



Fluid Therapy in Small Ruminants – A Review

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ABSTRACT

Body fluid constitutes averagely 60% of the body weight of ruminants and this must be maintained in order to ensure optimal bodily function. Several homoeostatic mechanisms go on within the body in order to keep these fluids and electrolytes relatively constant. When these mechanisms are overwhelmed, life-threatening imbalances can occur rapidly. The use of fluid therapy is viewed as a medical therapy just as important as other medications in the management of sick or debilitated livestock where anaesthesia and/or surgery is required. It therefore, becomes imperative to review its uses and effect in small ruminants. Fluid therapy in any patient should aim to; replace existing deficits, replace on-going water and electrolyte loss, meet maintenance requirements and serve as a vehicle for the infusion of certain intravenous medications. In order to ensure appropriate fluid therapy, the volume of fluid deficit, type of fluid required and the route of administration should be punctiliously considered.

Keywords: Electrolytes; Fluid Therapy; Surgery, Small Ruminants, Anaesthesia

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INTRODUCTION

Body water, electrolytes and acid-base balance are important considerations in evaluation and treatment of animal diseases and restoration of these are priorities as adjunctive therapy [1]. Water and salt, known for centuries to be essential elements of life, are critical to survival [2]. Fluid and electrolyte balance in the body are kept relatively constant by several homeostatic mechanisms [3]. However, life-threatening imbalances can occur rapidly when these homeostatic mechanisms are overwhelmed [2]. The intake of water is inseparable from feeding by natural or artificial means and careful attention to salt and water balance is a vital component of perioperative care and nutritional supports [4].

Fluid therapy as a rapidly evolving clinical practice is dependent on several factors [5]. It is administered to veterinary patients to improve haemodynamics, replace deficits and maintain hydration [6]. Fluid resuscitation is a life-saving intervention [7]. Its proper use can be beneficial and life-saving. Fluid therapy should be viewed as a medical therapy, important as other medications in the management of sick or debilitated livestock where anaesthesia and/or surgery is required [8].

Fluids are administered to replace deficits, prevent dehydration, treat hypovolemic shock and intravascular volume depletion, correct acid-base and electrolyte abnormalities, and maintain vascular access for administration of drugs, blood product components, and parenteral nutrition [9].

FLUID THERAPY

Fluids are drugs, and although often considered to produce therapeutic effects, they should only be administered after thorough consideration of the indication for which they are prescribed [10, 11]. It can be administered via intravenous, intraperitoneal, intraosseous, intrarectal,

nasogastric, subcutaneous and oral routes. Veterinary professionals provide fluid therapy to patients for many reasons, including rehydration, expansion and support of intravascular volume, correction of electrolyte disturbances, and for facilitating appropriate redistribution of fluids that may be in the wrong compartments [12]. Fluid therapy is an important component in the treatment of many hospitalized veterinary patients [6] and is frequently used to provide immediate and short-term nutrients [13].

Although it is widely recognized as a mainstay therapy in human and veterinary medicine, fluid therapy is not always innocuous and can cause significant harm through fluid overload, which increases patient morbidity and mortality [5]. Administering large volume of fluids may expand intravascular space and improve organ perfusion [14], however, it may also increase the incidence of perioperative cardiopulmonary and tissue-healing complications [15, 16]. On the other hand, fluid therapy may reduce the length of hospital stay; although, it might increase the risks for postoperative complication [17].

Dehydration and hypovolemic shock are important indications for rehydration, especially intravenous (IV) therapy. Failure to institute appropriate fluid therapy can result in case fatality regardless of surgical expertise [18]. Examples of fluid intake failures include a lack of thirst as a result of neurologic depression or toxemia or inability to drink as would occur with oesophageal obstruction [8]. Diarrhoea is the most common cause of excessive fluid loss. Other causes especially in small ruminants include: vomiting and polyuria (renal disease) [8]. When dehydration occurs, all fluid compartments are affected, but not uniformly, rapid dehydration causes disproportionate reduction in the intravascular

compartment, contraction of the interstitial fluid compartment, and subsequently, contraction of the intracellular fluid compartment. Subsequently, equilibration occurs and all compartments become dehydrated [2]. Other indications for fluid therapy include hypovolemic shock, electrolyte abnormalities, disturbances in acid-base balance, hypoglycaemia, hypothermia, diuresis following toxin exposure, malnutrition, trauma, and failure of passive transfer [8].

