FLUID THERAPY

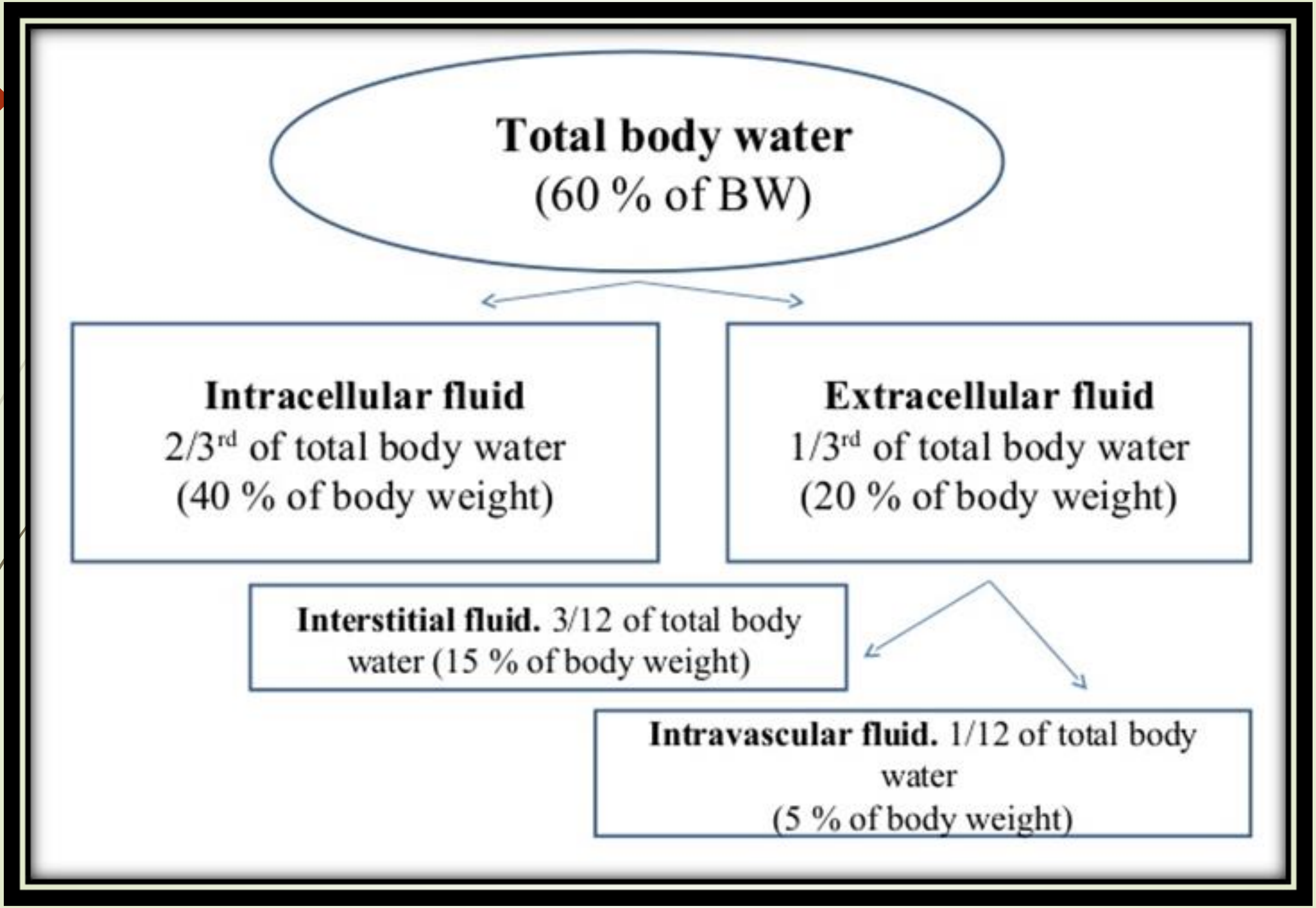
Dr. Pınar CAN

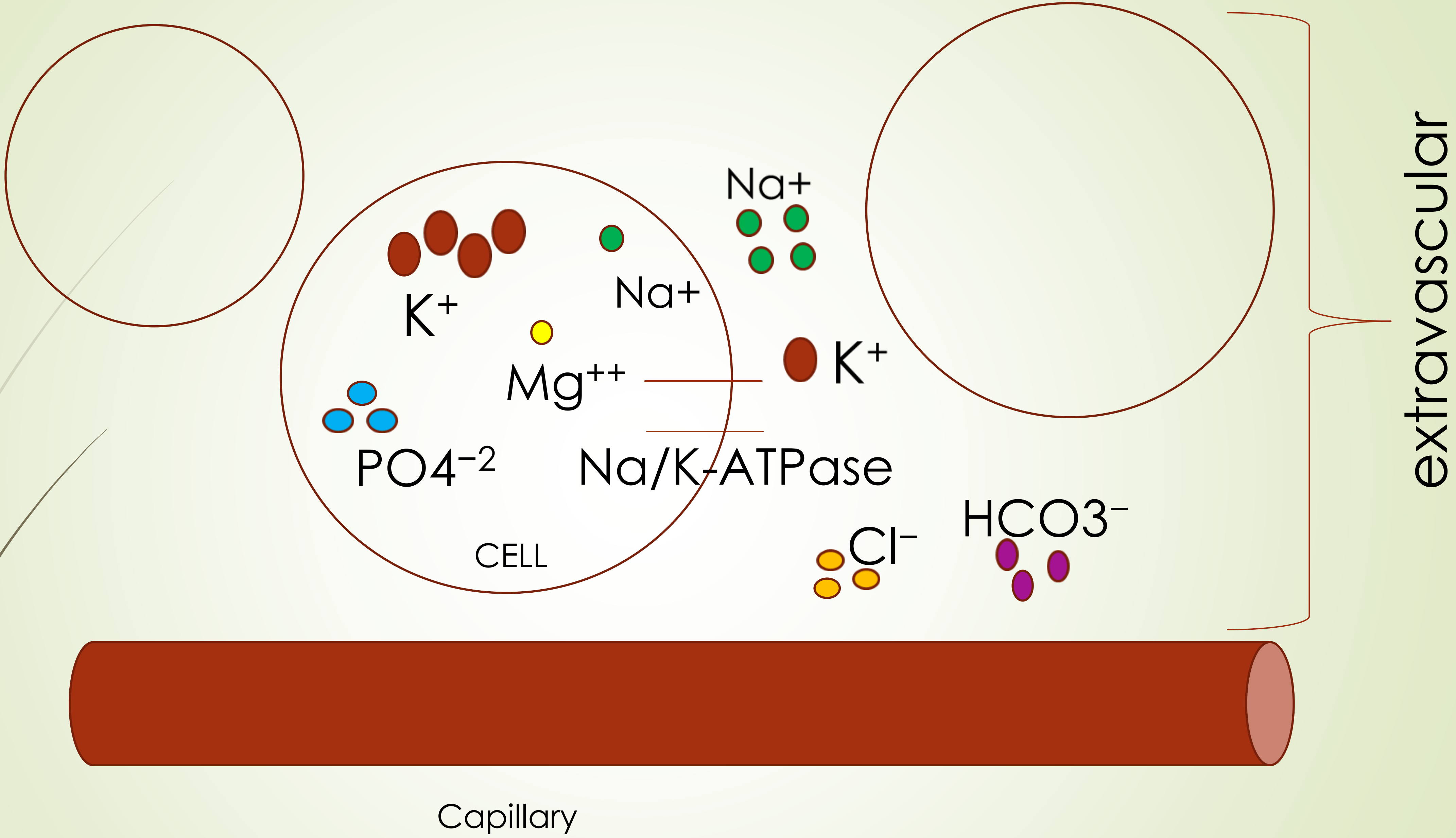
Introduction

- Small animal surgical patients commonly require fluid, electrolyte, and/or acid-base therapy to maintain adequate perfusion to the tissues and to ensure acid-base and electrolyte homeostasis.
- Perioperative patients often are not drinking or eating, yet the animal continues to make urine, saliva, and gastrointestinal secretions, and to lose fluid via respiratory evaporation.

