Maintenance fluid management in paediatrics

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Abstract

Intravenous maintenance fluids are life sustaining and form one of the cornerstones of paediatric in-patient management. Similar to other medical therapies fluids come with side effects and the potential for significant associated morbidity and mortality. An appreciation of their side effect profiles in the context of paediatric physiology, particularly during critical illness, is essential in order to minimise the risks. This article summarises the history of paediatric fluid prescribing practice, highlighting the associated iatrogenic risks and provides a strategy for safer practice.

Keywords balanced solutions; fluid prescribing; maintenance fluids; normal saline; risks of fluid administration

Introduction

Intravenous maintenance fluids continue to be one of the most commonly prescribed therapies for hospitalised children and yet there is great heterogeneity in clinical practice. Broadly speaking parenteral fluids are safe and potentially life-saving but as children's total body water composition may be up to 75–80% of their body weight they are markedly more prone to water and electrolyte imbalance than young adults, particularly during periods of acute illness. Trial data over the last 60 years has provided great advances in our understanding of the biochemical and physiological impact of fluid administration but yet no consensus has been reached regarding the optimal fluid composition. Consequently fluids should be prescribed with great caution as with any other drug such as antibiotics or chemotherapy. Clinicians have a responsibility to consider the indications and contraindications as well as dose–response relationship and side effects. We need to choose our 'drug' with caution and be aware that 'the dose makes the poison'. There is no doubt that fluids offer a therapeutic benefit but one must remember that there is an iatrogenic 'dark side'. This article will prompt you to critically question your maintenance fluid prescribing and help you to physiologically justify your practice.

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Tonicity and osmolality

The tonicity of a fluid solution refers to the amount of sodium found within it. Hypotonic solutions contain less than 131 mmol/litre of sodium. Hypertonic solutions contain more than 145 mmol/litre of sodium. In contrast the osmolality describes the amount of osmotically active material i.e. salt and sugar. Thus a solution may be isoosmolar or even hyperosmolar but still be hypotonic.

What is the ideal intravenous maintenance fluid?

Vincent and De Backer proposed a framework for the phases of fluid therapy during a patients admission - Rescue, Optimisation, Stabilisation and De-escalation [see further reading]. Maintenance fluids are intended for stabilisation and are prescribed for children and young people to account for losses of red blood cells, plasma and water or electrolytes beyond the usual losses in urine, stool and sweat. As such their primary purpose is maintaining fluid and electrolyte homoeostasis. With this in mind the ideal maintenance fluid is one that produces predictable effects, has a chemical composition as close as possible to that of extracellular fluid, is metabolised and completely excreted without accumulation in tissues. It should not produce adverse metabolic or systemic effects, and is cost-effective in terms of improving patient outcomes. Unfortunately no such 'ideal' fluid is currently available commercially and so clinicians must lean on best evidence and national guidance and recognise that different fluids have different therapeutic targets.

In 1957 Halliday and Segar published guidance for maintenance fluid therapy for children who were unable to ingest fluids, including the well known '4-2-1 rule' to calculate maintenance fluid volumes. They recognised that maintenance requirements for water depended upon insensible loss of water and renal loss and as a result created a hypotonic solution for maintenance fluid delivery. Their guidance was widely adopted and even used inappropriately for replacement fluids and peri-operative fluid losses which led to complications including hyponatraemia, which was known to be associated with encephalopathy and death. Over the last decade there has been a flurry of interest in fluid prescribing and development of new UK national guidance. The National Patient Safety Agency (NPSA) published guidelines in 2007 restricting the use of 0.18% (hypotonic) saline with glucose and emphasising the importance of electrolyte monitoring to minimise the risk of hyponatraemia. It was recognised that whilst the fluid was isosmolar the dextrose was rapidly metabolised in free water resulting in a hypotonic fluid, as defined by its electrolyte composition. Consequently practice moved towards prescribing 0.9% saline with 5% glucose as a isotonic solution. Later the National Institute for Health and Care Excellence (NICE) released updated guidance in December 2015 stating that if term neonates, children or young people need IV fluids for routine maintenance, isotonic crystalloids that contain sodium in the range 131–154 mmol/litre should be used initially. Additionally one should adjust the intravenous fluid prescription to account for existing fluid and/or electrolyte deficits or excess,

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ongoing losses or abnormal distribution (for example tissue oedema in sepsis). However, the guideline was based on very low quality evidence from one randomised control trial and the experience and opinion of the Guidance Development Group. With no 'ideal' fluid available and a lack of high quality evidence the great fluid debate continues.