Fluid therapy in any patient should aim to; replace existing deficits, replace ongoing water and electrolyte loss, meet maintenance requirements and serve as a vehicle for the infusion of certain intravenous medications [18]. Patients who undergo surgery often require rehydration and electrolyte therapy, particularly in cases of surgery of the gastrointestinal tract [18]. Intraoperative administration of fluids aims to maintain or restore effective circulating blood and hence assuring adequate organ perfusion [19]. Prolonged abdominal surgery, occurs with depletion of the extracellular space as a result of transudation from traumatized tissues, sequestration into the intestinal tract, and evaporation from exposed viscera [20].

Fluid Therapy in Veterinary Medicine

Fluid therapy paradigms are constantly changing [21, 22, 23] due to new discoveries [24, 25] and ongoing debate on the ideal fluid choice, dose, rate, and efficacy in different patient populations [11, 26, 27]. The limited and poor-quality scientific literatures on intravenous fluid therapy in Veterinary Medicine [28], has given rise to empirical fluid therapy recommendations [29, 30] that are based on broad assumptions, outdated physiological principles, clinician's anecdotal experiences, or extrapolation from human

clinical trials and canine experimental models [5].

As a routine treatment of hospitalized patients, fluid therapy has the potential to cause fluid overload which increases morbidity and mortality [31, 32]. The discovery by the “Fluid Expansion as Supportive Therapy” (FEAST) study [33] is an important reminder that intravenous fluid therapy can exert varying physiologic effects depending on the context in which they are administered [34] and can be detrimental if administered inappropriately [11, 27].

Yiew *et al.* [5] noted that with limited evidence to support current fluid administration practices in Veterinary Medicine, a greater understanding of parameters such as volume kinetics and body water physiology in veterinary species; and the detailed time course of intravenous fluids within the body, volume expansion effect, efficacy, half-life (duration of effect), and body water physiology in different patient populations under various clinical conditions, may allow for more evidence-based support for safer and more effective intravenous fluid therapy prescriptions for veterinary patients [5].

Fluid therapy in food animals is both challenging and rewarding, it is often technically difficult, labour intensive, and inconvenient [2]. This basic therapeutic modality produces clinical results that no sophisticated surgical technique or drug can duplicate [2].

Physiology of Body Fluids

Safe and effective prescribing of fluids and electrolytes require general understanding of the physiology of fluid and electrolyte homeostasis, fluid status of the patient, physiological responses to injury and disease,

as well as knowledge of the composition of fluids and how these fluids are affected during anaesthesia, surgery and disease states [3, 8].

Body fluid is gained from feed and liquid (milk and water) intake; including a small amount from carbohydrate metabolism while it is lost via the urine, sweat, faeces, as well as insensible losses via the lungs and skin [3]. Lactating animals require additional water intake equivalent to 85% to 90% of their daily milk production [18]; a lactating goat requires 1.4 litres (0.3 gallons) of water per 1 kg (2.2 lb) milk produced [35]. A goat may drink up to 18 litres (4 gallons) of water each day, depending on weather, ambient temperature, type of diet fed and milk yield [35].

In healthy animals, volume homeostasis is regulated largely by antidiuretic hormone (ADH) which is released when osmoreceptors and baroreceptors detect a little decrease in osmolality and blood pressure; and the renin-angiotensin mechanism, which is activated by falling renal perfusion pressure. These elicit a sensation of thirst and reduces renal excretion of water [3].

Total body water comprises between 57% to 67% of body weight for ruminants [8], which in most literatures, are always approximated to 60% of body weight [36]. This amount of fluid can vary slightly with age, body composition, and breed [8]. On the other hand, neonates have relatively more body water, as much as 86% of body mass [2]. The total body water is inversely related to the body fat; therefore, fattened livestock have relatively less body water [2]. Overweight animals have less total body water content compared to lean animals since adipose tissue contains very little water. For example, estimations of total body water for fattened sheep is approximately 50% of

body weight [36].

