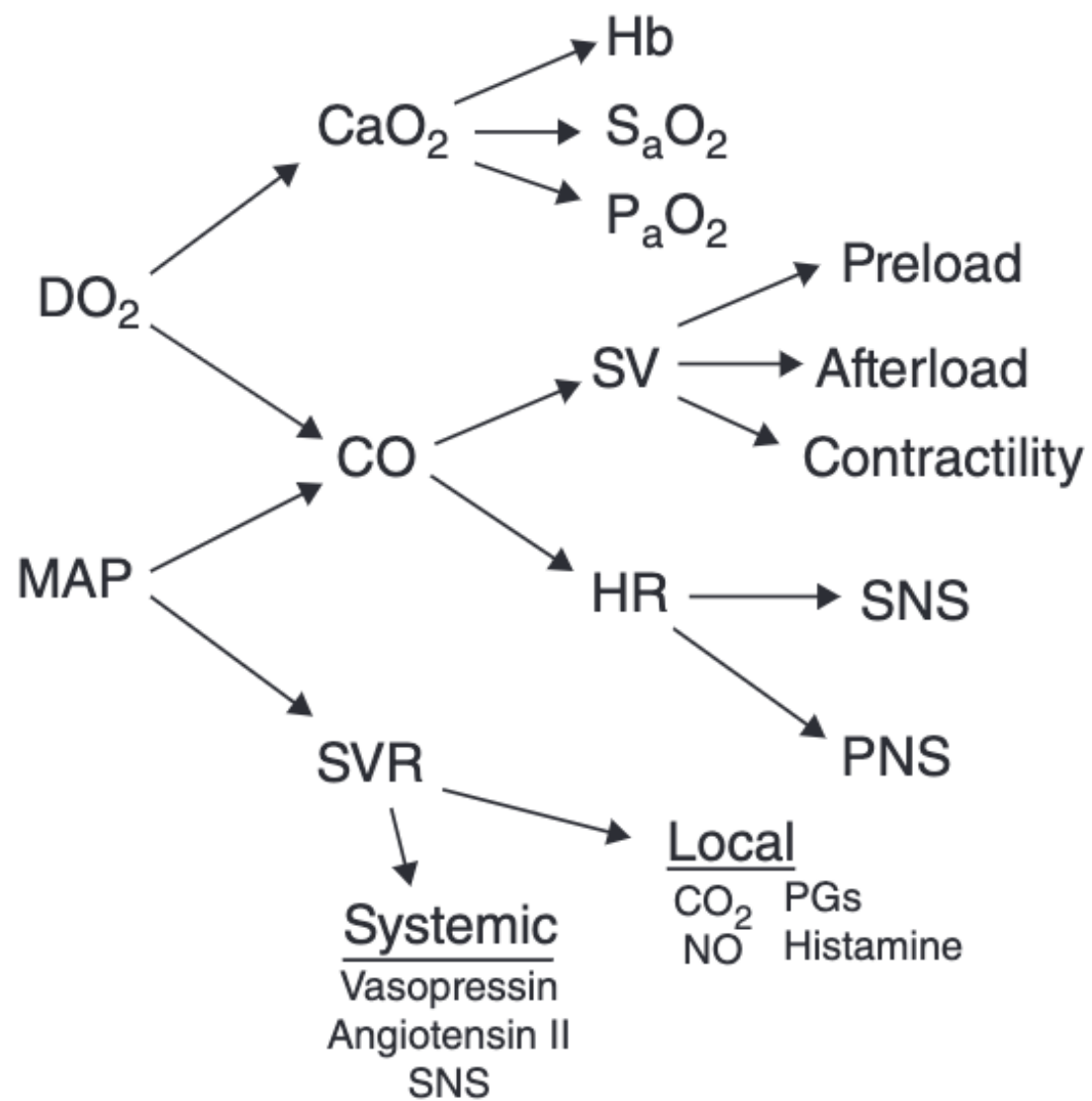


# Goal of Treatment

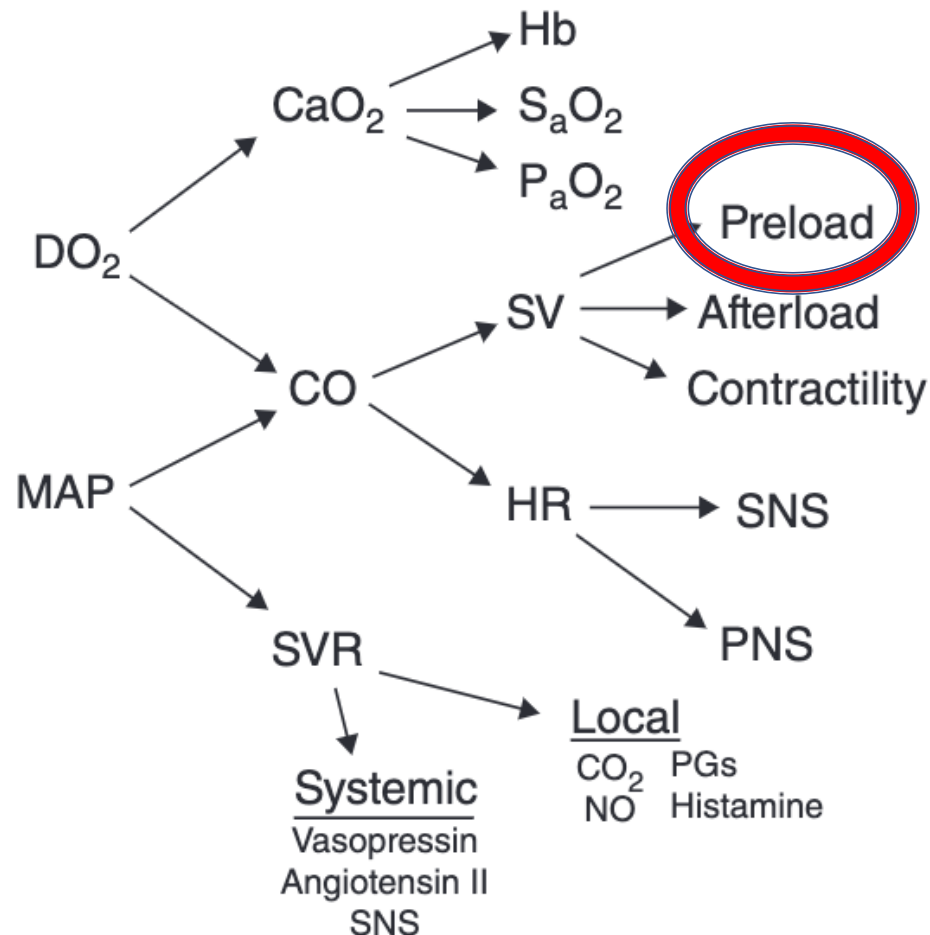
- A guide for end points
  - Improved level of consciousness (responsive, alert is ideal)
  - Improved heart rate (ideally to normal range)
  - Improved arterial pulse quality
  - Improved mm color (at least light pink)
  - normalized CRT
  - Normothermia
  - Blood Lactate < 1.5 to 2.0 mmol/L
  - Normal blood pressure (SBP > 90 mmHg, MAP >60mmHg, ideally SAP > 110 mmHg)
  - CVP  $\geq$  5 cmH<sub>2</sub>O (especially with distributive shock; before reaching for vasopressors)
  - PCV 20-25%
  - Urine output at least 1.5 to 2 ml/kg/hour

