CALF FLUID THERAPY MADE SIMPLE

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A simple explanation of the theories behind fluid therapy. A summary of the latest recommendations. A comparison of products available in Australia. Practical guidelines for fluid therapy in the field. Tips to help farmers act on your advice.

ACID-BASE BALANCE

The pathophysiology of neonatal calf diarrhoea is complex. As the fluid therapy of scouring calves often involves the correction of a lowered blood pH, an understanding of acid-base balance is important.

Acidosis (a decrease in pH) results from an accumulation of hydrogen (H^+) ions. For example:

1) Carbon dioxide elimination is inadequate relative to tissue production. Partial pressure of carbon dioxide, pCO_2, increases and shifts the following equation to the left:

$$HCO_3^- + H^+ \leftrightarrow H_2CO_3 \leftrightarrow CO_2 + H_20$$

2) In body fluids, the sum of all positive ions *must* equal the sum of all negative ions. The difference in charge between the fully dissociated ('strong') cations and anions in the blood influences H^+ dissociation from body water. When this strong ion difference (SID) becomes more negative (eg. loss of Na^+, production of lactate$^-$), H^+ concentration rises.

Figure 1 incorporates many references into a pathophysiology flow chart for neonatal calf diarrhoea. For those wanting to read about acid-base balance in more detail, Constable (1999) and Kellum (2005) are recommended.

ORAL REHYDRATION SOLUTIONS

You're just sitting down for lunch (at 3.30pm!) when you're called to the front counter. Farmer Suzie has some scouring calves and wants to know what fluids to give them. Further questioning reveals that they're all still able to stand and suckle, albeit weakly. You decide oral rehydration is the way to go.

Oral rehydration solutions (ORS) need to contain the following (Smith 2009):

1) Sodium, to draw water into the blood stream to correct dehydration.

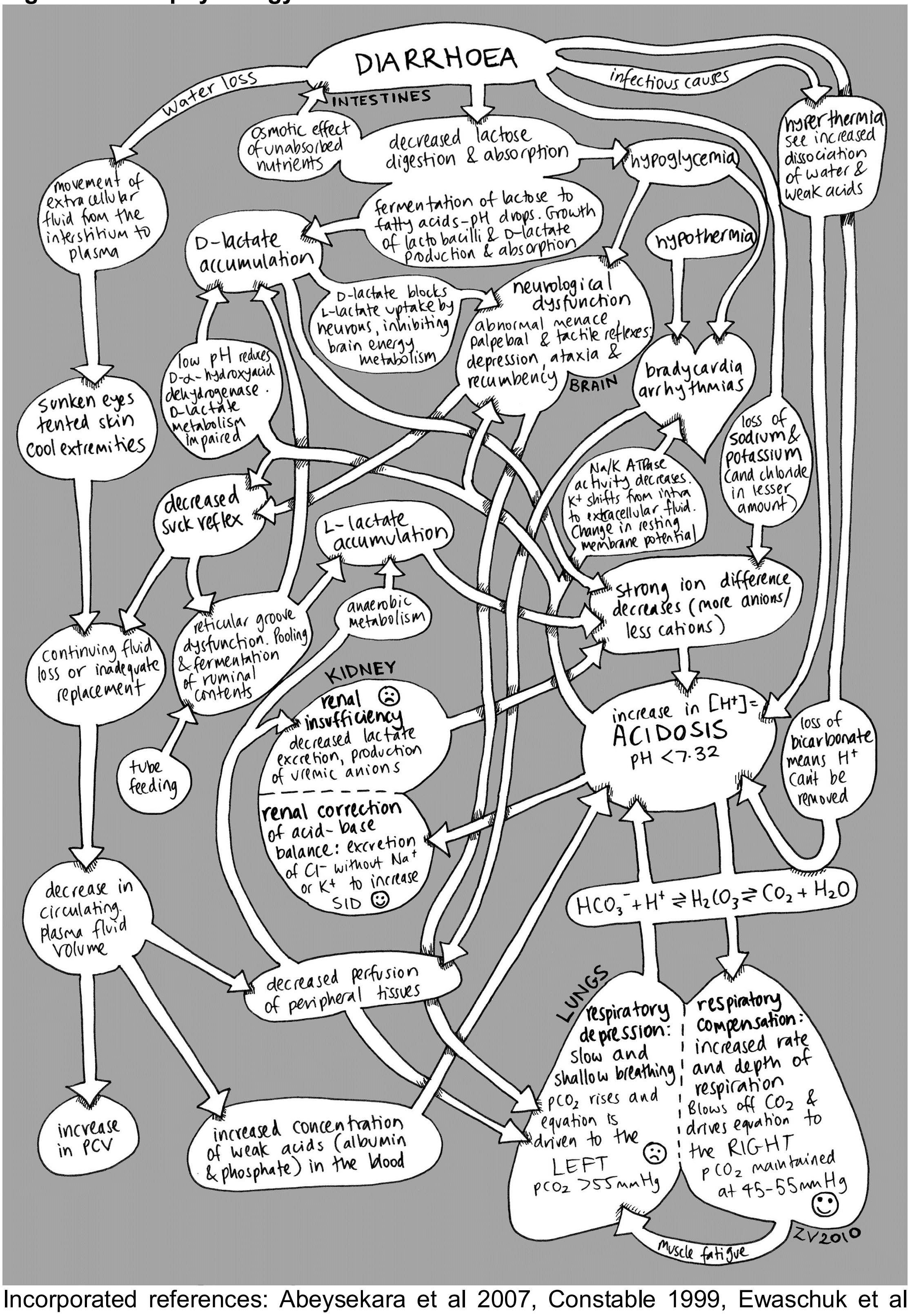
2) An excess of strong cations (sodium and potassium) to anions (chloride) to correct strong ion acidosis.

