Maintenance fluid therapy

What routine intravenous maintenance fluids should be used?
N P Mann

An introduction to the debate

Intravenous maintenance fluid is widely used in general paediatric practice and more children who come into hospital receive intravenous fluid than in the past. The intravenous route is frequently used because enteral maintenance or rehydration treatment is more labour intensive and uses valuable staff time; furthermore modern pumps for delivery of fluids are safe. Nevertheless in developing countries the enteral route is still more widely used even for sick dehydrated children. Are there any dangers of intravenous fluids? Clearly there is a possibility of miscalculation of infusion rates and also the potential for mistakes in terms of dosing errors with additives. It has been widely recognised in recent years that there is a high incidence of hyponatraemia in children treated with intravenous maintenance fluids. Is this because of excessive water or too little salt?

Moritz and Ayus discussed the high frequency of hyponatraemia in these children in their paper in Pediatrics in February 2003. They suggested the use of isotonic saline rather than use of hypotonic fluids for maintenance therapy. More than 20 years ago there were concerns about profound neonatal hyponatraemia causing neurological problems in infants as the result of either excessive or the wrong kind of fluid given to mothers during labour.

It is therefore timely to revisit this problem. Two experts have been asked to give their views to encourage further debate (see accompanying articles 1–4). Do write to ADC with your comments about how paediatric practice in this area can be improved. Arch Dis Child 2004;89:411

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REFERENCES
patients are catabolic, often relatively inactive, and, in the intensive care environment may be pharmacologically sedated or muscle relaxed. Almost half of the caloric intake suggested by Holliday and Segar is designated for growth, an unrealistic goal in acute disease. Although fever and sepsis per se may increase metabolic rate this is usually limited to less than 1.5 times the basal metabolic rate, burns being an exception.

**Water requirements**

Historically water requirements have been based on crude estimates of both insensible (skin, respiratory tract) and sensible (urine and stool) water losses.

**Insensible water loss**

This was generously estimated at 930 ml/m²/day (27 ml/kg/day). Recent data suggest the true figure may be only half of this, with basal insensible losses from the skin being 250 ml/m²/day (7 ml/kg/day) and via the respiratory tract 170 ml/m²/day (5 ml/kg/day). Additionally many other risk factors may reduce insensible water loss such as use of humidifiers in ventilated patients (80% reduction in respiratory water loss) or a thermo neutral environment. Bluemlke et al have shown insensible water losses of as little as 330 ml/m²/day (10 ml/kg/day) in catabolic acute renal failure patients.

*Crawford calculated caloric expenditure based on the calories utilised per surface area of the body. The calculated caloric expenditure at each body surface area increment can be converted to weight using standard growth charts. The ratio of weight to surface area rapidly declines from birth to 10 kg. The Holliday and Segar method does not take this into account.

**From the data of Talbot.**

**Urinary loss of water**

According to Holliday and Segar, urinary water losses for healthy children amount to 50–60 ml/kg/day based on the work of Pickering and Winters (table 1). The basis of this fluid regime was the observation that 15/28 infants and 20/25 children (unsuspected diagnoses) who were given intravenous dextrose produced urine with an “acceptable” urine osmolality between 150 and 600 mosm/l H₂O. They presumed patients with dilute urine received too much water and conversely those with concentrated urine too little water.

Today we recognise this does not take into account the overriding influence of antidiuretic hormone (ADH) on urine flow rate. When ADH is present, the renal solute load is effectively excreted in a smaller urine volume producing concentrated urine. Under these conditions urine output is often less than half the values observed in healthy children (approximately 25 ml/kg/day). An increase in ADH is common during many childhood diseases, in response to stress (pain, fever, surgery) or secondary to use of opiates and non-steroidal anti-inflammatory drugs. Under these conditions the administration of free water frequently leads to hyponatraemia because the kidneys are unable to excrete the water load. Interestingly, the type of fluid administered may influence ADH levels. Judd et al showed that 0.9% saline but not 5% dextrose reduced ADH concentrations postoperatively.

Thus the total fluid loss (sensible plus insensible) during acutely illness or following surgery may amount to approximately half that suggested by Holliday and Segar (50–60 ml/kg/day). Also, the often overlooked production of endogenous water from tissue catabolism (water of oxidation) may be increased in acute disease. In healthy children, this has been estimated to be 15 ml/100 kcal burnt. Thus, all these factors need consideration when assessing overall water balance.