# Treatment of Shock Con't

- Major components of therapy rely on supportive care
  - Optimization of oxygen delivery and reestablishment of adequate tissue perfusion
  - Aggressive support of organ dysfunction
  - Identify and treat the underlying disease
  - Bundle concept



# Treatment of Shock –Fluid Therapy



- Vascular access is essential!!
  - No subcutaneous fluids
- Short large bore catheter
- Intravenous fluids increase a patient's preload which increases stroke volume and cardiac output

# Fluid Therapy-Types of Fluids

## Isotonic crystalloids

Table 59-1 Isotonic Crystalloid Compositions

Fluid Type	Osmolality (mOsm/L)	[Na <sup>+</sup> ] (mEq/L)	[K <sup>+</sup> ] (mEq/L)	[Cl <sup>-</sup> ] (mEq/L)	[Mg <sup>2+</sup> ] (mEq/L)	[Ca <sup>2+</sup> ] (mEq/L)	Lactate (mEq/L)	Acetate (mEq/L)	Gluconate (mEq/L)
0.9% NaCl	308	154	—	154	—	—	—	—	—
Lactated Ringer's solution	273	130	4	109	—	3	28	—	—
Plasmalyte 148	295	140	5	98	3	—	—	27	23
Normosol-R	295	140	5	98	3	—	—	27	23

CCM

“Shock dose”

90ml/kg for a dog, divided by 4 for each bolus, over 15 minutes

60ml/kg for a cat, divided by 4 for each bolus, over 15 minutes



# Fluid Therapy- Con't

- Hypertonic saline (7-7.5% NaCl)
  - Excellent for rapid, small volume resuscitation
  - Able expand its volume 3-5x the volume administered
  - Improves cardiac output, tissue perfusion, reduces intracranial pressure
  - Administered @ 3-5ml/kg over 15 minutes, followed by crystalloid resuscitation