Inadequate intravascular volume can lead to;

- hypotension,
- tissue hypoxia,
- release of vasoactive substances,
- potentially organ failure and death.


Total body water
(60 % of BW)
Intracellular fluid
2/3rd of total body water
(40 % of body weight)
Extracellular fluid
1/3rd of total body water
(20 % of body weight)
Interstitial fluid. 3/12 of total body water (15 % of body weight)
Intravascular fluid. 1/12 of total body water
(5 % of body weight)


K+
Na+
Mg++
PO4−2
Na/K-ATPase
CELL
Na+
K+
Cl−
HCO3−
extravascular
Capillary

- Dehydration, also known as hypohydration, is defined as loss of bodily fluids and can cause changes in all fluid departments, depending on the type of fluid lost.
- Abnormal fluid losses commonly occur via;

urinary (e.g., polyuria) and gastrointestinal (e.g., diarrhea and vomiting) losses,

although skin (e.g., burns), respiratory tract, salivary gland,

hemorrhage, and third-space (e.g., abdominal fluid, hematomas,

pleural effusion, tissue trauma) losses

also result in decreased effective circulating volume

Estimating % dehydration based on P/E

% Dehydration	Physical Examination Findings
< 5	History of **fluid loss** but no findings on physical examination
5	**Dry oral mucous membranes** but no panting or pathological tachycardia
7	Mild to moderate **decreased skin turgor, dry oral mucous membranes, slight tachycardia,** and normal pulse pressure
10	Moderate to **marked degree of decreased skin turgor, dry oral mucous membranes, tachycardia, and decreased pulse pressure**
12	Marked loss of skin turgor, dry oral mucous membranes, and significant signs of **shock**

- Isotonic replacement fluids should be administered according to the patient's estimated dehydration, maintenance needs, and anticipated ongoing losses

Fluid deficit calculation

- Body weight (kg) x % dehydration = volume (L) to correct PLUS estimated ongoing losses PLUS Maintenance = Fluid amount to be given over next 6 to 24 hours

- Ongoing losses include those caused by vomiting, diarrhea, polyuria, open wounds or burns, fever, third-spacing, or blood loss.
- Maintenance fluid rates are estimated at 2 to 4 mL/kg/hr, with larger or overweight animals using the lower end of the range and smaller or thin patients the upper end

- Animals requiring surgery often need fluid therapy before receiving general anesthesia.
- It is important to ensure that preoperative patients are well hydrated and cardiovascularly stable, and have adequate oxygen content.
- Correction of clinical anemia, volume deficits, or electrolyte and acid-base derangements is especially important in the presurgical patient population because anesthetic drugs commonly have negative effects on the heart, blood pressure, and baroreceptor response.

- During anesthesia, most animals are given 5 to 10 mL/kg/ hr of isotonic crystalloids (without added electrolytes) intravenously to maintain intravascular volume and pressures.
- Monitoring animal before, during and after surgery

During surgery;

- vital signs,
- Blood pressure, and pulse oximetry readings (to ensure adequate oxygen saturation of the blood) will help to ensure adequate tissue perfusion and oxygen delivery.
- Some animals will also benefit from central venous pressure monitoring during surgery.

FLUID TYPES AND USES

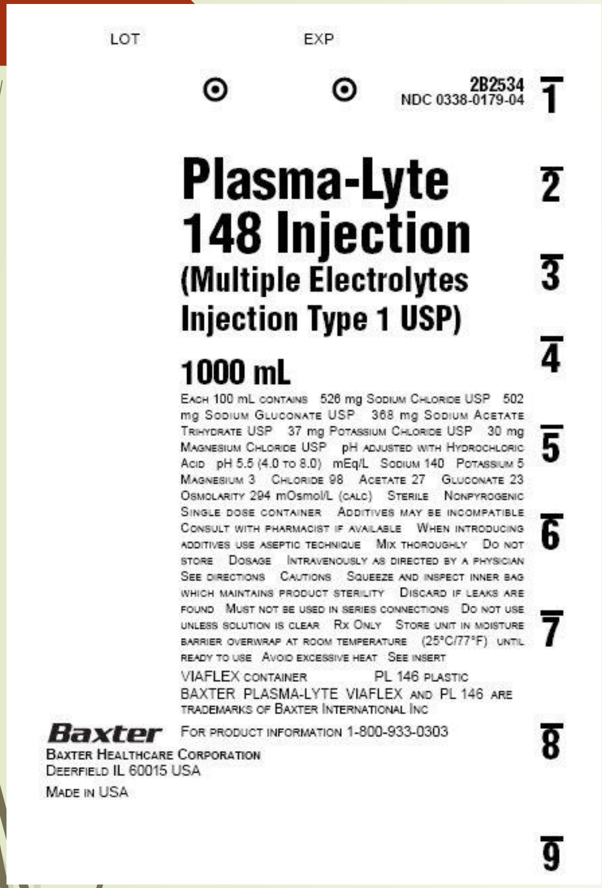
- Various types of fluids are available and are commonly categorized on the basis of their tonicity, electrolyte composition relative to extracellular fluid, molecular weight, and pH.