Total body fluids are divided into two major physiologic compartments that have imperfect anatomic corollaries [2], which are: extracellular fluid compartments and intracellular fluid compartments [8]. Water moves freely across the membranes that separate the compartments to maintain osmotic equilibrium [3]. The largest compartment is the intracellular fluid compartment (ICF) [2], which accounts for approximately two-thirds of total body water (40% of body weight); and the extracellular fluid compartment (ECF) makes up one-third of the total body water (20% of body weight) [8]. Water and certain molecules such as urea, move freely from one compartment to the next, but the movement of certain ions and molecules is restricted or controlled by membrane channels and pumps [2]. The extracellular fluid compartment can be further subdivided into interstitial fluid (~15% of body weight), the intravascular fluid or plasma volume (~5% of body weight), and transcellular fluid (very small % of body weight) [8]. The interstitial fluid compartment consists of cerebrospinal fluid, connective tissue, and most importantly, the contents of the reticulorumen and the rest of the gastrointestinal tract [8]. The reticulorumen is an important reservoir of fluid for adult ruminants during periods of water restriction, and the gastrointestinal tract can also be a site for water deposition during disease processes such as grain overload or endotoxemia [8].

The beneficial volume effects of intravenous fluids have been acknowledged for more than a century, however, their impact on the extracellular and intracellular concentrations of electrolytes, acid-base balance, and survival is only beginning to be appreciated [37].

The need for fluid therapy in physiologically compromised patient is well recognized [38]. In some situations, sodium loss may exceed water loss, which results in hypo-osmolar or at least hyponatremic dehydration. This is seen in ruminants with ruptured bladders when sodium ion moves into the peritoneal cavity and in some calves with diarrhoea when sodium is lost in the faeces [2]. Most clinically dehydrated ruminants and swine have iso-osmolar or nearly iso-osmolar fluid losses. Therefore, it is essential to supply electrolytes, particularly sodium, in addition to water for rehydration and volume replacement. Failure to do so will result in relative water excess, which will be quickly corrected by the kidneys, subsequently returning the animal to a volume-depleted state again [2].

Assessment of Fluid Volume Deficits

Fluid and electrolytes losses occur continuously and have to be replaced to maintain homeostasis [39]. The degree of dehydration or fluid volume deficit may be estimated by knowing the duration of the problem and evaluating various clinical signs [38]. When estimating the volume of fluid needed by a patient, the veterinarian considers not only the deficit, but also maintenance requirements and compensation for continuing loss [2]. A thorough physical examination is an important component of the evaluation of any patient, aiding in the diagnosis of the primary disease condition and the extent to which fluid and electrolyte therapy is indicated [1]. Acid-base and electrolyte abnormalities usually can be predicted on the basis of the suspected disease process; however, laboratory measurement is required to accurately quantify the magnitude of the derangement and when not available, clinical signs may serve [13]. The amount of fluid to be administered to a dehydrated animal can be determined by

assessing the hydration status of the animal [35]. A thorough physical examination is an important component of the evaluation of any patient, aiding in the diagnosis of the primary disease condition and the extent to which fluid and electrolyte therapy is indicated [1]. Altered hydration status (usually dehydration) can be estimated and quantified using eye position within the orbit, the extent of skin elasticity, and degree of mucous membrane moistness [40] (Table 1). The effective circulating blood volume and cardiac output can be estimated and quantified by the clinical assessment of activity level, heart rate, mucous membrane colour, capillary refill time, and temperature of the extremities (e.g. ears and feet) [40].

The time required for cervical skin to return to its normal position after tenting and the degree of eyeball recession in dehydrated preruminant calves are reasonably accurate methods to determine the state of hydration for calves [41]. Skin tent is a useful measure in the field: when the upper eyelid is pinched, it should return to its normal position within 1 – 2 seconds [35]. A delayed response of 3 – 5 seconds indicates about 5 – 7% dehydration. With 10% dehydration, the skin turgor is typically lost completely (i.e. the skin fold remains) [35]. As dehydration increases, the mucous membranes become drier, and from about 8% dehydration, the eyes become sunken; however, the animal's body fat reserves must be taken into account when assessing eye position (with loss of retrobulbar fat in emaciated animals) [35]. The degree of enophthalmos has been used to assess hydration status in calves [42] and can be used to assess hydration in young small ruminants as well. Anuria sets in at 10% dehydration, the animal becomes weak and/or recumbent, with a weak pulse, and moribund from 12% [35]. Alterations in packed cell volume (PCV) and total plasma protein (TPP) may also be used as

indicators of hydration status, but are limited in their utility [1]. Total protein tends to increase with ECF loss, unless there is a protein-losing process present [35]. The reference interval for PCV is fairly wide, making it an insensitive indicator of hydration, and baseline values for an individual are rarely available [1].

