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# Essentials of Fluid Therapy

# Mini Series

## Session One: The Basics

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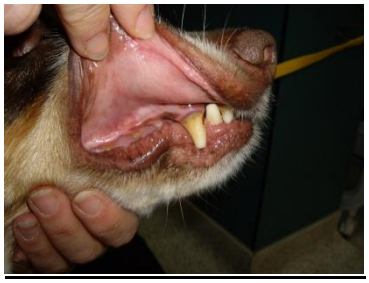


**Webinar 1 Study Notes**

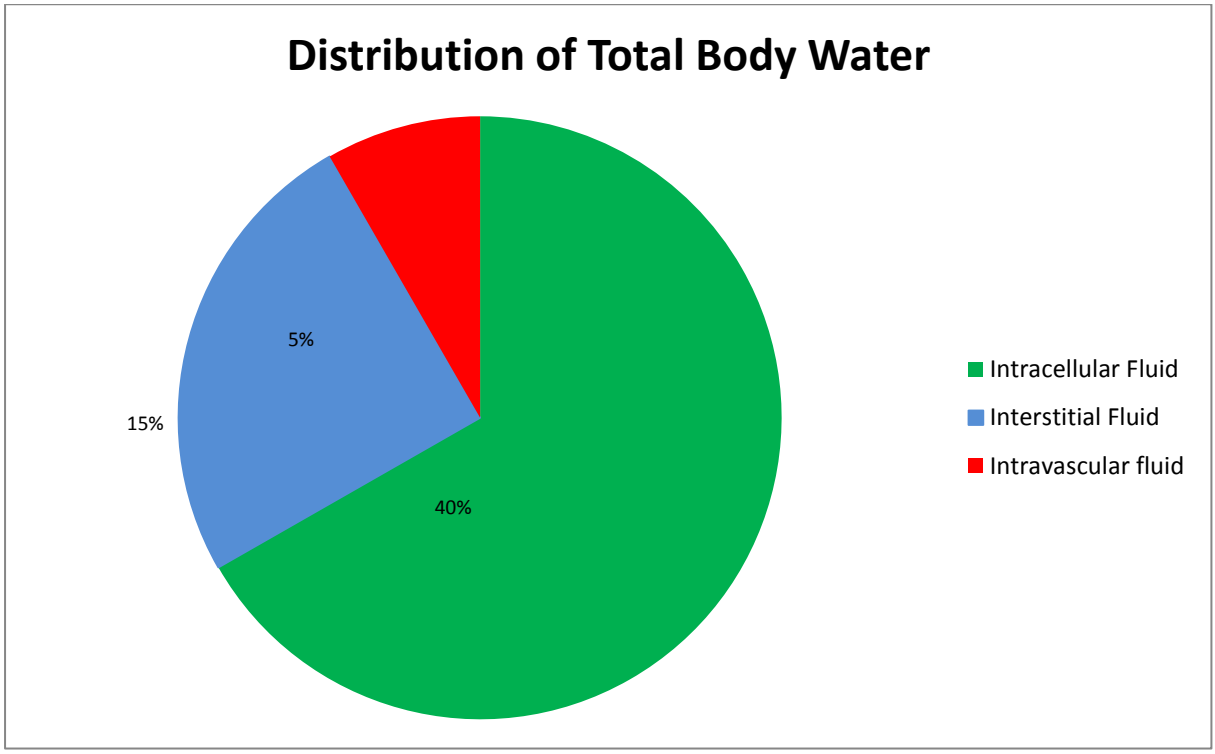
**Fluid Therapy in Small Animal Practice: Part 1 – The Basics**

## Introduction

To be able to formulate an appropriate fluid therapy plan it is important to have a basic understanding of the physiological concepts. This first part in a 3 part series discussing fluid therapy, will cover some basic physiological concepts associated with body fluids, and also describe how to detect and assess fluid deficits in animals.