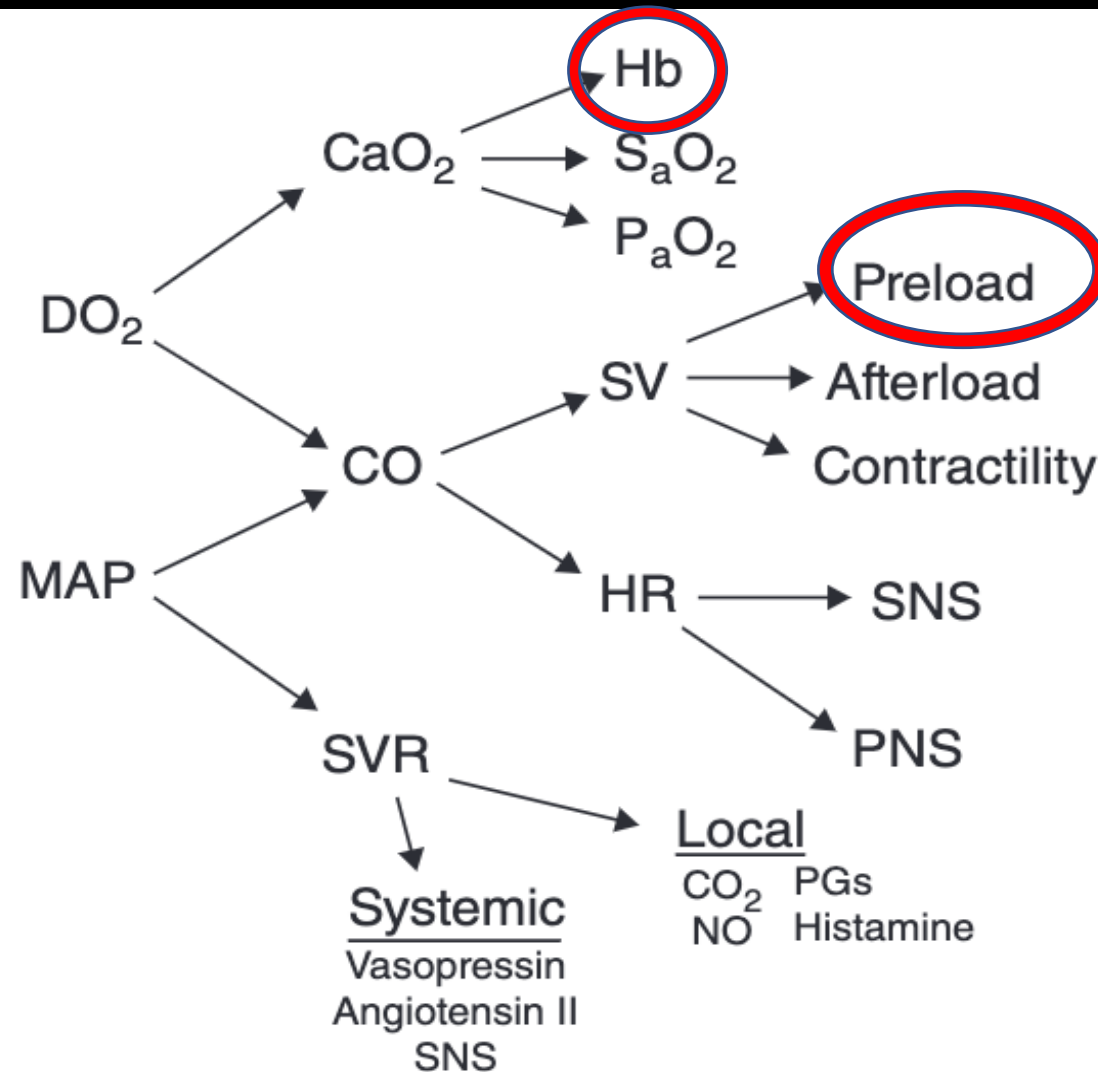
# Fluid Therapy- Con't



<https://nurse.plus/become-a-nurse/black-box-warnings/>

- Synthetic colloids
  - Hetastarch
  - Pentastarch
  - Tetrastarch
  - Vetstarch
- More sustained intravascular expansion
- 10-20ml/kg IV over 30 minutes
- Falling out of favor

# Fluid Therapy- Blood Products



# Fluid Therapy- Blood Products Con't

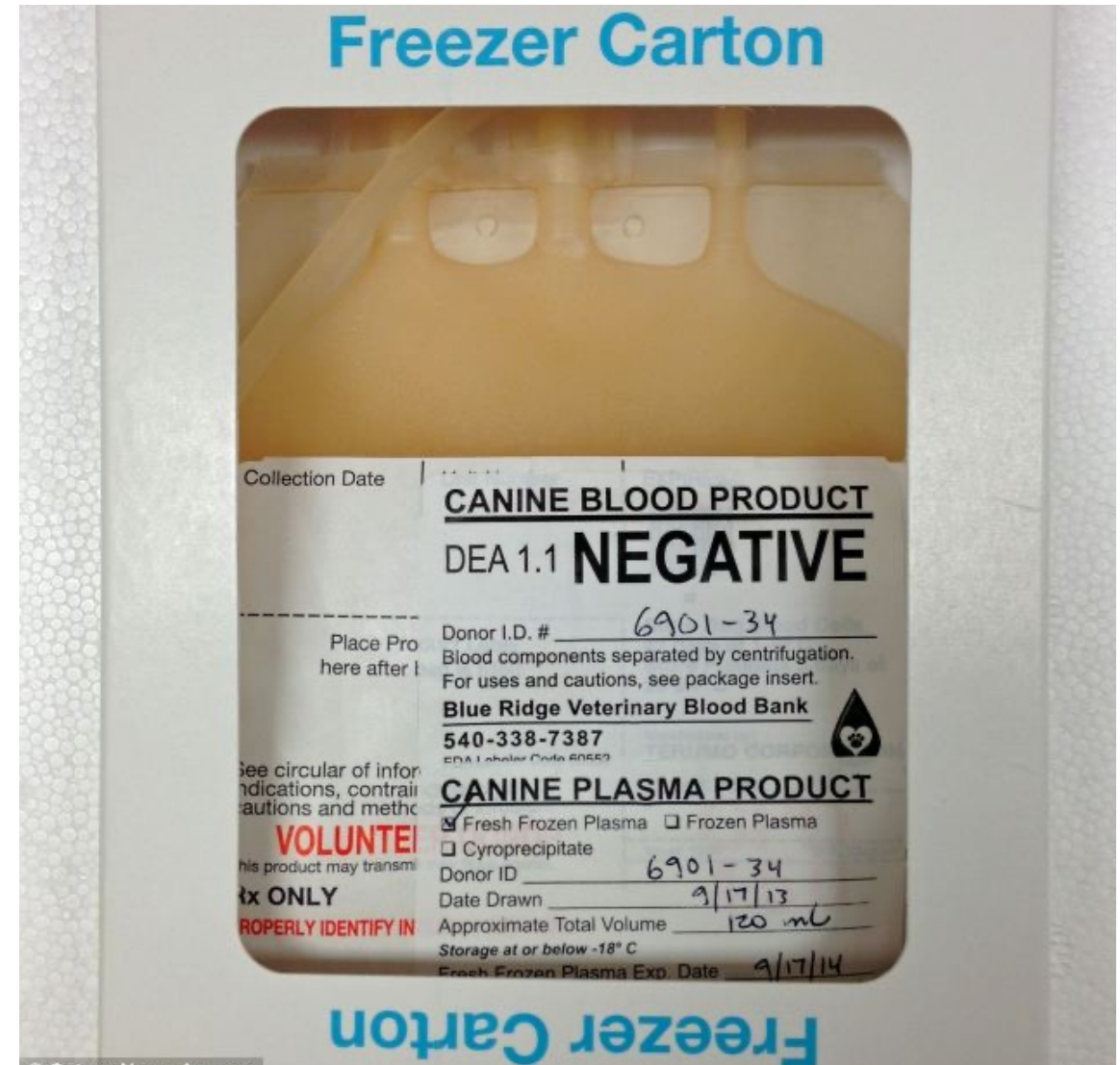
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- Albumin (canine and human)
  - Ideal for hypoalbuminemic patients (<2g/dl)
  - Quick dose; 2g/kg over 6-8 hours
  - Albumin deficit;  $10 \times (\text{desired albumin} - \text{pt albumin}) \times \text{kg} \times 0.3$
  - Risk of anaphylaxis and hypersensitivity reactions



