WHAT'S THE SOLUTION?

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Fluid management strategies are described in order to assist colleagues or other institutions who may be developing fluid management guidelines for the first time, or who are interested in different perspectives on perioperative fluid intervention. This is not intended to be a dogmatic approach to the topic, but rather to suggest a perioperative fluid replacement model to evaluate the effectiveness of care, improve clinician practices, and reduce the risk of fluid-related adverse events. In the absence of definitive guidelines, an approach to choice of fluid therapy based on patient factors, the type of surgery, and the type of fluid available is presented. Recently published recommendations for choice of fluid therapy and important clinical trials are examined.

When choosing an intravenous fluid for perioperative use, the following questions need be considered. Does the patient need fluid? How much fluid? What type of fluid- crystalloid or colloid? What type of crystalloid or colloid? When should it be given? What haemodynamic goal should we use to guide fluid delivery? The presentation focuses only on the specific choice of crystalloid or colloid, taking in to consideration the available evidence and each fluid unique physiochemical properties.

No fluid can improve patient-centred outcomes unless it is coupled to a treatment that improves outcome.[1] Thus, choice of fluid must be considered within the context of proven medical therapies, success of which is dependent on the clinical condition, pathophysiological state, and ability to reverse the identified disease process.

The composition and discriminate use of IV fluids should solely be dictated by the targeted fluid space. There appears to be no merit in differentiating between intraoperative, perioperative, postoperative and ICU settings.

Volume replacement should replace intravascular fluid losses and correct hypovolaemia to maintain haemodynamics and vital signs. Using a physiological solution that contains both colloid osmotic and oncotic components is reasonable. Fluid replacement, on the other hand, should compensate for an extracellular deficit as a result of cutaneous, enteral, or renal fluid loss. This is achieved with a physiological solution that contains all osmotically active components, ie an isotonic fluid. Electrolyte replacement or osmotherapy aims to restore a physiological total body fluid volume (intracellular fluid volume plus extra cellular fluid volume) when cutaneous, enteral, or renal fluid losses have altered the composition and / or volume of either or both fluid spaces (ICFV and / or ECFV).

Table 1 overviews the physiochemical properties of the available crystalloids

There is a growing body of evidence that normal saline (0.9%) should be avoided and replaced with balanced salt solutions. Normal saline results in hyperchloraemic acidosis and may have adverse effects on renal outcomes. Balanced electrolyte solutions containing K^+ can be used cautiously even in patients with AKI in preference to normal saline.[2] Currently there is not a single study showing normal saline to be superior to balanced solutions. Normal saline would not pass a single Phase 1 RCT, is unphysiological, and its use should be discouraged.[3] Even healthy human volunteers can take over two days to excrete a rapid infusion of 2 L of 0.9% saline.[4]

There is convincing animal data that demonstrates the adverse effects of chloride on the kidney. Hyperchloraemia has been shown to result in increases in inflammatory cytokines, increases renal afferent arteriole vasoconstriction[5] and adverse effects on renal oxygen consumption.[6] In human studies recently published research has also now demonstrated negative effects of chloride on renal blood flow in healthy volunteers.[7] In addition balanced solutions may reduce the incidence of major complications and kidney injury in patients undergoing major abdominal surgery when compared to normal saline.[8]

	Plasma	Plasmalyte	Hartmann's	Normal Saline
Sodium (mmol/L)	136 – 145	140	129	154
Potassium (mmol/L)	3.5 – 5.0	5.0	5.0	
Magnesium (mmol/L)	0.8 – 1.0	1.5		
Calcium (mmol/L)	2.2 – 2.6		2.5	
Chloride (mmol/L)	98 – 106	98	109	154
Acetate (mmol/L)		27		
Gluconate (mmol/L)		23		
Lactate (mmol/L)			29	
Osmolarity (mosmol/L)	290 – 310	295	274	308
pH	7.4	7.4	5.5 – 6.2	5.5 – 6.2
Strong ion difference (meq/L; effective)	42	49	29	0
Cost (AU$/L)		1.89	1.00	1.00

Table 1. Physiochemical properties of the commonly used crystalloids compared to plasma

The effective strong ion difference (SID) of each crystalloid will have significant effects on acid base homeostasis. Plasma has a normal SID of 42 meq/L. If a fluid with an effective SID lower than that of plasma is infused, this creates a metabolic acidosis by reducing plasma and extracellular SID. For example normal saline has an effective SID of zero. If large amounts of normal saline are infused, it will dilute the plasma SID forcing it towards that of normal saline. Hyperchloraemic acidosis is preventable if there is substitution of the organic anion Cl^- for HCO_3^-. The following anions are used as metabolisable bases in the available balanced crystalloids – lactate in Hartmann's solution, gluconate and acetate in Plasmalyte. The organic anions are strong anions and can be regarded as 'balanced,' provided they are metabolised rapidly after infusion. The effective strong ion differences of the crystalloids are summarised in Table 1.