3) Glucose to provide energy and assist sodium absorption. Glycine, acetate, propionate and citrate also assist in sodium absorption.

4) Potassium. Although scouring calves are often hyperkalemic, on correction of dehydration and acidosis there is a total body deficit.

5) An alkalinising agent. This can be bicarbonate, which buffers H^+, or agents such as acetate, propionate or citrate that consume H^+ when they're metabolised (Naylor 1996). Acetate and propionate are the agents of choice. They don't alkalinise the small intestine, minimising the risk of any ingested *E. coli* and *Salmonella* surviving to cause clinical disease (Constable 2009) and they are also a source of energy (Brooks et al 1996). They don't interfere with milk digestion.

Figure 1 Pathophysiology of Neonatal Calf Diarrhoea



Incorporated references: Abeysekara et al 2007, Constable 1999, Ewaschuk et al 2004, Ewaschuk, Naylor and Zello 2005, Kellum 2005 and Lorenz 2003.

Table 1: Composition of oral rehydration solutions available in Australia[#]

Product, Company and mixing rate			Sodium	Potassium	Chloride	SID[%]	Alkalinizing agent		Glucose:Na^	Osmolarity[~]	Energy*
Recommended values (Smith 2009)			90-130 mmol/L	10-30 mmol/L	40-80 mmol/L	60-80 mEq/L	50-80 mmol/L Acetate, propionate		1:1 to 3:1	500-600 mOsm/L	MJ/L
Bovelyte	Provimi	90g/2L	112	18	46	84	84	Bicarbonate (66) Citrate (18)	1.7	435	0.53
Diarrest sachets	Virbac	248.5g/2L	148	31	103	76	60	Bicarbonate (18) Citrate (12) Acetate (30)	1.2	526	1.26
Hydrate liquid concentrate	Bomac	160ml/2L	76	15	74	17	2	Propionate	2.3	359	0.38
Hydrate sachets	Bomac	68.5g/2L	76	15	74	17	2	Propionate	2.2	347	0.35
Lactolyte sachets	Virbac	90g/2L	79	28	55	52	47	Acetate (30) Propionate (17)	1.3	328	0.64
Lectade sachets	Jurox	64g/2L	73	16	73	16	4	Citrate	2.2	344	0.35
Lite-Scour-Diet	Agvantage	20g/2L	12	3	10	5	5	Bicarbonate	4.3	79	0.14
Maxi-Trans	Virbac	20g/2L	12	3	10	5	5	Bicarbonate	4.3	79	0.14
Mega-Lyte	Sykes	100g/2L	88	0	59	29	29	Bicarbonate	2.5	399	0.62
Mega-Lyte Plus	Sykes	60g/1.5L	82	14	46	50	50	Bicarbonate (36) Citrate (14)	1.1	291	0.26
Pronto	Dasco	100g/2L	84	0	57	27	27	Bicarbonate	2.5	383	0.60
Res-Q	DeLaval	100g/2L	173	0	114	59	59	Bicarbonate	2.6	791	1.25
Resus	Dasco	100g/2L	84	0	57	27	27	Bicarbonate	2.5	383	0.60
Scour-Ade sachets	Sykes	248.5g/2L	148	31	103	76	60	Bicarbonate (18) Citrate (12) Acetate (30)	1.2	526	1.26
Scourlyte	Novartis	110g/2L	89	19	76	32	32	Citrate	1.8	356	0.47
Veanalyte Electroguard	Veanavite	60g/1.5L	79	14	46	47	47	Bicarbonate (34) Citrate (13)	1.1	285	0.26
Vy'Trate Liquid Concentrate	Jurox	160ml/2L	73	31	73	31	5	Citrate	2.3	373	0.35
Vy'Trate Sachets	Jurox	64g/2L	73	16	73	16	4	Citrate	2.2	344	0.35
Zoe's recipe		110g/2L	124	13	65	73	73	Acetate	1.8	503	0.70