## Fluid Distribution within the Body

Figure 1 – distribution of body water




Intracellular water –

There are 2 major compartments within the body that contain water:

1. the intracellular compartment or fluid inside cells accounts for 40% of total bodyweight (TBW) and 2/3rds of total body water. The amount of water inside cells is determined by the electrolyte concentration. If the inside of the cell has more salt, then water will move inwards to reduce the osmolality. The main electrolytes inside cells are potassium, magnesium and calcium.
2. the extracellular compartment accounts for approximately 20% of TBW. It can be further divided into that which resides in the interstitial space (15% of TBW) and that which is in the intravascular space (5% of TBW). The main electrolytes outside the cells are sodium and chloride, both in the interstitium and in the blood.

The volume of fluid in each compartment is not fixed, but is always in a dynamic state, with fluid moving from one compartment to another via osmosis, or being lost in the urine, faeces, sweat and from the respiratory tract. Total body water in an adult animal is approximately 60% of the total bodyweight, but there are small variations in this, dependent on age, species and breed, and how much fat content the animal has. Neonates have higher body water (approx. 80% of body weight). As fat holds less water than other tissues, fluid therapy calculations must be based upon lean body weight (estimated).

**Physical Principles**

**1. Osmosis** - the movement of WATER only. Its movement is determined by the concentration of particles that exert an osmotic effect (e.g. glucose) in one compartment compared to another. Providing that there is a permeable membrane between 2 compartments, water will move from an area where there are fewer molecules of glucose, to an area where there are more molecules of glucose, until the glucose concentration of the compartments either side of the membrane are equal. As a clinical example – if a hypertonic solution (a solution with a lot of particles) is intravenously administered to an animal, water from the other compartments will move into the vascular space because there is a high concentration of active particles within the vascular space. Water will only stop moving once the concentrations of particles within each compartment have equilibrated with one another. Those particles with the ability to move water in this way are said to exert osmotic pressure (the theoretical pressure that would need to be applied to stop that movement).

**2. Osmolality and osmolarity** - indicates the concentration of osmotically active particles within a solution. Remember that an osmotically active particle is one that has the ability to draw in water into a body compartment. Osmolality is only dependent on the NUMBER of particles, and not their size, weight or charge. It is measured as the number of particles per kilogram of solvent. This is in contrast to osmolarity which refers to the number of particles per litre of solution, but in biological fluids, essentially they are synonymous, and are often used interchangeably. When an osmotically active particle draws in water, it is said to exert an osmotic pressure. Osmotically active particles include electrolytes like sodium, and other molecules like glucose.

Serum osmolality of the dog and cat are 300 and 310 mOsm/kg respectively. Osmolality can be **estimated** by multiplying the plasm sodium concentration by two (as it constitutes the main osmotically active substance).

**3. Tonicity** - similar to osmolality but reflects how effective that solution is at initiating water movement. It can be thought of as the effective osmolality. Not all particles exert an osmotic effect, and a solution can contain both effective and ineffective particles. The tonicity of a fluid only reflects effective particles. This is an important concept as tonicity is used to categorise fluids as hypotonic, isotonic or hypertonic when compared with plasma.

**4. Oncotic Pressure** - the vascular endothelium is relatively freely permeable to water and electrolyte molecules, but is only selectively permeable to larger molecules like proteins. As a result, there is a high concentration of proteins within the vascular compartment.

Proteins, like electrolytes and glucose, are also osmotically active and they have the ability to retain water through osmosis and exert an osmotic pressure. To distinguish the protein effect from other solute effects, the term oncotic pressure (or colloid osmotic pressure) is used, and it is a very important physiological mechanism in the maintenance of vascular volume. Albumin and globulins are the proteins within the body responsible for oncotic pressure. Oncotic pressure is also present in the interstitium as albumin is small enough to be able to pass through blood vessel walls. To make this relevant to clinical practice, consider an example of a decrease in protein concentration, such as that seen in hypoalbuminaemia. Overall body fluid is reduced as albumin provides oncotic pressure in the interstitium as well as within the vasculature. Blood volume is reduced, and these animals may suffer from hypotension and perfusion problems. In addition, because there are no proteins holding water in the intravascular space, fluid can accumulate in the tissues and be evident as oedema. An understanding of oncotic pressure forms the basis for administering colloids to animals.