Moreover, owing to the prevalence of diseases in sheep, goats, and camelids that alter PCV and TPP (internal parasitism, failure of passive transfer, chronic inflammatory disease), these values must be interpreted in light of the history and physical examination findings.

Table 1: Physical examination parameters for estimation of hydration deficit in ruminants

	Mild (4% – 6%)	Moderate (7% – 9%)	Severe* (>10%)
Cervical skin tent	4 – 5 secs	5 – 7 secs	>7 secs
Globe recession	2 – 3 mm	3 – 4 mm	6 – 8 mm
Eyes	Bright	Duller than normal	Dry cornea
Oral mucosa	Moist, warm, pink	Tacky, warm, pale	Dry, cool, cyanotic
Extremities	Warm	Cool	Cold
Demeanour	Standing, bright	Sternal, slow	Lateral, depressed

*More dramatic clinical signs will be apparent in acute hypovolemic shock.

Adapted from: Constable *et al.* (1998).

Fluid Requirement

Effective and safe fluid administration depends on comprehensive patient assessment, particularly the ability to distinguish between hypovolaemia and dehydration [43]. The severity of the clinical signs and the relative probabilities of the differential diagnoses, determines if fluid and electrolyte therapy is needed [13]. When indicated, treatment may be instituted immediately or delayed until laboratory test results are available [13]. Fluid and electrolyte replacement therapy in livestock is required when fluid intake by the animal is not enough to meet their metabolic needs [8].

Clinical signs may be used to estimate the approximate fluid volume deficit (Table 1), if dehydration is moderate, the fluid deficit is considered to be 4 – 6% of the body weight. Severe dehydration generally indicates that a fluid deficit is at least 10% of the body weight [38]. This means that in a 50 kg animal, a fluid volume deficit of 5 L exists. A simple laboratory estimate of the degree of hypovolemia may be obtained by simultaneous measurement of the packed cell volume (PCV) and total plasma protein (TPP). Analyses of the components of body fluid composition [44] have the potential to reveal whether total body water is normal or not [45].

The practical methods available for assessing volume deficits in the surgical patient include the surgeon's clinical assessments and knowledge of the pathophysiology of the disease, estimation of the PCV and TPP, and probably most important, serial evaluation of the response to replacement therapy by both clinical examination and PCV and TPP estimation [38]. When determining appropriate fluid volume and rate to be administered, one must consider: replacement of hydration deficit, maintenance fluid needs, replacement of ongoing losses and plasma protein concentration [1].

Replacement of Hydration Deficit: The volume required for hydration replacement is calculated using the following formula: (estimated % dehydration) x (body weight in kg) = litres of fluid needed to replace deficit

As a general rule, fluid replacement should span over a 4-hour period, with maintenance and ongoing losses administered over the remaining hours in the day [1].

Maintenance Fluid Requirement: This accounts for normal water losses attributable to urination, defecation, respiration, sweat, and other evaporation, and differ based on physiologic status (lactation, pregnancy) and age [1]. Neonates have higher total body water volume than adults, and require a higher maintenance fluid volume. Calculation of maintenance fluids is based upon the physiologic requirements of the patient [8]. Maintenance fluid needs can be estimated using the following general guidelines [1]:

Adults: 50 mL/kg/24 hours or 1 mL/lb/h

Neonates: 70 to 80 mL/kg/24 h or 2 mL/lb/h

These numbers are typically used in all species and are supported by established water

requirements of goats, which range from 30 to 66.6 mL/kg/d with a mean of 44.8 mL/kg/d [46]. Neonates are typically assigned a higher maintenance volume, with 70 mL/kg found to be acceptable in calves [47]. Fluid administration rates of 3 – 10 ml/kg/hour of crystalloid solutions (e.g. normal saline, lactated Ringer's solution), but not to exceed 20 ml/kg, are used when the surgical procedure does not result in significant blood loss [48].