Composition calculated using Microsoft Excel. Only products whose mixing rates are known are included (APVMA 2010, MIMS 2010).

% SID = [Na] + [K] - [Cl]

^ Glycine (in Hydrate, Lectade and Vy-Trate) is included in the Glucose:Na ratio. It is assumed that the lactose in Diarrest, Lactolyte and Scour-Ade was totally digested.

~ Osmolarity >700mOsm/L increases the risk of osmotic diarrhoea and ileus (Smith 2009).

* Glucose, lactose & rice flour → ~16kJ/g, acetate → 0.9kJ/mmol, citrate → 2.1kJ/mmol, propionate → 1.5kJ/mmol (Brooks et al 1996). A 45kg calf on a milk-only diet has a maintenance requirement of 7.26MJ/day (NRC 2001). Excluding Lite-Scour-Diet and Maxi-Trans, these products fed at 4L/day contain ~15-70% of this requirement.

COMMERCIAL PRODUCTS

Table 1 contains the mixing instructions and composition of oral electrolyte products available in Australia. When compared with recommended values (Smith 2009), no product is 'ideal'. But, looking at the components that affect acid-base balance (alkalinising ability and strong ion difference and SID), several are good: Bovelyte, Diarrest, Lactolyte, Mega-Lyte Plus, Res-Q and Scour-Ade. The cost price for farmers per 2L dose is roughly 70c–$2 for powders available in buckets, $3 for liquid concentrates and $4–7 for sachets.

Lactolyte's main source of energy is lactose (Diarrest and Scour-Ade contain both lactose and glucose). Lactose is hydrolysed at the intestinal mucosa by lactase to form glucose and galactose. Lactase activity can be halved with rotavirus infection and decreased even further in combined rotavirus/*E. coli* infections (Tzipori et al 1983). Calves that are unable to turn lactose into glucose and galactose may have insufficient glucose to assist sodium and water absorption. The risk of intestinal fermentation and D-lactate production will also be increased (see Figure 1).

A homemade recipe that meets all the recommendations can be made:

12g sodium acetate anhydrous
2g potassium chloride
6g sodium chloride
90g dextrose monohydrate
2L water

To make 2.2kg buckets you need:

240g sodium acetate anhydrous
40g potassium chloride
120g sodium chloride
1800g dextrose monohydrate

Batches of 10–20kg can be blended easily in a drum mixer and divided out (C. Wood, 2010, pers. comm., 21 Jan). Including labour, the cost of this homemade recipe is comparable to the cheaper commercial products. Kept clean and dry, the electrolyte mixture should remain stable if combined with water just prior to use (J. Fairweather, Sypharma Pty Ltd, 2010, pers. comm., March 10).

Choice of ORS will need to take into account convenience (both for the vet and the farmer), composition, cost and intravenous fluid regimes (see later).

HOW MUCH TO GIVE?