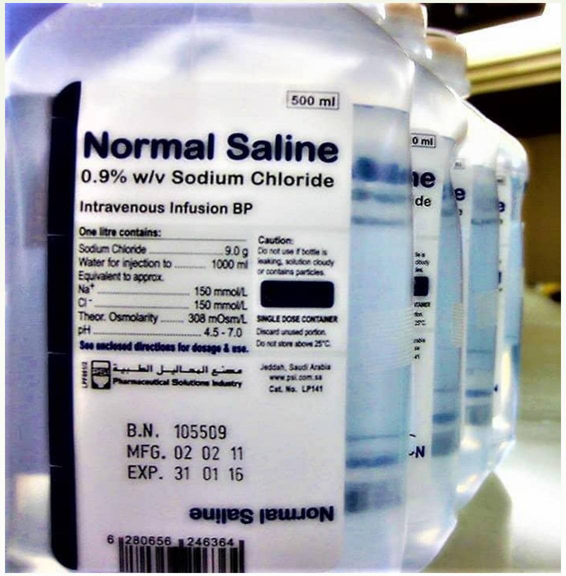
- Fluids that have the same osmolarity as the extracellular space are isotonic,
- those with a lower osmolarity are hypotonic,
- those with a higher osmolarity are hypertonic.
- Fluids that contain electrolytes similar to those of the extracellular space are referred to as balanced, and those that do not are unbalanced.

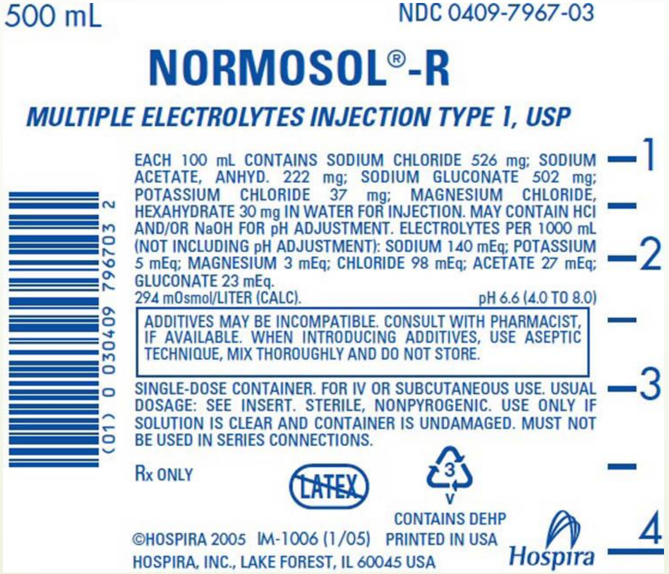
Crystalloid solutions

- contain electrolytes and other solutes that are distributed throughout all compartments
- Isotonic crystalloids, also known as replacement fluids, are electrolyte containing fluids with a composition similar to that of extracellular fluid
- They have the same osmolarity as plasma (290 to 310 mOsm/L), and the electrolytes are small

isotonic crystalloids







Isotonic Crystalloid Compositions

FLUID TYPE	OSMOLARITY (MOSM/L)	[NA⁺] (MEQ/L)	[K⁺] (MEQ/L)	[CL⁻] (MEQ/L)	[MG⁺⁺] (MEQ/L)	[CA⁺⁺] (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

- change the osmolarity of the vascular or extravascular (both interstitial and intracellular) space.
- typically used to expand the intravascular and interstitial spaces and to maintain hydration.
- most commonly used contain mixtures of electrolytes, water, ±acid-base components, ±dextrose.