# Fluid Therapy- Blood Products Con't

- Fresh frozen plasma
  - Used to treat hemorrhage secondary to acquired/hereditary coagulopathy
- Contains all coagulation factors
- 10-20ml/kg over 2-4 hours
- Not used to raise albumin





# Fluid Therapy- Blood Products Con't

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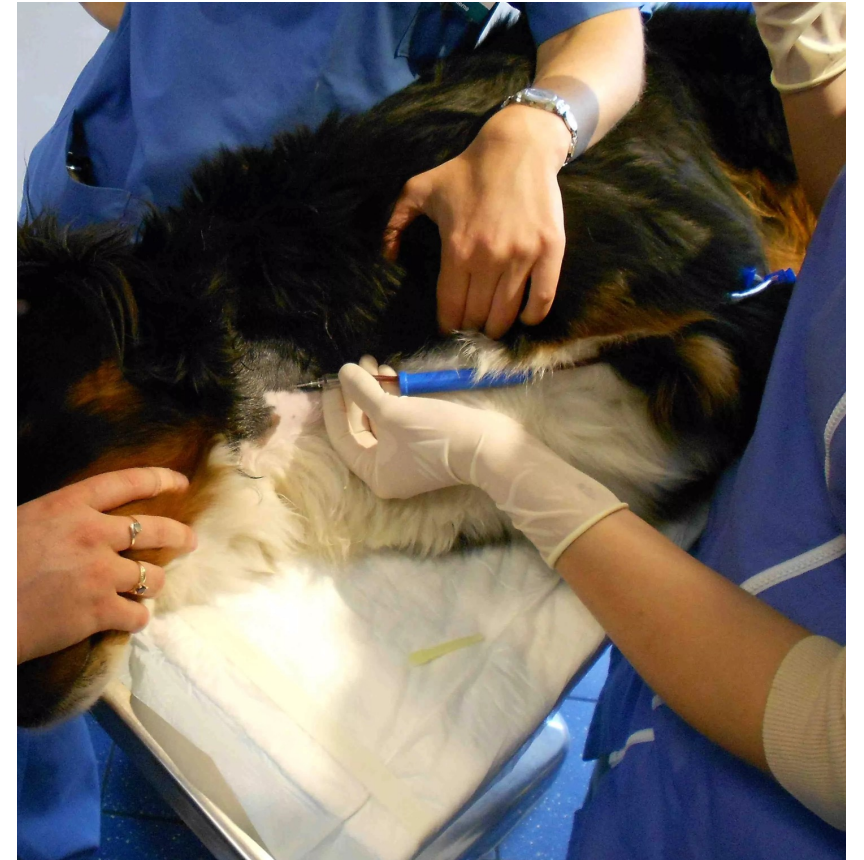
- Packed RBCs
  - Severe anemia or active hemorrhage
  - Restore oxygen carrying capacity and treat tissue hypoxia
  - 10-20 ml/kg over 4 hours



# Fluid Therapy- Blood Products Con't

---

- Whole blood
  - Replaces red blood cells, platelets and plasma
  - Contains all cellular elements of blood
  - 20-30ml/kg over 2-4 hours



# Hypotensive Resuscitation

- Restoration of a lower than normal systolic blood pressure
- Goal is a systolic blood pressure of 80-90mmhg or mean arterial pressure of 60mmhg
- Helps facilitate control of hemorrhage