Daily maintenance fluid requirements for calves range from 5% body weight to 10% in hot weather. Table 2 assumes 70% absorption efficiency and ongoing losses of 2L per day while scouring (Naylor 1996). Any pre-existing dehydration would need to be treated with additional fluid. It is important to note that the dosage instructions for many ORS products do not supply a scouring calf's daily fluid requirement (APVMA 2010, MIMS 2010).

Table 2: Daily fluid requirements for scouring calves

BW (kg)	Feeds/day Cold weather	Feeds/day Hot weather
30	4 x 1.3 L	4 x 1.8 L
40	4 x 1.4 L	4 x 2.2 L
50	4 x 1.6 L	4 x 2.5 L
60	4 x 1.8 L	4 x 2.9 L

Studies have shown that diarrhoeic calves fed milk and ORS gain weight throughout treatment and their diarrhoea is not worsened or prolonged (Garthwaite et al 1994, Heath et al 1989). Maintain calves on their normal milk diet, with additional ORS feeds. However, if calves become depressed or refuse to suckle (i.e. D-lactate acidosis is suspected), withhold a milk feed and substitute with ORS (Ewaschuk, Naylor & Zello 2005, Smith 2009).

Calves should have access to ad lib water.

INTRAVENOUS FLUID THERAPY

You've just finished a rotten calving. As you're about to get in your car and drive off for a much needed shower, farmer Bob says "While you're here…" and takes you to the calf shed where a week old scouring calf is lying comatose on the ground."

A calf such as this is likely to be suffering severe acidosis. The ideal treatment is intravenous administration of isotonic (1.3%) sodium bicarbonate ($NaHCO_3$). It provides HCO_3^- to buffer H^+ and prevent further decrease in pH. It also provides Na^+ ions to increase the SID. The fluid expands plasma volume and assists in the excretion of D-lactate (Berchtold et al 2005).

However, 1.3% $NaHCO_3$ is unavailable commercially. Bicarbonate solutions are unstable if stored in permeable plastic due to atmospheric CO_2 loss. They must be stored in glass and infused promptly (Morgan 2005). A sterile 1.3% $NaHCO_3$ product is under development (J. Fairweather, Sypharma Pty Ltd, 2010, pers. comm., February 10) and it is hoped to be available in the near future.

In the meantime, 13g of $NaHCO_3$ can be added to 1L water for injection or, if unavailable, 1L 0.9% NaCl. Place 10ml (2 cooking teaspoons) into a 20ml syringe, dissolve in some of the water or NaCl and squirt back into the bag. An alternative (and more expensive!) option is to add 155ml 8.4% $NaHCO_3$ to 845ml of your chosen fluid.

Tables 3, 4 and 5 take into account the degree of acidosis predicted by a recumbent calf's clinical signs and age (Naylor 1989) and calculate how many litres of 1.3% $NaHCO_3$ the calf needs.

Table 3: Calf ≤8 days old

BW (kg)	30	40	50	60
Sternal	1.4L	1.8L	2.3L	2.8L
Lateral	1.5L	2.0L	2.5L	3.0L

Table 4: Calf >8 days old

BW (kg)	30	40	50	60
Sternal	1.8L	2.5L	3.1L	3.7L
Lateral	2.3L	3.1L	3.8L	4.6L

Table 5: Tables 3 and 4 simplified

Calf size	≤40kg	>40kg
≤8 days, recumbent	2L	3L
>8 days, sternal recumbency	2L	3L
>8 days, lateral recumbency	3L	4L

Maximum recommended fluid rates are 80ml/kg/hour (4L/h in a 50kg calf). Unless other conditions, such as septicemia, are evident, calves should respond quickly. They can be switched to ORS once they can stand and suckle. Calves still depressed the next day can be given additional bicarbonate (Naylor 1996).

Jugular catheterisation:

1) Prepare 1.3% sodium bicarbonate
2) Fill 20ml syringe with 10ml fluid
3) Warm fluids and attach giving set
4) Shave skin with razor and prep with iodine
5) Nick the skin with a scalpel
6) Insert 18–gauge 32mm catheter. When you see blood, remove stilet, attach the syringe and push in fluid while advancing the catheter
7) Attach giving set and superglue catheter to the skin, with a loop of the giving set glued to the calf's ear. Set drip going and ensure calf isn't able to wander once it is standing.

A technique for auricular catheterisation is described in detail (Berchtold 2009) but only allows for fluid administration rates of ~1-2L/h (Radostits et al 2007).