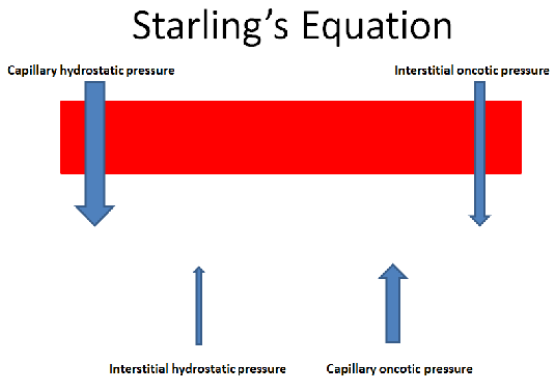
**5. Hydrostatic Pressure -** another determinant of fluid movement into and out of tissues and the vascular space. In the blood vessels, it is the pressure exerted by the blood on the blood vessel walls, independent of osmotic and oncotic pressure. At the arterial end of a blood vessel, the hydrostatic pressure will be high and therefore fluid will move out of the blood vessel into the interstitium. At the venous end of a blood vessel, hydrostatic pressure will be low because the venous system is a low pressure system. This will favour the movement of fluid from the interstitium into the vascular space.

**Fluid Movement and Control**

Fluid movement is dependent on the permeability of the barrier to fluids. Water, generally speaking, can move relatively freely across capillary and cellular walls. Electrolytes however, cannot move freely into cells, and their movement is controlled by a variety of sophisticated pumps and channels. However, electrolytes can move relatively freely across the vascular endothelium.

In the normal healthy animal there are mechanisms that control movement of fluid across the capillary as described by Starling's equation (Figure 2).

Figure 2




$$\text{Net filtration} = K_f S\,[(P_{cap} - P_i) - \sigma\,(\pi_{cap} - \pi_i)]$$

$K_f$ = filtration coefficient or hydraulic conductance (flow rate of fluid per unit pressure gradient across the endothelium)

S = surface area of the endothelium

σ = an expression of the permeability of albumin; has a value between 0 and 1; where 0 indicates free passage and 1 indicates total impermeabilty. This coefficient varies from organ to organ. The coefficient also changes in disease processes e.g. inflammation will push σ towards zero

$P_{cap}$ = hydrostatic pressure in the capillary

$P_i$ = hydrostatic pressure in the interstitium

$\pi_{cap}$ = oncotic pressure in the capillary

$\pi_i$ = oncotic pressure in the interstitium

As fluid is lost from the intravascular space, it becomes concentrated. This increases the oncotic pressure and reduces the hydrostatic pressure. This 'protects' the intravascular space from further fluid loss. Volume is monitored by osmoreceptors in the brain and receptors in the renal vasculature. When osmolality increases due to net water loss, receptors in the brain stimulate thirst and concentrate urine by causing the release of antidiuretic hormone. If blood volume decreases, receptors in the renal blood vessels activate the renin-angiotensin-aldosterone system which serves to increase sodium and water reabsorption. There is very fine control over osmolality and therefore body fluid content.

The endothelial glycocalyx layer (EGL)

This is a relatively recent theory in that the vascular endothelium is covered by the EGL. The EGL acts as a protein sieve and can be damaged (trauma, sepsis etc.). It has a key role in vascular function and integrity and determines vascular oncotic forces. Damage to it can lead to interstitial oedema.

**Indications for Fluid Therapy**

The administration of fluids to a patient is indicated in the treatment or prevention of reduced tissue perfusion and reduced tissue oxygen delivery as a result of reduced cardiac output and hypotension; dehydration; electrolyte and acid base disturbances. It is important that the clinician is able to select an appropriate fluid and know how that fluid will equilibrate throughout the body as a result of hydrostatic, osmotic and oncotic forces.