Ongoing Losses: This include fluid, protein, and electrolytes, which are lost as a result of a continuing disease process, such as diarrhoea or internal or external loss of fluid [1]. Quantifying ongoing losses can be challenging and, in the absence of the ability to measure these directly, parameters such as PCV, TPP, serum electrolyte panel, and body weight may be used to monitor the success of fluid therapy to sustain body fluid, protein, and electrolyte balance [1].

The quantity of fluids given in cases of severe hypovolemic situations such as fulminant endotoxic shock is based on the patient's response to therapy, rather than on any previous calculations [38]. This is because the clinical signs manifested by the patient such as a weak, irregular pulse and colour changes in the mucous membranes (brick red in the vasodilatory phase of septic shock, progressing through to the cyanotic 'muddy' appearance in very low cardiac output states), do not give a quantitative estimate of the volume deficit [38].

Routes of Fluid Administration

Fluids are typically administered to veterinary patients through enteral, subcutaneous and intravenous routes [29, 49, 50], or less commonly, into the medullary cavity [51] or into the coelom in reptiles [52]. The ideal method of fluid delivery will vary depending on

the species, the underlying disease processes, and the size of the fluid deficit [6].

The size, temperament and economic value of the patient, the underlying disorder, hydration status and resources in terms of equipment and facility will influence the route of fluid administration in veterinary patients [53]. The route of administration of fluids should depend on the presentation and severity of the patient's condition [35]. Where intravenous fluids are warranted to treat the underlying systemic abnormalities, enteral fluids may be a useful adjunct to therapy [54] while subcutaneous administration of fluid can be used as supportive therapy in cases of chronic renal diseases [55].

Enteral Administration

According to the World Health Organization, the development of oral rehydration therapy was one of the most significant advances in medicine of 20th century [56]. Administration of oral electrolyte solutions (OES) is often the primary method used to treat neonatal diarrhoea in humans [57, 58] and calves [59, 60].

In bovine medicine, fluid therapy is most commonly administered by intravenous and oro-ruminal routes [61]. Due to the large volumes administered, professional supervision is required during fluid therapy, and the final cost of administration via the parenteral route is sometimes unviable [62]. Enteral fluid therapy, like the oro-ruminal route, allows a large volume of electrolyte fluid to be administered directly into the rumen in cases of mild and moderate dehydration [63], and is used carefully in cases of motility disorder [64].

Calves and piglets with mild dehydration will usually voluntarily drink oral rehydration

solutions, making treatment more cost effective than intravenous fluids [65]. If some rumen activity is present, oral fluids may be considered unless the deficit needs to be restored rapidly [35]. In ruminants and camelids, large volume of fluids may be administered into the rumen or first compartment, allowing for effective treatment of mild to moderate dehydration [1]. The animals most likely to benefit from oral fluid therapy are those that are mentally alert, have good intestinal motility, and are less than 8% dehydrated [1]. Animals not meeting these criteria are best managed with at least initial parenteral fluid resuscitation and correction of acid-base and electrolyte abnormalities [1]. Enteral fluid therapy is not suitable in patients suffering from severe dehydration, shock, or where there is massive disruption of the gastrointestinal tract [66, 67]. In these cases, rapid rehydration with intravenous fluid therapy followed by enteral fluid therapy may reduce the effects of villous atrophy and malnutrition and shorten the duration of hospitalization [68, 69]. Oral electrolyte solutions are preferred as treatment by producers because they are inexpensive, easy to administer on-farm, provide an easy way to administer large amounts of fluid, and have good efficacy for animals that still have a partially functional gastrointestinal tract [56].

However, despite there being a wide application for enteral fluid therapy in veterinary medicine, intravenous fluid therapy is used far more commonly [70]. The major disadvantage with oral fluid administration is that it slowly resuscitates, relative to intravenous fluid administration [71].

Parenteral Administration

In small ruminants, jugular catheterization is the most practical means of administering

intravenous fluid therapy [1]. Fluids should ideally contain electrolytes. In kids, absence of a suck reflex indicates likely gastrointestinal tract stasis, and fluid should be administered intravenously to ensure absorption. For the intravenous route of fluid administration, placement of an intravenous catheter is highly advisable. For fluid therapy on farm, the catheter should be secured enabling the owner to remove it, suitable veins include the jugular, cephalic, saphenous and ear veins [35].