- Most available isotonic crystalloids (except 0.9% NaCl) contain a bicarbonate precursor such as lactate, acetate, or gluconate.
- Lactated Ringer’s solution contains either just l-lactate or a racemic mixture of d- and l-lactate.
- Because d-lactate is not readily metabolized in dogs, the alkalinizing effect is not as profound as that seen with acetate

- Large amounts of 0.9% NaCl will cause a mild increase in sodium, a marked increase in chloride, and a moderate decrease in bicarbonate and potassium

- The kidneys will typically compensate, if possible, by excreting the excess electrolytes and conserving potassium

- Animals with hypochloremia, hyponatremia, or a metabolic alkalosis will often benefit from the administration of 0.9 % NaCl.

- Excessive fluid administration should be avoided and can be harmful to the small animal surgical patient
- Interstitial fluid gain can lead to interstitial edema, pulmonary edema, and cerebral edema
- Surgical patients that have low colloid osmotic pressure, pulmonary contusions, cerebral trauma, fluid nonresponsive renal disease, or cardiac disease are at highest risk for complications.

- Although all isotonic crystalloids have a similar composition, in some situations a certain fluid type might be preferable over another.

1. Surgical patients with head trauma should be resuscitated with 0.9% NaCl, if possible, because this fluid has the highest sodium concentration and therefore is least likely to cause a decrease in osmolarity and subsequent water movement into the brain interstitium.

2. Perioperative animals with severe hyponatremia or hypernatremia should receive crystalloid fluids that most closely match the patient's sodium concentration during resuscitation to avoid a rapid increase or decrease in serum osmolarity and subsequent central pontine myelinolysis (often delayed in onset) or cerebral edema, respectively.

3. Surgical patients with a hypochloremic metabolic alkalosis will benefit from 0.9% NaCl because this is the highest chloride-containing fluid. It will help to normalize blood pH by dilution and by increased chloride, with a subsequent decrease in bicarbonate concentration.

4. Surgical animals that are severely acidotic may benefit from a crystalloid that contains a buffer agent such as acetate, gluconate, or lactate

- Large quantities of acetate can cause vasodilation and a decrease in blood pressure in animals with preexisting hypovolemia.
- This occurs secondary to adenosine release from muscle tissue, and adenosine is a potent vasodilator.

Hypotonic Solutions

- Maintenance fluids are hypotonic
- the volume of fluid and quantity of electrolytes that must be consumed on a daily basis to keep the volume of total body water and electrolyte content within the normal range
- useful in perioperative patients that are not eating or drinking but are otherwise stable and do not have ongoing fluid losses beyond those of a normal animal.

hypotonic crystalloids that are low in sodium, chloride, and osmolarity, but may be high in potassium compared with normal plasma concentrations

Maintenance and Free Water Solutions

FLUID TYPE	OSMOLARITY (MOSM/L)	[NA⁺] (MEQ/L)	[K⁺] (MEQ/L)	[CL⁻] (MEQ/L)	[MG⁺⁺] (MEQ/L)	[CA⁺⁺] (MEQ/L)	LACTATE (MEQ/L)	ACETATE (MEQ/L)	DEXTROSE
0.45% NaCl	150	77		77					
0.45% NaCl with 2.5% dextrose	203	77		77					2.5%
Plasmalyte 56	110	40	13	40	3			16	
Normosol M	110	40	13	40	3			16	
½ Lactated Ringer's solution with 2.5% dextrose	265	130	4	109		3	28		2.5%
5% Dextrose in water (D5W)	252								5%

plasma 290 to 310 mOsm/L

- The dextrose, if included, is rapidly metabolized to CO_2 and H_2O. These fluids are distributed into all body fluid compartments and therefore are contraindicated as bolus therapy in animals with hypovolemia that require rapid extracellular fluid resuscitation.
- Large volumes of hypotonic maintenance fluid administration can lead to a rapid decrease in osmolarity and subsequent cerebral edema.