**1. Hypovolaemia** is a reduced circulating blood volume such as that which occurs during an acute haemorrhagic episode. There is a rapid reduction in circulating volume without an effect on other body compartments. Clinical signs will be dependent on the severity of the reduction in circulating blood volume. Things that will alert the clinician to hypovolaemia include

- elevated heart rate
- reduced pulse quality or absent peripheral pulses
- prolonged capillary refill
- changes in mucous membrane colour
- cold extremities

- reduced urine output
- obtundation

**2. Dehydration** is a reduction in interstitial fluid without a concurrent loss in circulating volume – this may result from excessive panting with inadequate water intake, for example a dog left in a hot car. Although fluid is lost from the interstitial space, circulating blood volume is protected, and only when dehydration is severe, will hypovolaemia occur at the same time.

When dehydration is relatively mild and uncomplicated by hypovolaemia, using skin turgor and mucous membrane moisture may alert the clinician to a reduction interstitial fluid. Mucous membranes will become tacky, and skin tenting will start to appear at approximately 6 % dehydration, and will become more pronounced as dehydration continues. The eyes may also be sunken due to dehydration of the retrobulbar fat pad. This method of assessment of dehydration is very subjective, and other factors, such as age, may alter skin changes. If dehydration is suspected, then perfusion parameters should also be monitored to determine if hypovolaemia is present. Dehydration is not immediately life threatening, but uncorrected hypovolaemia can result in death of the animal.

| **Dehydration (%)** | **Clinical signs** |
|---|---|
| <5 | Not detectable |
| 5-6 | Slight skin tent |
| 6-8 | Mild skin tent, prolonged capillary refill time, dry mucous membranes |
| 10-12 | Definite skin tent, prolonged capillary refill time, sunken eyes, dry mucous membranes, evidence of shock |
| 12-15 | Signs of shock |

**Laboratory Tests**

1. **Packed cell volume (PCV) and total solids (TS)** – must be interpreted with other findings as changes can be confusing and non-specific. The patient's baseline values are usually not known at the time of presentation. Note that recent haemorrhage will not affect PCV and TS since all components of blood are lost. Once fluid shifts have occurred then a fall in PCV and TS may be appreciated. Elevated PCV and TS generally indicate dehydration.
2. **Urine specific gravity (USG)** – can be used to detect dehydration. Renal function will affect results. A functioning kidney will concentrate urine (and therefore elevate USG) in the face of fluid deprivation. However, if the kidneys are injured (as is often the case in critical illness), then USG may not change as anticipated. Normal USGs are 1.025 (dog) and 1.035 (cat).
3. **Lactate** – may be used as a prognostic indicator. If tissue perfusion falls then cells switch to anaerobic metabolism with the production of lactate. High levels of lactate will remain until perfusion is restored. Hyperlactatemia does not necessarily contraindicate lactate containing fluids since the aim of treatment is simply to restore circulating volume and tissue perfusion.

Normal lactate in dogs and cats is < 2.0 $mmoll^{-1}$. Samples must be analysed immediately (or kept on ice).

4. **Electrolytes** – interpretation of electrolytes is complex and can be affected by many factors and many disease processes. It will not be discussed in detail in these webinars.
5. **Urea/Creatinine ratio** – high ratios (>20:1) may indicate dehydration

**Routes of Fluid Administration**

The route of fluid administration is very dependent on:

- the patient
- the condition
- the type of fluid
- the rate required
- the practice facilities

1. **Oral -** suitable in some circumstances, but the majority of animals requiring fluid intervention will require parenteral administration via other routes. Animals must be physiologically normal such that they are able to absorb fluid from the gut. Oral fluids can be administered via a feeding tube. This route is unsuitable for rapid fluid resuscitation.
2. **Subcutaneous** - suitable for the administration of up to 10 ml/kg per site, and can be used for maintenance fluid therapy requirements. Severely ill patients are not suitable candidates for administration of fluids via this route as blood flow to the skin is reduced and absorption is poor. Hypothermic animals will also have hypoperfusion of the skin in an attempt to maintain core body temperature. Administration can be painful – slowly inject fluids at body temperature. Indwelling subcutaneous catheters are now available which allow owners to administer palliative fluids at home e.g. for cats with chronic renal disease. Clients require training if an indwelling catheter is used.
3. **Intraosseous** – can be a useful alternative to intravenous administration if catheterisation of a vein is difficult – for example in the neonate. Sites suitable for placement of an intraosseous needle after local infiltration of the periosteum include the wing of the ilium, the trochanteric fossa of the femur, the tibial tuberosity and the greater tubercle of the humerus. There is a commercially available slow powered drill for IO needle insertion.
4. **Intravenous -** acute and severe disorders require rapid fluid resuscitation by administering fluids through 1 or more wide bore intravenous catheters. Any peripheral vein that can be catheterised is suitable for the administration of fluids, but any potentially irritating solution, such as hypertonic saline, should be administered using a central (jugular) vein. Intravenous administration of fluid therapy facilitates rapid correction of the disorder, and precise dosing. However, the maintenance of an intravenous catheter requires more intensive nursing than using other routes of administration.