The maintenance rate is 2 ml/kg/hour (equivalent to 50 ml/kg/day), translating to 1 drop every 1.5 – 2 seconds for a 70 kg goat when using a giving set delivering 20 drops per ml. As a rule of thumb, of every litre of intravenous crystalloid fluid administered, only a quarter remains in circulation after 1 – 2 hours. This highlights the need for continued fluid administration until the patient is fully stable [35]. Goats are relatively susceptible to pulmonary oedema when being overhydrated, care must be taken with 'shock-doses' of fluids (10 – 20 ml/kg/ hour) [35]. Once life-threatening hypovolaemia has been addressed, the remaining fluid deficit is best replaced over 12 – 36 hours. During surgery, fluid rates may be increased to 5 ml/kg/hour, provided the goat is monitored for overhydration [35].

Types of Fluids

Many different and correct fluid types are available for intravenous administration in veterinary patients (Table 2) [8]. The type of fluid to be administered ideally should be based on the individual patient's disease process and the measured or predicted acid-base or electrolyte deficits that must be corrected [8]. The 4 basic types of solutions used in clinical practice, are; crystalloid solutions, colloid solutions, parenteral nutrition, and blood products, and these vary in compositions, cost,

and usefulness depending on the pathologic conditions of the patients [1].

Crystalloid Solutions

Crystalloids are solutions containing electrolyte and non-electrolyte solutes capable of entering all body fluid compartments [72]. Crystalloid fluids are the mainstay of fluid therapy during anaesthesia and consist primarily of water with a sodium or glucose base [8]. Crystalloid solutions are prepared by diluting relatively small amounts of crystalline solids (salts) of physiologically relevant elements (Na^+ , K^+ , Ca^{2+} , Mg^{2+} , Cl^-) in water [28, 73]. Compounded crystalloids may contain added NaHCO_3 in order to treat (buffer) or resist pH changes from non-respiratory causes of acidosis [28]. Most commercial manufacturers of crystalloid solutions have abandoned the addition of $\text{Na}^+\text{HCO}_3^-$ because of the potential to form divalent carbonate (CO_3^{2-}) and precipitate with calcium and magnesium. This $\text{Na}^+\text{HCO}_3^-$ has been replaced with chloride ion which when stored in plastic bags, allows equilibrium with atmospheric CO_2 [74, 75]. Most manufacturers replaced HCO_3^- with an organic anion (lactate, acetate, citrate) with the expectation that it will act as a 'precursor' or stable surrogate for bicarbonate [76]. Because crystalloids dissolve completely in water, crystalloid solutions containing sodium is distributed throughout the entire extracellular fluid space and are not confined to the intravascular space [13]. They can be used as replacement fluids as seen when commonly administered during general anaesthesia to diminish the cardiovascular effect of anaesthetic drugs, replace ongoing extracellular fluid losses and as maintenance fluids [35], as seen in long-term fluid therapy such as the Intensive Care Unit setting [73]. They are also used to replace acute blood loss by administering 3 volumes of crystalloid

solution for each 1 volume of blood lost [73].

A wide variety of crystalloid fluids is available for veterinary use [9]. Crystalloid solutions are characterized in terms of the number of molecules (numerator) per volume of solution (denominator). The number of molecules is expressed in moles (abbreviated as mol), where one mole of a compound is equivalent to the molecular weight of the compound in grams. Ruminant body fluids are dilute and are expressed as millimoles (mmol = mol/1000) to facilitate readability [13]. Examples of crystalloid solutions are Ringer's solution, lactated Ringer's solution, acetated Ringer's solution, 0.9% sodium chloride (NaCl), 7.2% NaCl (hypertonic saline), 1.3% sodium bicarbonate (NaHCO₃), 8% NaHCO₃, 10% NaH₂PO₄, 25% magnesium sulfate, Carbicarb, 23% calcium borogluconate, calcium gluconate, 5% dextrose, 50% dextrose, McSherry's solution, Darrow's solution, Tromethamine 1.15% potassium chloride [13].

Crystalloid fluids can be divided into four groups based upon purpose and include replacement, maintenance, hypertonic saline, and dextrose in water [8]. Alternatively, crystalloid fluids can be divided based on tonicity and include hypotonic, isotonic, and hypertonic [8].