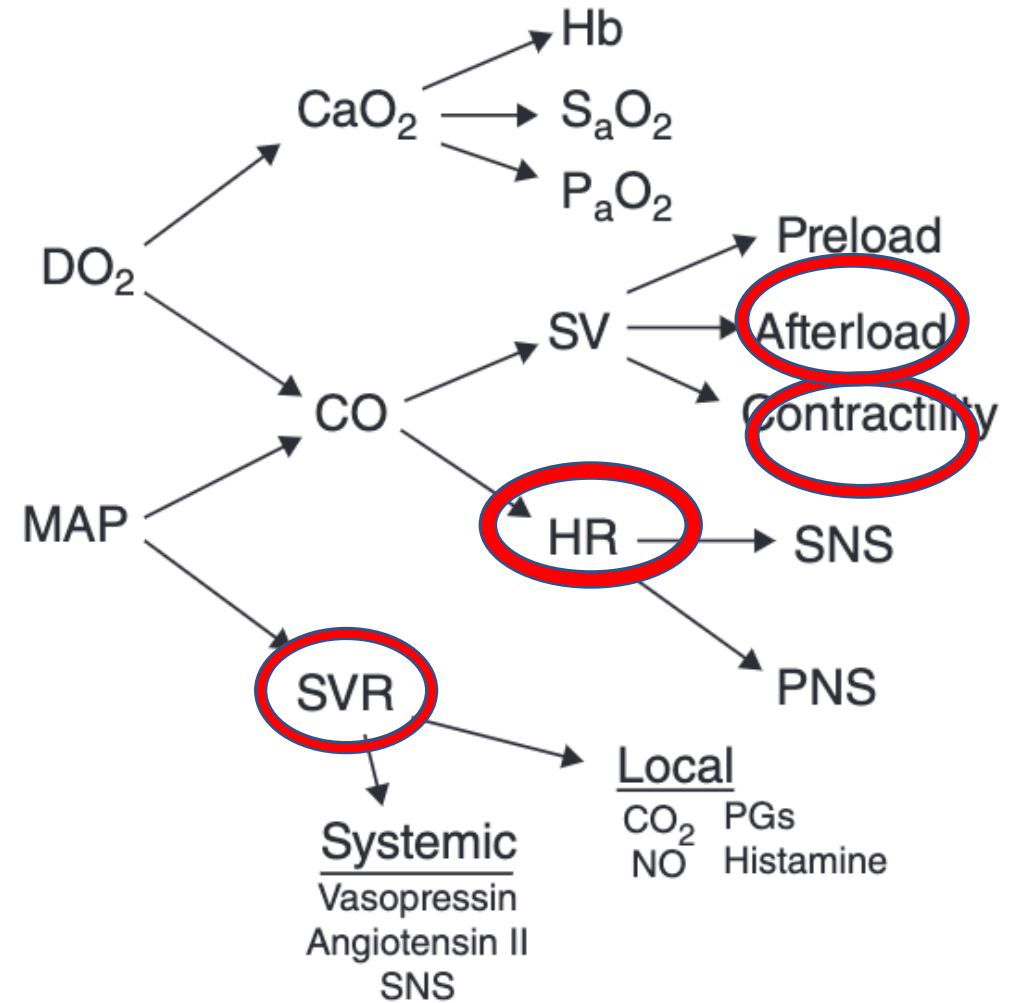
# Continuous Re-evaluation

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- Fluid requirements can change quickly
- Excessive fluid can lead to cellular edema
- Patients may remain hypovolemic

# Treatment of Fluid Unresponsive Shock





# Vasoactive and Inotropic agents

	Receptor activity			Effect on*					Dosage
	$\beta_1$	$\beta_2$	$\alpha_1$ & $\alpha_2$	Contractility	Heart rate	Cardiac output	Vasomotor tone	Blood pressure	
Dobutamine	++	+	+	↑↑	↑	↑↑	↓	Variable	5–20 $\mu\text{g/kg/min}$
Dopamine <sup>§</sup>	++	+	++	↑↑	↑↑	Variable	↑↑	↑↑	5–20 $\mu\text{g/kg/min}$
Epinephrine	+++	+++	+++	↑↑↑	↑↑↑	↑↑	↑↑↑	↑↑↑	0.05–1 $\mu\text{g/kg/min}$
Norepinephrine	+	0	+++	↑	Variable	Variable	↑↑↑	↑↑↑	0.1–2 $\mu\text{g/kg/min}$
Phenylephrine	0	0	+++	0	↓	↓	↑↑↑	↑↑↑	0.5–5 $\mu\text{g/kg/min}$
Vasopressin	0	0	0	0	↓	↓	↑↑	↑↑	0.5–5 mU/kg/min

Silverstein, Deborah & Beer, Kari. (2015). Controversies regarding choice of vasopressor therapy for management of septic shock in animals. Journal of veterinary emergency and critical care (San Antonio, Tex. : 2001). 25. 48-54. 10.1111/vec.12282.

# Antibiotic Therapy

**Duration of hypotension before initiation of effective antimicrobial therapy is the critical determinant of survival in human septic shock**

Anand Kumar <sup>1</sup>, Daniel Roberts, Kenneth E Wood, Bruce Light, Joseph E Parrillo, Satendra Sharma, Robert Suppes, Daniel Feinstein, Sergio Zanotti, Leo Taiberg, David Gurka, Aseem Kumar, Mary Cheang

- Should be administered within the first hour of recognition
- Right drug
- Right dose
- De-escalation
- Right duration

# Antibiotic Therapy Con't

- Four quadrant therapy
- Bactericidal over bacteriostatic
- Duration of antibiotics should typically be 7-10 days
- Source control

**Initiation of inappropriate antimicrobial therapy results in a fivefold reduction of survival in human septic shock**

Anand Kumar<sup>1</sup>, Paul Ellis<sup>2</sup>, Yaseen Arabi<sup>3</sup>, Dan Roberts<sup>4</sup>, Bruce Light<sup>4</sup>, Joseph E Parrillo<sup>5</sup>, Peter Dodek<sup>6</sup>, Gordon Wood<sup>7</sup>, Aseem Kumar<sup>8</sup>, David Simon<sup>9</sup>, Cheryl Peters<sup>4</sup>, Muhammad Ahsan<sup>4</sup>, Dan Chateau<sup>10</sup>;

Cooperative Antimicrobial Therapy of Septic Shock Database Research Group

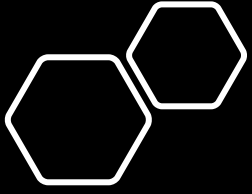
# Suggested Empiric Antimicrobials

Situation	Antimicrobial drug	Intravenous dosage	Spectrum of activity
<b>Scenario 1</b>			
Patients with no recent antimicrobial history (30 days) and community-acquired infection	Ampicillin/sulbactam	50 mg/kg q6h	Gram-negative bacteria, streptococci, susceptible staphylococci and enterococci, most anaerobes
	OR Clindamycin	12 mg/kg q8h	
	AND	15 mg/kg q24h	
	Amikacin		
<b>Scenario 2</b>			
Patients in scenario 1 with acute kidney injury or chronic kidney disease*	Ampicillin/sulbactam	50 mg/kg q8h	Most gram-negative bacteria, anaerobes, streptococci, and susceptible staphylococci and enterococci. Not effective for MDR gram-negative bacteria
	OR Clindamycin	12 mg/kg q8h	
	AND	Dogs: 15 mg/kg first dose then 10 mg/kg q24h	
	Enrofloxacin		
<b>Scenario 3</b>			
Patients with recent antimicrobial use or hospital-acquired infection	Third-generation cephalosporin with anti- <i>Pseudomonas</i> activity		Gram-negative rods including <i>Pseudomonas</i> and streptococci. Not active against methicillin-resistant staphylococci and enterococci†
	Cefotaxime	30 mg/kg q8h	
	Ceftazidime	30 mg/kg q8h	
<b>Scenario 4</b>			
Patients that developed new-onset or worsening severe sepsis/septic shock while on a third-generation cephalosporin	Meropenem	12 mg/kg q8h	MDR aerobic gram-negative bacteria, streptococci, and anaerobes
AND/OR	AND/OR		
have risk factors for methicillin-resistant <i>Staphylococcus</i> or MDR <i>Enterococcus</i>	Vancomycin	15 mg/kg q8h	Methicillin-resistant staphylococci and MDR enterococci

# Oxygen therapy

- Flow by oxygen
- Nasal lines
- Oxygen cage
- Intubation and mechanical ventilation





# Nutrition

- Acute catabolic response
- Surviving sepsis guidelines recommend starting enteral nutrition within 72 hours.