Complications of IV catheterisation:

- Infection
- Phlebitis
- Catheter obstruction
- Patient interference
- Rarely – embolism

Central Catheters

These should be wide bore, preferably multi lumen catheters. Commercially available kits are available and they are inserted using the Seldinger technique (over the wire). A decision to place a central catheter should be made EARLY before all other peripheral veins are damaged. Patients requiring long term fluid or IV drug therapy, patients requiring multiple blood samples or those being administered irritant solutions should have a central catheter placed. Central lines must be appropriately secured and bandaged. Take care if oesophageal feeding tubes are used in the same patient. Administration of feeding solutions through a venous catheter will obviously be catastrophic.

**Administration Equipment**

1. **Gravity giving sets** – readily available and cheap. Fluid rate is calculated by counting the number of drops. Available as 20 drop or 60 drop/ml sets. Dual purpose sets are available which work via gravity or using a fluid pump. It is easy to overload patients with fluids using these sets
2. **Burette sets (Buretrol)** – these devices are mandatory for small patients if using gravity to drive fluid infusions. The chamber allows a prescribed volume of fluid to be safely administered without risk of administering the entire bag.
3. **Volumetric fluid pumps** – Use drip counters (older technology) or peristaltic rollers. Easily available through equipment suppliers and are relatively cheap (approx. £500). Must be serviced annually and maintained appropriately. The correct giving sets must be used otherwise inaccuracies can occur. Fitted with alarms to alert the nurse/vet to low power, occlusions, volume delivered etc.
4. **Syringe drivers** – similar to fluid pumps but deliver from a syringe and intravenous extension set rather than a giving set. Very useful for small patients. Again, this type of equipment must be maintained appropriately and staff must be trained on their use.
5. **Warming devices** – many are commercially available. A clamp device is available through which the administration set can be wound. If this is placed as close to the catheter as possible, there will be some warming effect. Unless fluids are to be given rapidly, warming a bag of fluids will do very little to prevent hypothermia e.g. during general anaesthesia. Usually, by the time the fluid reaches the patient, it will be back at room temperature. Fluids can be warmed close to the patient (e.g. with a proprietary fluid warming device) and this is more effective. Microwave warming of fluids does not seem to alter the fluid in any way, but ‘hotspots’ can develop and bags should be thoroughly agitated prior to administration.

6. **Extension sets and connectors** – multiple options are available. In the author's hospital, we routinely used double or triple connectors which attach to the IV catheter. This then facilitates the infusion of 2 or 3 different fluids. When administering through one catheter, the fluids MUST be compatible with each other. Some drugs can precipitate in certain fluids, and administering blood with calcium containing crystalloids is contraindicated.
7. **High speed fluid administration** – fluid pumps can only deliver a maximum rate of 999 ml/hour. If a large breed dog requires rapid fluid resuscitation it is much better to place the bag of fluids inside a pressure bag. The bag is then inflated which forces the fluid in quickly (in a similar way to having a person squeeze the bag). These pressure bags are very cheap and easily available.
8. **Blood administration** – use sets with blood filters to remove microthrombi. Ensure fluid pumps are compatible with blood as some peristaltic rollers can fracture cells. For small volumes, the blood can be administered in a syringe with a special in-line filter.