The tonicity of the solution is an important clinical issue. Complete understanding of the tonicity concept requires differentiation of two terms, osmolality and osmolarity [13]. Osmolality is the number of dissolved particles per kilogram of solution and is expressed as mOsm/kg of solution. The normal plasma osmolality in ruminants is approximately 285 mOsm/kg, and plasma osmolality is defended aggressively by increasing water intake

(osmolality >285 mOsm/kg) or promoting free-water excretion (osmolality <285 mOsm/kg) [13]. Osmolarity is the number of particles per litre of solution and is expressed as mOsm/L of solution. The normal plasma osmolarity for ruminants is 306 mOsm/L [13].

Colloid Solutions

Colloids are dispersions of large organic molecules in a liquid [3]. They act as plasma volume extenders due to the fact that they do not cross the semi-permeable membrane and so, exert a colloid osmotic (oncotic) pressure [73]. Hypertonicity pulls fluids into the vascular space thereby rapidly expanding circulating volume which effect is longer lasting compared to crystalloid therapy [73]. The characteristics of colloid infusions depend mainly on their molecular size. Many modern colloid solutions are based on hydroxyethyl starches (HESs) which have high molecular weights (70 000 – 450 000 daltons) and can provide volume expansion for 6 – 24 hours [3]. They may also be considered in animals with hypoproteinaemia (TP < 35 g/l) to prevent oedema formation. Colloids remain in circulation longer than crystalloids [35]. However, they do draw fluids from the interstitial and intracellular compartments and therefore should be combined with isotonic fluids, especially in patients already dehydrated. Examples of colloids include whole blood, stroma-free haemoglobin, plasma, hydroxyethyl starches (6% Hetastarch or Pentastarch)x, Gelofusine®, Haemaccel®, Dextran 40 or 70, 7.2% NaCl with starch, Oxyglobin, modified gelatin solutions. [35].

Conclusion

Fluid therapy is rapidly evolving as fluid resuscitation is a life-saving intervention. The proper use in operative procedures can be beneficial and life-saving. It should therefore

be viewed as a medical therapy just as important as other medications in the management of sick or debilitated livestock where anaesthesia and/or surgery is required.

Table 2: Composition of commonly used intravenous fluids. Units are in mmol L⁻¹ unless otherwise stated. Osmolality in mosmol Kg⁻¹

Fluid	Na ⁺	K ⁺	Ca ²⁺	Cl ⁻	Others	Osmolality	pH	Uses
Saline 0.9%	154			154		308	5	Brain injury, hypochloaemic metabolic alkalosis or hyponatraemia
Hartmann's	131	5	2	111	Lactate 29	281	6.5	Extra cellular fluid replacement
Glucose 5%					Glucose 50 g	278	4	Hypernatraemia, preventing hypoglycaemia in diabetes
Saline 0.45%	77			77		154	4 - 5	Water and Na replacement, hypernatraemia
Glocose 4%-saline 0.18%	31			31	Glucose 40 g	284	4 - 5	Maintenance of normal fluid volume
Bicarbonate 8.4%	1000				HCO ₃ ⁻ 1000		8	Severe metabolic acidosis
1.26%	150				HCO ₃ ⁻ 150		7	
Gelofusine MW 30 000	154	0.4	0.4	125	0.4	274	7.4	Plasma volume expander
Haemacel MW 30 000	145	5.1	6.25	145	Gelatine 35 g	301	7.3	Plasma volume expander
Dextran 70					Dextran 60 g,	287		Reduction of plasma viscosity, plasma expander
In 5% glucose					Glucose 50 g or		5 - 6	
In saline 0.9%					as saline 0.9%		4 - 5	
MW 70 000								
HAS 4.5%	100 - 160	<2		100 - 160	Albumin 45 g, citrate <15	270 - 300	6.4 - 7.4	Abnormal loss of protein from the vascular space as in peritonitis and burns.
HAS 20%	50 - 120	<10		<40	Albumin 200 g	135 - 138	6.4 - 7.4	Abnormal loss of protein from the vascular space as in peritonitis and burns. Nephrotic syndrome
Hespan 6% MW 200 000	154			154	Starch 60 g	310	5.5	Plasma volume expander
Voluven MW 130 000	154			154	Starch 60 g	307	4 - 5.5	Plasma volume expander

MW = Molecular weight

Adapted from Rassam and Counsell, (2005).

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