- To give free water intravenously without using a dangerously hypotonic fluid, sterile water is combined with 5% dextrose (D5W) to yield an osmolarity of 252 mOsm/L
- This fluid is indicated in animals with moderate to severe free water deficit (i.e., hypernatremia) or marked ongoing free water losses (i.e., diabetes insipidus)

Hypertonic Solutions

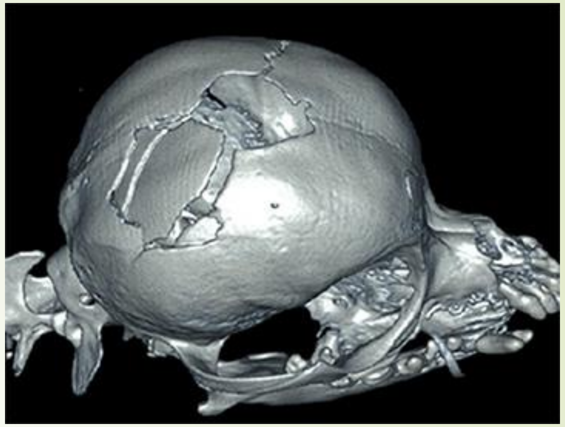
Hypertonic Fluids

FLUID TYPE	OSMOLARITY (MOSM/L)	[NA+] (MEQ/L)	[K+] (MEQ/L)	[CL−] (MEQ/L)	[MG++] (MEQ/L)	[CA++] (MEQ/L)	LACTATE (MEQ/L)	ACETATE (MEQ/L)	GLUCONATE (MEQ/L)
7.5% NaCl	2400	1200							
23.4% NaCl	8000	4000							
25% Mannitol	1250								

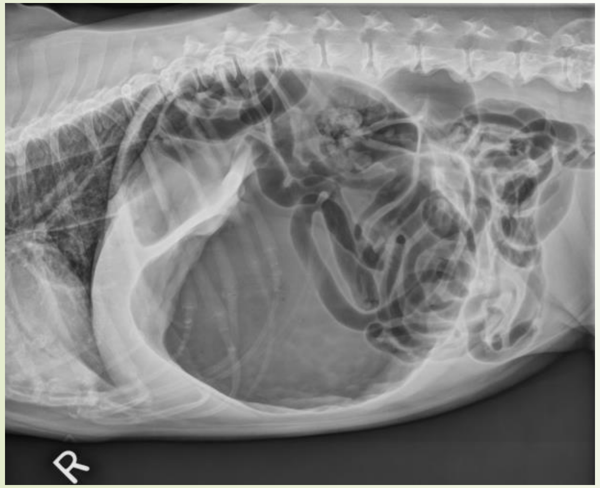
plasma 290 to 310 mOsm/L

- Hypertonic (7.0% to 7.5%) sodium chloride administration causes a transient osmotic shift of water from the extravascular to the intravascular compartment.
- Small volumes of ≈4 to 6 mL/kg can be administered over 10 to 20 minutes.
- Rates exceeding 1 mL/kg/min may result in osmotic stimulation of pulmonary C-fibers, which leads to vagally mediated hypotension, bradycardia, and bronchoconstriction and should be avoided!!!!

- Although hypertonic saline is given primarily to shift extravascular water into the intravascular space, evidence suggests that it may also help to reduce endothelial swelling,
- increase cardiac contractility, cause mild peripheral vasodilation,
- modulate inflammation, and decrease intracranial pressure.



- head trauma
- cardiovascular shock in animals >30 kg that require large amounts of fluid for resuscitation
- and in which time is of the essence (e.g., patients with gastric dilatation volvulus)



- Because of the osmotic diuresis and rapid redistribution of sodium cations that ensue following administration of hypertonic saline, the intravascular volume expansion is transient (<30 minutes), and additional fluid therapy must be used to maintain intravascular volume and prevent dehydration.