Frequently calves have clinical signs of severe acidosis with minimal dehydration. At other times, additional fluid is required to correct a concurrent moderate to severe dehydration. Lactated and acetated Ringer's solutions can be used. Compared to other commercially available isotonic solutions, their effective SID reduces the chance of an acid-base disturbance (Constable 2003, Morgan 2005).

Eyeball recession and skin tenting (Table 6) provide the best assessment of dehydration (Smith 2009).

Table 6: Volume of fluid required to correct degree of dehydration

Dehydration	8%	10%	12%
Skin tent (sec)*	2	5	10
Eyeball recession	4mm	6mm	8mm
30 kg	2.4L	3.0L	3.6L
40 kg	3.2L	4.0L	4.8L
50 kg	4.0L	5.0L	6.0L
60 kg	4.8L	6.0L	7.2L

**Pinch a fold of neck skin, rotate it 90 degrees and time how long it takes to return to normal*

For example, a 10 day old, 50kg calf in lateral recumbency and 12% dehydrated would receive 4L of 1.3% bicarbonate and another 2 L of lactated or acetated Ringer's.

WHEN TIME IS OF THE ESSENCE…

You're taking a drive with a beef farmer, checking out his scouring calves, when you see a recumbent calf in a paddock. You need to treat it quickly without getting gored by its dam. What are some options?

Other intravenous fluids

Commercial colloid solutions contain high molecular weight glucose polymers. By increasing plasma oncotic pressure they draw fluid from the interstitium to the intravascular space (Constable 2003).

In calves, administration of 6% dextran-70 combined with hypertonic saline and ORS increases cardiac output and plasma volume and decreases blood lactate concentration and hematocrit (Constable et al, 1996). The hypertonic saline draws water into the blood and the hyperoncontic dextran-70 keeps it there. To make this solution, add 31.6g NaCl to a 500ml bag of 6% dextran-70 in 0.9% saline (Constable 2003). Refrigerate if not using immediately. Administer at a rate of 4–5ml/kg, over 4–5 minutes, and tube feed 55ml/kg ORS. The ORS should have a low osmolarity (preferably 300-312mOsm/L) and have bicarbonate as its alkalinising agent to increase blood pH rapidly (Naylor 1996).

Pentastarch and Voluven are other commercial colloids available as 6% solutions. Theoretically they could be used in the same way.

Intraperitoneal fluids

Intraperitoneal (IP) fluids have the potential to give colloids or isotonic fluids easily (Constable 2003). A catheter or needle is inserted 10cm ventral to the lateral processes of the lumbar vertebrae, midway between the last rib and the tuber coxae (Radostits 2007). The ability to use larger bore catheters allows much faster rates of fluid administration than with IV fluids. There have not been many studies on the use of IP fluids in calves. There are questions about altered peritoneal absorption and risk of adhesions (Constable 2003) and further studies would be useful.

GIVING ADVICE

Each farmer and situation is different. Here are some strategies to help get your message through – you just need to TWEET:

1) Have no more than THREE main points, for example: 'Colostrum, electrolytes, isolation'.

2) WRITE instructions down. This ensures that instructions aren't forgotten, especially if there's been some time since the last scours outbreak. Your advice is then available for other people as well. Tailor-make handouts for your clinic and have them

photocopied and ready to be filled in and left on-farm.

3) EMPATHISE. Having sick calves is an extra stress for farmers. How you impart your advice needs to take this into account: 'I know it's a big ask, but can you manage an extra 2 feeds of electrolytes a day…'

4) EXPLAIN your recommendations using analogies that will mean something to the farmer: 'Not having extra electrolytes is like you playing a whole footy match without water'.

5) TELEPHONE to see how things are going. Adapt any of your recommendations that aren't working.

SUMMARY

Neonatal calf diarrhoea is a complex disease process. However, cattle practice in Australia needs simple, practical fluid therapy. Calves able to stand and suckle should be treated with an ORS with adequate alkalinising ability and SID. Recumbent calves with acidosis ideally need 1.3% bicarbonate IV. Combined hypertonic/colloid solutions IV allows faster expansion of plasma volume, intraperitoneal isotonic fluids or colloids have the potential to allow rapid infusion of fluids.

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