**Early nutritional support is associated with decreased length of hospitalization in dogs with septic peritonitis: A retrospective study of 45 cases (2000–2009)**

Debra T. Liu DVM, Dorothy C. Brown DVM, MSCE, DACVS,  
Deborah C. Silverstein DVM, DACVECC [✉](#)

**Retrospective evaluation of the route and timing of nutrition in dogs with septic peritonitis: 68 cases (2007–2016)**

Kristin M. Smith DVM, DACVECC [✉](#), Aaron Rendahl PhD, Yiwen Sun,  
Jeffrey M. Todd DVM, DACVECC

# Adjunctive Therapy

- Dextrose
- Anti-thrombotics
- Pain management
- Low dose hydrocortisone

## Effect of treatment with low doses of hydrocortisone and fludrocortisone on mortality in patients with septic shock

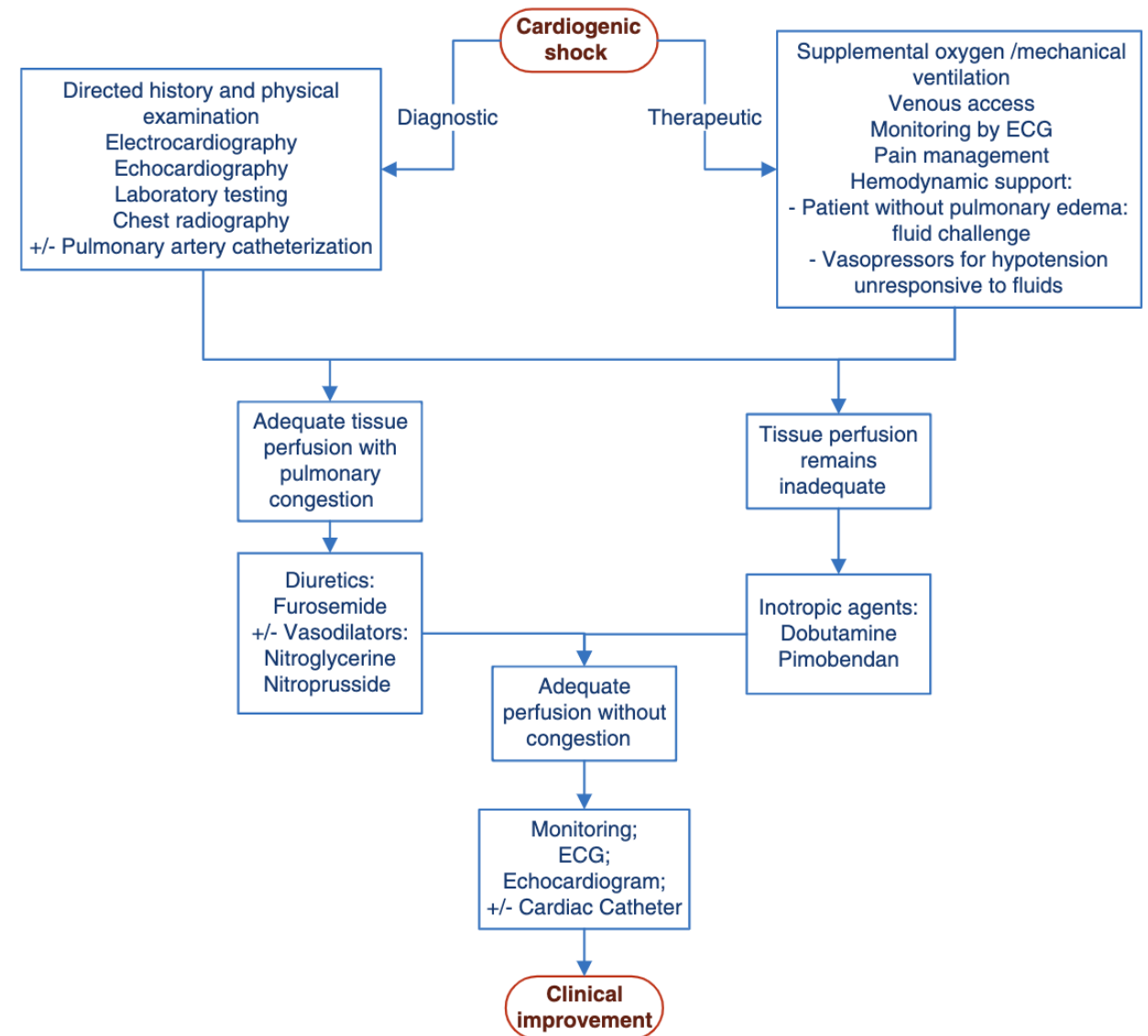
Djillali Annane <sup>1</sup>, Véronique Sébille, Claire Charpentier, Pierre-Edouard Bollaert, Bruno François, Jean-Michel Korach, Gilles Capellier, Yves Cohen, Elie Azoulay, Gilles Troché, Philippe Chaumet-Riffaud, Eric Bellissant

## Hydrocortisone therapy for patients with septic shock

Charles L Sprung <sup>1</sup>, Djillali Annane, Didier Keh, Rui Moreno, Mervyn Singer, Klaus Freivogel, Yoram G Weiss, Julie Benbenishty, Armin Kalenka, Helmuth Forst, Pierre-Francois Laterre, Konrad Reinhart, Brian H Cuthbertson, Didier Payen, Josef Briegel; CORTICUS Study Group