- Although 25% mannitol could also be used as a hypertonic fluid, it is less effective at increasing intravascular volume because the osmolarity is approximately half that of 7.5% saline

Risks

- An increase in the concentrations of sodium and chloride in the blood will occur after administration (in addition to an increase in osmolarity). A decrease in potassium (from dilution and osmotic diuresis) and bicarbonate (secondary to dilution and increased chloride) concentrations should also be anticipated.
- should not be given to dehydrated animals because these patients are interstitially volume depleted, thus limiting the effectiveness of the fluid and predisposing to further dehydration.

- If hypertonic solutions are administered in small peripheral veins, hemolysis and phlebitis can result because of the hypertonicity of the fluid and subsequent damage to red blood and endothelial cells.

Synthetic Colloid Solutions

- Synthetic colloid solutions contain primarily large molecules (molecular weight >20,000 daltons) that do not readily sieve across the vascular membrane.
- Colloidal particles generally range from a few thousand to several million daltons and are suspended in an isotonic crystalloid fluid.

- When administered intravenously, they increase the colloid osmotic pressure of the plasma, making it hyperoncotic to the extravascular fluid, and therefore pull fluid into the intravascular space
- resultant increase in blood volume is greater than that of the infused volume, and the colloid particles help to retain this fluid in the intravascular space in the animal with normal capillary permeability.

- Synthetic colloid solutions are commonly used for the treatment of shock and in patients with moderate to severe hypoproteinemia and a decrease in colloid osmotic pressure.

Synthetic Colloid Solution Characteristics

COLLOID PRODUCT	RANGE OF MOLECULAR WEIGHTS	COLLOID OSMOTIC PRESSURE (MM HG)	NUMBER AVERAGE MOLECULAR WEIGHT (DA)	WEIGHT AVERAGE MOLECULAR WEIGHT (DA)	DEGREE OF SUBSTITUTION	C2:C6 RATIO	OSMOLARITY (MOSM/L)	[NA^+] (MMOL/L)
Hetastarch 450 (Hespan)	10,000-1,000,000	29-32	69,000	450,000	0.7	4.6:1	310	154
Hetastarch 670 (Hextend)		31		670,000	0.75	4-5:1	307	143
Hetastarch/ pentastarch 264 (Pentaspan)			63,000	264,000	0.45		326	154
Hetastarch 200 (Expahes)		65		200,000	0.5	5:1	300	154
Hetastarch 200 (Haes-steril)				240,000	0.4-0.55	5:1	308	154
Hetastarch 200 (Elohäst)		25		200,000	0.6-0.66	5:1	308	154
Hetastarch 130 (Voluven)		37		130,000	0.4	9:1	308	154
Dextran 70	15,000-3,400,000	62	41,000	70,000			302	154
Hemoglobin glutamer 200 (bovine) (Oxyglobin)	64,000-500,000	43		200,000			300	150

- Potential side effects of synthetic colloid use are related primarily to disruption of normal coagulation.
- These include a decrease in factor VIII and von Willebrand factor concentrations(decrease beyond a dilutional effect),
- impairment of platelet function,
- interference with the stability of fibrin clots, which makes the clot more susceptible to fibrinolysis.

- Synthetic colloids in animals with acute hypoproteinemia (total protein <3.5 mg/dL) are typically dosed as a continuous rate infusion of 0.5 to 2 mL/kg/day. A total dose of <20 mL/ kg/day is advised to avoid side effects.
- For the treatment of animals in hypovolemic shock that are not adequately responsive to isotonic crystalloids alone, doses of 5 to 20 mL/kg in the dog and 2.5 to 10 mL/kg in the cat are typically used.
- Synthetic colloids are used frequently in combination with isotonic crystalloids to maintain adequate plasma volume expansion with less expansion of the interstitial space

Hypertonic Saline/Colloid Solutions

- To pull fluid into the vascular space and prolong the effects of intravascular volume expansion, a hypertonic saline/synthetic colloid mixture is commonly used for the resuscitation of animals with noncardiogenic shock.
- 1 : 2.5 ratio of 23.4% sodium chloride to hydroxyethyl starch (e.g., Hextend) or hypertonic saline Dextran 70 will make a 7.5% saline mixture (i.e., 17 mL of 23.4% saline added to 43 mL of Dextran 70).
- Traumatic shock, pyometra with septic shock, burns, hemorrhagic shock, endotoxemia, and gastric dilatation volvulus.