Normal saline or balance solutions?

Intravenous fluids can be categorised by physical composition, as summarised in Table 1.

Crystalloids are solutions of small molecules in water which tend to disperse more readily into the tissues. They contain various combinations of electrolytes and buffers and are referred to by their tonicity with reference to human plasma. Perhaps the most well known crystalloid is the inappropriately named 'normal saline' or 0.9% sodium chloride. Normal saline has been the solution most commonly used in both resuscitation and maintenance fluid management over the past 50 year despite its known side effects including dilutional-hyperchloraemic acidosis. A number of trials have shown association with hyperchloraemia and acute kidney injury when normal saline is used in large volumes, especially in resuscitation. It is unclear if normal saline, when used at a maintenance rate for less than 72 hours is associate with these complications.

The balanced solutions are theoretically more similar to plasma, containing electrolytes in the same proportions. All those solutions have organic anions like acetate, lactate, malate, gluconate as precursors of bicarbonate in order to balance the total content of positive charges. The balanced solutions have calcium that can be incompatible with blood products and some medications.

Dextrose is added in maintenance fluids to provide sufficient calories and prevent hypoglycemia and limit tissue catabolism. The default maintenance solution is 5% dextrose in 0.9% saline. There are recently available balanced solutions with dextrose; there is no evidence that shows that the use of those solutions have fewer side effects.

What are the risks of fluid administration?

Adverse outcomes of fluid administration are as a consequence of inadequate or excessive provision or electrolyte and acid-base imbalance. NICE guidelines clearly state that failing to deliver correct fluids can have a significant impact on morbidity and mortality and so one must recognise the potential iatrogenic 'dark side' of intravenous fluids. These are summarised below:

Fluid overload

Delivering excessive volumes of fluid can lead to overload throughout the body fluid compartments and even into potential spaces including the pleural and peritoneal cavities (also known as 'third spaces'). This movement of fluid from the intravascular to extravascular compartments can lead to increased strain on the myocardium and ultimately to pulmonary and interstitial oedema. Pathological oedema formation is known to be associated with adverse outcomes. To minimise this risk maintenance fluids requirements should be calculated according to the Holliday and Segar formula mentioned above (4, 2, 1 or 100, 50, 20) and take into account fluid boluses and infusions given during the rescue and optimisation phases of resuscitation.

During periods of acute illness the risk of oedema is even greater due to degradation of the endothelial glycocalyx - a web like membrane of glycoproteins and proteoglycans on endothelial cells - as a consequence of the inflammatory process. This membrane is a key determinant in endothelial cell wall permeability and so damage leads to capillary leakage, even before haemodynamic fluid overload. In fact even a healthy cell membrane will allow movement of protein free fluid and electrolytes into the extravascular space.

Sodium imbalance

Hyponatraemia (serum sodium <135 mmol/litre) may occur when inappropriate fluids are administered, such as hypotonic solutions, or through dilutional effects of excess fluids given at high infusion rates. Significant hyponatraemia, particularly when less than125 mmol/litre, may present with headaches, seizures

Composition of intravenous crystalloid solutions

	Human plasma	0.45% Sodium chloride	0.9% Sodium chloride	Hartmann's, Ringer's lactate	Plasma-Lyte 148
pH	7.34–7.45	4.5–7.0	5.5	5.0–7.0	7.4
Osmolarity (mOsm/litre)	270–308	154	308	280.6	295
Sodium (mmol/litre)	135–145	77	154	131	140
Potassium (mmol/litre)	3.5–5.3			5.4	5.0
Chloride (mmol/litre)	95–105	77	154	111	98
Calcium (mmol/litre)	2.2–2.6			2.0	
Magnesium (mmol/litre)	0.8–1.0				1.5
Lactate (mmol/litre)	1–2			29	
Acetate (mmol/litre)					27
Gluconate (mmol/litre)					23

Additional dextrose is provided with maintenance fluids to provide sufficient calories, prevent hypoglycemia and limit tissue catabolism.
Plasma-Lyte 148 from Baxter International Inc.

Table 1

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