Hartmann's solution contains 29 mmol/L of L-lactate (anion). Metabolism of L-lactate will generate HCO_3^- buffer. Importantly, lactic acid is an acid, but the lactate in Hartmann's is a base, metabolised by the liver at 100 mmol/hr (4 L/hr). The effective SID of Hartmann's solution is 29 meq/L. The lactate anion is the conjugate base of lactic acid and represents potential bicarbonate and not potential H^+. Hartmann's is useful for ECF and intravascular volume replacement. Severe acidaemia may result in inadequate hepatic metabolism therefore the production of HCO_3^- from the infused lactate may be impaired in this setting. If lactate cannot act as a HCO_3^- source, an iatrogenic hyperlactaemia may occur.

Problems with Hartmann's solution –

- Elevations in lactate if the lactate cannot be metabolised in the liver (eg liver disease / liver transplantation). This can create clinical problems if using lactate as a marker of resuscitation
- Diabetics – some evidence that lactate is converted to glucose causing hyperglycaemia[9]
- Hypotonic – 278 mosmol/L vs normal saline 300 mosmol/L (Na^+ of 129 mmol/l). Caution with cerebral oedema
- Oliguric hyperkalaemic renal failure
- Calcium – in US, AUS / NZ, cannot be co-administered with blood because it causes clotting in the IV line (not proven)
- O_2 consumption increases rapidly after lactate administration

Plasmalyte solution is another balanced solution that has substitution of organic anions for HCO_3^-. These organic anions are gluconate & acetate. Gluconate and acetate are metabolised by the liver, but also in extra-hepatic sources such as the muscle. Plasmalyte contains no lactate (will not cause iatrogenic hyperlactaemia) and no calcium (therefore can be used with blood without causing precipitation). Its effective SID is 49 meq/L, higher than plasma, and therefore corrects acidosis. It has a normal osmolality of 295 mosm/L, is isotonic, and has physiological amounts of Na^+, making it suitable in neurosurgery. Acetate is converted to bicarbonate in the liver and extra-hepatic tissue, is more rapidly converted than lactate, and has more alkalinising ability than lactate. It is worth noting that the supra-physiological concentrations of acetate buffer in some dialysate solutions may result in myocardial depression and hypoxia – therefore acetate has been abandoned as a buffer in dialysis in Australia. Gluconate is converted to bicarbonate in liver and extra-hepatic tissue and mostly (80%) eliminated unchanged in

urine. There is animal data showing that concentrations of 2.4 – 4.8 mmol/L are protection against post ischaemic myocardial dysfunction and oxidative injury.

Practice at Austin Hospital for crystalloid fluid intervention –

1. No role for normal saline
2. Hartmann's for the majority of cases
3. Plasmalyte for –
   - All major liver surgery including transplantation
   - Complex cardiac (aortic surgery, redo, double valve, etc)
   - Critically ill patients with existing metabolic acidosis

	Plasma	Gelofusine	Albumin (20%)	Albumin (4%)	Voluven	Volulyte
Sodium (mmol/L)	136 – 145	154	48-100	140	154	137
Potassium (mmol/L)	3.5 – 5.0					4
Magnesium (mmol/L)	0.8 – 1.0					
Calcium (mmol/L)	2.2 – 2.6					
Chloride (mmol/L)	98 – 106	120		128	154	110
Acetate (mmol/L)						34
Octanoate (mmol/L)			32	6.4		
Strong ion difference (meq/L; effective)	42	50	40	12	0	31
Cost (AU$/L)		~22			~17	~17

Table 2. Physiochemical properties of the commonly used colloids compared to plasma

A detailed overview of each of the colloids is beyond the scope of this presentation and excellently discussed in other review articles.[10] A brief summary of the physiochemical properties of each of the colloids is outlined in Table 2. Similarly to the crystalloids, an important component of the colloid is the chloride content and the effective SID. Except for Albumex 20, all colloids have a high chloride content and therefore the SIDs of the commercially available weak acid colloids are all greater than zero. There is thus a tendency for standard albumin and gelatin based colloids to cause a metabolic acidosis similar to saline. The new third generation tetrastarches contain no weak acids, and have an effective SID of zero. Their acid base effects are similar to saline. There is a growing move towards using balanced colloids, ie colloid solution in a balanced crystalloid carrier. Volulyte is one such solution.

References

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