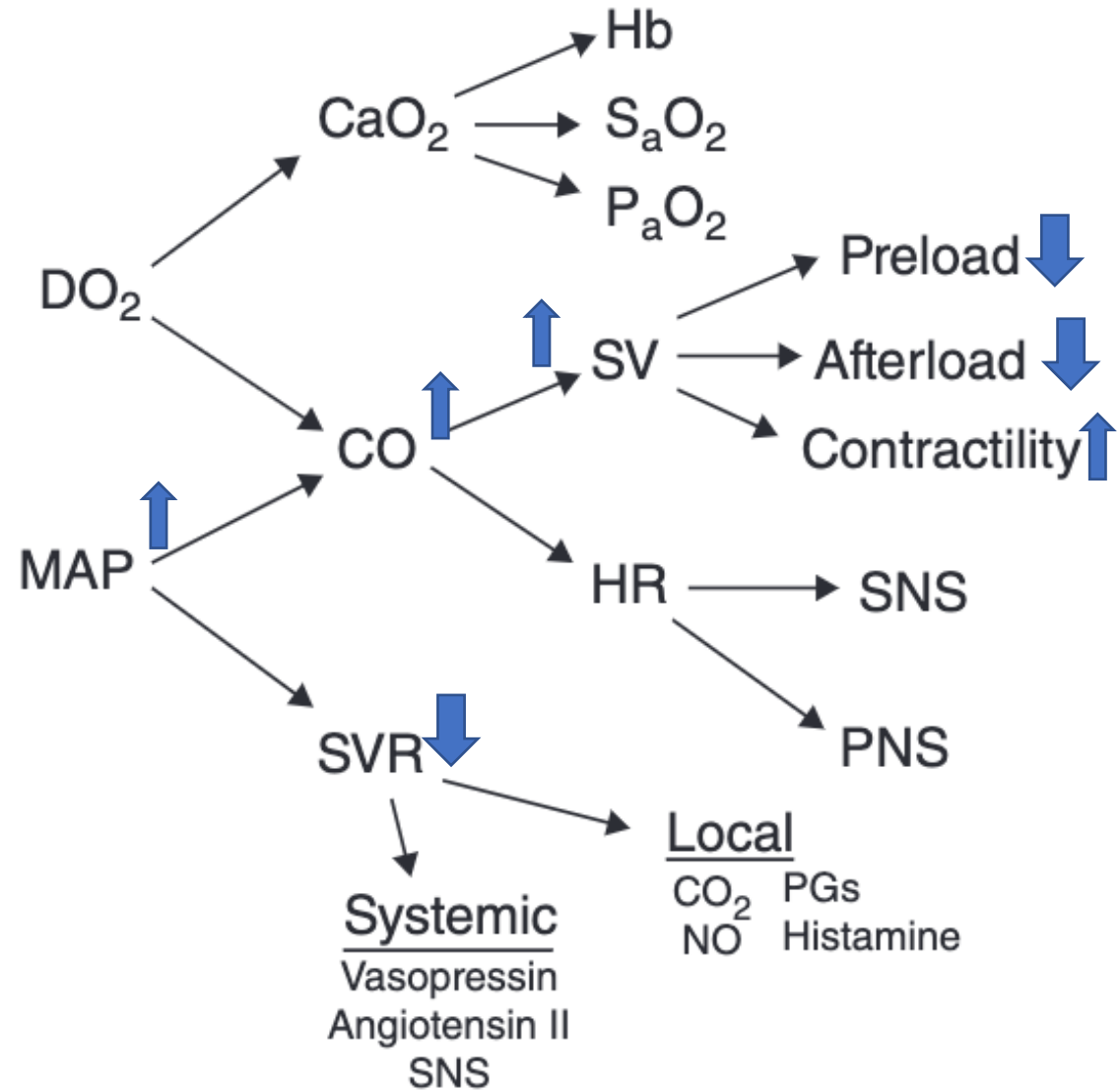
# Treatment of Cardiogenic Shock

- Rapid evaluation
- Brief physical exam
- Limited stress



# Treatment of Cardiogenic Shock Con't

- Diuretics
  - Furosemide (2mg/kg) IV or IM
- Inotropic agents
  - Dobutamine
  - Pimobendan
- Vasodilatory agents
  - Nitroprusside
  - Nitroglycerine