Shock

- Shock is the clinical picture observed when tissue oxygen delivery or utilization is compromised.
- Oxygen delivery (DO_2) depends upon adequate cardiac output (CO) and arterial oxygen content (CaO_2).
- Oxygen utilization reflects the ability of the cells to gain access to oxygen and convert it into energy.

- Tissue hypoxia is the result of inadequate oxygen delivery or utilization.
- The body responds to tissue hypoxia or shock by engaging a constellation of compensatory mechanisms to preserve vital organ function and host viability.

These compensatory mechanisms are manifest as the classic clinical findings in a patient in shock:

- tachycardia (to increase oxygen delivery),
- tachypnea (to increase oxygenation),
- peripheral vasoconstriction (to maintain perfusion of vital organs),
- mental depression (in response to decreased

perfusion or hypoxia).

Classification of Shock

- ***Hypovolemic shock i***s a consequence of a reduction in the circulating intravascular volume. It leads to impaired oxygen delivery through a reduction in venous return to the heart (preload) and, as a consequence, reduced cardiac output.
- Hypovolemic shock can be caused by hemorrhagic losses (internal or external bleeding) or by the loss of other body fluids (third space, gastrointestinal/urinary losses, burns).

- ***Cardiogenic shock*** results from an inability of the heart to propel the blood through the circulation.
- Cardiogenic shock can result from anything that interferes with the ability of the heart to fill (diastolic failure) or pump blood (systolic failure).
- This classification of shock also includes extra cardiac causes that, acting through compression on the heart or the great vessels, result in impaired cardiac filling or emptying (sometimes referred to as obstructive shock and classified as a separate category).

- ***Distributive shock*** is characterized by an impairment of the mechanisms regulating vascular tone, with maldistribution of the vascular volume and massive systemic vasodilation.
- The consequence of this decrease in systemic vascular resistance is that the amount of blood in the circulation is inadequate to fill the vascular space, creating relative hypovolemia and a reduction in venous return.
- The most common causes of distributive shock are sepsis and the systemic inflammatory response syndrome (SIRS).
- However, distributive shock can be caused by anaphylactic reactions (anaphylactic shock), drugs (anesthetics), or severe damage to the central nervous system associated with sudden loss of autonomic nervous stimulation on the vessels (neurogenic shock).

- ***Hypoxic shock*** is characterized by adequate tissue perfusion but inadequate arterial oxygen content or cellular oxygen utilization
- The most common causes of hypoxic shock are anemia (reduced hemoglobin [Hb concentration—anemic hypoxia) and hypoxemia associated with respiratory failure.
- Hypoxic shock can also be associated with toxicities that impair the ability of hemoglobin to bind oxygen, such as methemoglobinemia (e.g., acetaminophen toxicity in cats) or carbon monoxide poisoning.

- In metabolic or cytopathic shock, despite adequate tissue levels of oxygen, cells are not able to produce a sufficient amount of energy.
- This form of hypoxic shock is caused by intracellular interference with oxygen uptake and aerobic energy production (e.g., sepsis, toxins).

Common Causes of Shock

Hypovolemic	
Hemorrhagic	Blood loss
Nonhemorrhagic	Burns/large open wounds
	Severe diarrhea/vomiting
	Urinary losses
	Third-space losses
	Severe dehydration
Cardiogenic	
Systolic failure	Myocardial dysfunction (congestive heart failure, dilated cardiomyopathy)
	Severe arrhythmia
	Mechanical defects (valvular defects, stenosis/insufficiency)
	Drugs
Diastolic failure	Hypertrophic cardiomyopathy
	Cardiac tamponade
	Pericardial fibrosis
	Tension pneumothorax
Distributive	
Sepsis	(Septic shock, initiated by maldistribution can also lead to hypovolemic, cardiogenic, and hypoxic shock.)
Anaphylaxis	
Drugs	
Neurogenic	
Hypoxic	
Hypoxemia	
Anemia	
Methemoglobinemia	
Carbon monoxide poisoning	
Cytopathic (metabolic)	