INVITED COMMENTARY

The European Consensus Statement on intraoperative fluid therapy in children: a step in the right direction

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Intravenous fluids with a sodium concentration of less than 75 mmol l^{-1} are poisonous for children. It has taken over a decade for anaesthetists around the world to respond to the alert raised by Arieff *et al.*[1] when 16 previously healthy children in the region had a respiratory arrest associated with post-operative hyponatraemia. Nine of these died and the rest were severely brain damaged. Children are still suffering the same fate for the same reason.[2,3]

In this edition of the *European Journal of Anaesthesiology*, the German Scientific Working Group for Paediatric Anaesthesia presents a Consensus Statement recommending that intraoperative fluid should have an osmolarity and sodium content close to that of plasma, a glucose concentration of 1 or 2.5% and metabolic anions to act as bicarbonate precursors to prevent hyperchloraemic acidosis.[4] Despite fluids of this type being available in France, Switzerland, Belgium, Austria and Germany, many countries in Europe do not have access to such a fluid. The Group has proposed a European Consensus Statement to facilitate the provision of these fluids for the remaining European countries.

Dealing only with the intraoperative period, the Consensus Statement refers to currently available fluids which is a good initial step towards an immediate improvement in care. Many current fluids are derivatives of old recipes that were not based on clinical evidence. Clinicians are now beginning to look more critically at the composition of intravenous fluids for all of paediatric care. Deriving new fluids from existing ones like Hartmann's solution or saline 0.9% reduces the regulatory obstructions. However, we must not produce fluids whose development is based on what can most easily be achieved. It is time to start with a clean slate, check each step with research and produce fluids that are based on good scientific evidence.

If we study each recommendation in the Consensus Statement, we can learn in which areas some of the research is needed. What is important is the sodium concentration, not the osmolarity. Sodium is the most plentiful ion in intravenous solutions and governs the movement of water between compartments. We have yet to decide what the ideal sodium concentration should be in intraoperative fluids and are unable to say whether it is 129 mmol l^{-1} or 150 mmol l^{-1}. Neither do we know the optimum chloride concentration which has links to the concentration of sodium and other ions. Infusing saline 0.9% raises plasma chloride, producing deleterious effects that include renal vasoconstriction and a fall in glomerular filtration rate.[5]

One contributor to the Consensus Statement published a study that defined the ideal glucose concentration of intraoperative fluid as 1%, making it surprising that 2.5% glucose also appears in the Statement.[6] This is not to detract from the importance of providing glucose-containing fluid for children and a commercially prepared solution would prevent the risk of contamination and error when anaesthetists add glucose to fluid bags in the operating room.

The Consensus Statement refers to hyperchloraemic acidosis. This is more easily explained as strong ion acidosis which recognises that hydrogen ion concentration is simply a physico-chemical result. The pH of the infused solution does not have a significant effect on the plasma pH, but the strong ion difference (SID) does. The SID of the plasma moves towards that of the infused fluid, resulting in a change in pH.[7–9] Morgan has shown in rats that the SID for a given fluid that, despite infusion of a large volume, will not affect plasma pH is 24 mEq l^{-1}. This figure is the same as the standard bicarbonate concentration.[10] Plasmalyte causes an alkalosis as severe as the acidosis associated with saline 0.9%.[9] Traverso *et al.*[11] found that the worst survival in a pig resuscitation model was in the plasmalyte groups; saline 0.9% was next, and the best was Hartmann's solution with a SID of 28 mEq l^{-1}.[11] Cells prefer a normal pH, but if it alters they function better in the acidosis caused by 0.9% saline compared with the alkaline environment caused by plasmalyte.[12]

The choice of anion, which, together with chloride, electrically balances sodium in the bag and results in a

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SID of 24 $mEq\,l^{-1}$, must be based on evidence. The ideal anion should be stable in the bag, but should disappear immediately when infused or else it will act as a strong ion and continue to alter pH. Bicarbonate is ideal, but must be stored in glass bottles or Mylar bags and the solution must be prepared in a pure carbon dioxide environment which makes it expensive. Lactate is commonly used, but has to be metabolised before it ceases to affect SID; gluconate also persists and acetate has many harmful effects.[13] Until now, the choice has been driven by manufacturing convenience and cost, rather than clinical science. The anion that is eventually chosen must be tested to ensure that outcome is not worsened.[14]

Clear labelling of content will encourage more logical prescription. It would be useful to have an international standard for fluid names that indicates precisely what is in the bag. The expression 'normal saline' was first used in 1888 and is a colloquialism of the time.[15] It has no modern meaning nor do descendants like half-normal saline. The most prominent fonts should show the strong ions expressed as millimoles per litre and glucose concentration as percentage. Printing the SID of the solution would be more useful than a pH value, given that the latter will have no significant effect on the plasma pH. The osmolarity in the bag is not an indicator of the effect on the plasma osmolarity and writing hyperosmolar when glucose is added to the correct concentration sodium may discourage its use. The number of milligrams of an ion seems important to regulatory bodies, but not to clinicians.

Millimoles and milliequivalents are both used to express concentrations of ions. They are not always interchangeable. A millimole is 1000th of a gram molecular weight, but an equivalent is the amount of substance that will supply or react with one mole of hydrogen ions (H^+).
The composition of intravenous solutions is often given in millimoles per litre rather than milliequivalents per litre, but this does not take into account ions with multiple charges. The cation in intravenous solutions is largely sodium ion (Na^+) which has a valency of 1, and so for Na^+ 1.0 $mmol\,l^{-1} = 1.0\,mEq\,l^{-1}$. For ions with a double charge, 1.0 $mmol\,l^{-1} = 2\,mEq\,l^{-1}$ and so on. For this reason, multivalent ions, of which many are anions, are often given as milliequivalents per litre rather than the preferred unit millimoles per litre (http://en.wikipedia.org/wiki/Milliequivalent).

The history of the design of intravenous fluids is largely physiological theorising and it is vital that any document recommending composition or volumes of intravenous fluids must be evidence-based. Similarly, it must not become a tablet of stone. Research will change what we should do and documents like the European Consensus Statement must be under regular review to accommodate new knowledge.

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