# Treatment of Cardiogenic Shock Con't


- Anti-arrhythmics
- Pericardiocentesis
- Pace maker

Drug		Doses	Comments
Atenolol	PO	0.2–2.0 mg/kg twice daily (gradually titrated as necessary)	Titrate to effect, can decrease contractility, use cautiously if concurrent uncontrolled CHF; beta-blockers are often not well tolerated if AF is associated with significant underlying heart disease
Amiodarone	IV	2–5 mg/kg IV bolus administered over 10 min, followed by a CRI of 0.8 mg/kg/h for 6 h, then decrease to 0.4 mg/kg/h	Aqueous (water-based) formulations (Nexterone) are better tolerated than polysorbate 80/alcohol- based formulations
	PO	Week 1: 10–15 mg/kg twice daily Week 2: 5–7.5 mg/kg twice daily Week 3 onwards: 5–7.5 mg/kg once daily	After loading period (3–4 weeks) check amiodarone levels. Monitor hepatic and thyroid function and complete blood count bimonthly
Digoxin	PO	2.5–3.0 µg/kg twice daily If body weight >20 kg the dose can be calculated based on the body surface area at 0.22 mg/m <sup>2</sup>	Do not exceed 0.25 mg per dog q 12 h.
Diltiazem	IV	0.05–0.25 mg/kg IV bolus, followed by a CRI of 2–6 µg/kg/min	IV dosing can cause transient hypotension and excessive AV block
	PO	Modified-release formulation: 0.5–4 mg/kg three times daily Sustained-release formulation: 3–5 mg/kg twice daily	Monitor for excessive bradycardia or AV block, rarely can also cause GI signs (anorexia, vomiting, diarrhoea)
Esmolol	IV	50–100 µg/kg IV bolus (can be repeated up to max 500 µg/kg) CRI 50–200 µg/kg/min	May cause myocardial depression, hypotension, bradycardia, excessive AV block - close monitoring during administration is required. The authors would only use esmolol if diltiazem IV is not available.
Lidocaine	IV	2–3 mg/kg over 5 s (repeat up to 3 times, not to exceed 8 mg/kg)	Side effects: depression, vomiting and seizures
Sotalol	PO	1.5–2.5 mg/kg twice daily	Reduces contractility, titrate to effect in cases with severe systolic dysfunction
Electrical cardioversion	Transthoracic	Biphasic defibrillator shock: 0.5–3.0 J/kg Monophasic defibrillator shock: 4–10 J/kg	Synchronization of the shock delivery to the R-waves of the QRS complexes is imperative to prevent induction of ventricular fibrillation. The authors prefer transthoracic cardioversion.
	Transeosophageal Intracardiac (transvenous)	Monophasic defibrillator shock: 0.5–2.5 J/kg Biphasic shock: 0.6–1.6 J/kg	



# Treatment of Cardiogenic Shock Con't

**Retrospective evaluation of the outcome and prognosis of  
undergoing positive pressure ventilation due to cardiac and  
noncardiac causes in dogs and cats (2019–2020): 101 cases**

Nama Oppenheimer DVM , Efrat Kelmer DVM, MS, DACVECC, DECVECC, Noam Shwartzshtein BSC,  
Gilad Segev DVM, DECVIM, Dan Ohad DVM, PhD, DACVIM, DECVIM ... [See all authors](#) ▾

# Case 1

- 10 year old male neutered golden presented for lethargy and collapse. On presentation patient is quiet and tachypneic. Initial physical exam revealed pale mucus membranes, CRT >2, HR of 160, with a palpable fluid wave. The patient also has normal to cool limbs, normal to weak pulses with a blood pressure of 70. You place a catheter and are only able to obtain a pcv/ts; 20/4.
- What is your initial management



## Case 2

- 3 year old male neutered golden presented with a one week history of vomiting, anorexia and lethargy. Over the last 12 hours the patients lethargy has progressed. On presentation the patient is dull to obtunded. Temp 104, HR 160, panting, CRT <1, Hyperemic MM, with warm limbs but weak pulses. Patient has abdominal discomfort. Blood pressure of 50.
- What is your initial management



<https://www.cliniciansbrief.com/article/quiz-mucous-membrane-evaluation-dogs>

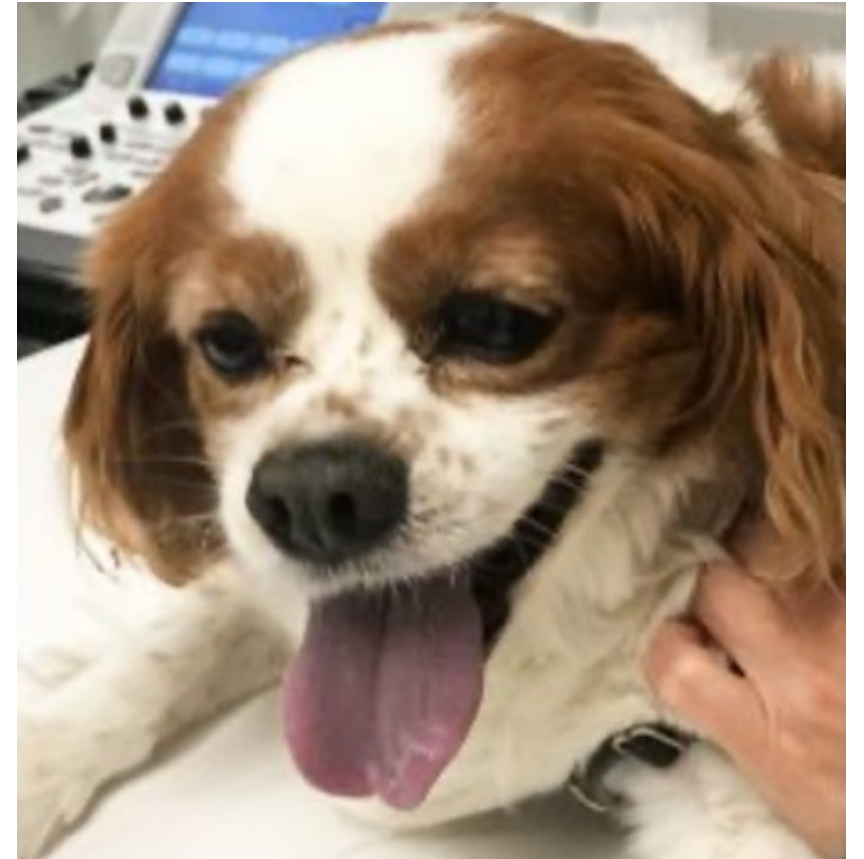


<https://todaysveterinarynurse.com/emergency-medicine-critical-care/shock-an-overview/>

# Case 3

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- 8 year old male neutered Cavalier presented for hyporexia, and progressive tachypnea. On presentation the patient was anxious, RR 60, HR 150, and cyanotic mucus membranes. Physical exam revealed bilateral crackles, fair to weak pulses and a grade 4/6 murmur. Unable to obtain blood pressure because patient was in distress
- What is your initial management





A photograph of a brown dog and an orange and white cat lying together on a dark blanket with a white geometric pattern. The dog is on the left, looking towards the camera, and the cat is on the right, also looking towards the camera. The word "Questions?" is written in white text across the middle of the image, underlined.

Questions?



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