**Electrolyte requirements**

In healthy breast fed infants Holliday and Segar computed a dietary sodium intake of 1 mEq/100 calories per day. Darrow recommended 3 mEq of sodium per 100 calories of energy expended per day. This is based on urinary excretion rates of sodium in healthy, milk fed infants. However, daily electrolyte requirements in disease may differ considerably from this. For example, large urinary losses of sodium and potassium may occur through the phenomenon of desalinisation. Furthermore, Al-Dahhan et al showed a beneficial effect on neurodevelopmental outcome from doubling the daily sodium intake (4 to 5 mmol/kg) in neonates. This refutes the assumption that the neonatal kidney is incapable of “handling” a high sodium load. The recent discovery of the most potent natriuretic hormones, urodilatin and gut-related natriuretic peptide has also shed new light on sodium regulation.

The rationale behind the traditional approach is to balance sodium intake to match sodium loss. However, this fails to appreciate the single most important role of sodium in acute illness, namely maintenance of plasma tonicity. There is a strong inverse relation between plasma sodium concentration and intracellular volume. Cell membranes are permeable to water but not electrolytes. As sodium is the major extracellular cation (and hence osmole), it regulates the movement of water across cells along an osmotic concentration gradient, thus explaining cellular swellling in the presence of hyponatraemia.

It is also important to recognise the role of potassium in the regulation of tonicity balance. Potassium is a major intracellular osmole, and may directly influence extracellular sodium concentration by altering the distribution of water between fluid compartments. Potassium loss, both urinary and stool, may be significant in disease; yet its direct influence on serum sodium concentration is often not considered.

**Tonicity of intravenous fluids**

It is crucial that clinicians appreciate the difference between osmolality and tonicity. The osmolality of a solution is the number of osmoles of solute per litre of solution. The tonicity of a solution refers to the total concentration of solutes that exert an osmotic force across a membrane in vivo. For example, 5% dextrose has the same osmolality as plasma (286 mosm/l H₂O) but is rapidly metabolised in blood to water. Thus its in vivo tonicity

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**Table 1 Typical water losses per 100 kilocalories (kcal) of energy expended for a healthy 10 kg child**

<table>
<thead>
<tr>
<th>Source of water loss</th>
<th>Estimated water loss (ml per 100 kcal/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Insensible Skin</td>
<td>30</td>
</tr>
<tr>
<td>Respiratory</td>
<td>15</td>
</tr>
<tr>
<td>Sensible Stool</td>
<td>10</td>
</tr>
<tr>
<td>Minimal sweating</td>
<td>10</td>
</tr>
<tr>
<td>Urine</td>
<td>50</td>
</tr>
<tr>
<td>Total</td>
<td>115</td>
</tr>
</tbody>
</table>

Data calculated according to Pickering and Winters. **From the data of Talbot.**
is equal to that of electrolyte free water, as it contains no salt or other active osmole (zero tonicity). Every litre of 5% dextrose infused results in the expansion of the intracellular and extracellular fluid space by one litre (two thirds of this distributes to the intracellular space and one third to the extracellular space). Similarly, for every litre of 0.18% saline in 4% dextrose water infused, only 1/5th (200 ml) is isotonic to plasma (table 2). The remaining 800 ml is electrolyte free water, which will expand the intracellular fluid compartment. This is particularly relevant if excretion of water is limited by ADH.5–7 21 22 23 Shann et al recently showed a third in hospitalised adults where isotonic maintenance fluids are routine. When present, the aetiology of hyponatraemia in this scenario is frequently due to well recognised factors such diabetics insipidus or over-use of loop diuretics.24

The debate as to the optimal isotonic fluid is ongoing. For example, Hartman’s solution has a more physiological concentration of chloride than 0.9% saline and hence does not cause hyperchloraemia. The benefit of Hartman’s solution versus 0.9% saline is not currently known. It is important to stress that dextrose may be added to these isotonic solutions (commonly in concentration of 5–10%), when clinically indicated to avoid hypoglycaemia without changing the solution’s in vivo tonicity (table 2). Recent evidence suggests that a 1% dextrose solution following uncomplicated paediatric surgery may be adequate.27 A suitable solution for neonates and infants is 0.9% saline in 5% dextrose water, which is commercially available. We advocate 0.9% saline (with or without added dextrose) as a safe maintenance solution, both peri- and in the acute phase of most childhood illnesses requiring hospitalisation (for example, pneumonia, bronchiolitis, and meningitis). Here, the water retaining effect of antidiuretic hormone may necessitate a moderate degree of fluid restriction (50–60%) to prevent fluid overload. The concept of fluid maintenance should not be confused with replacement therapy where abnormal or excessive quantities of water and electrolytes may be lost. In this instance the biochemical composition and tonicity of the replacement solution should approximate that which is lost.

### Table 2 Approximate sodium concentration, in vitro osmolarity, in vivo tonicity, and theoretical volume of electrolyte free water (EFW) provided by commonly used intravenous solutions

<table>
<thead>
<tr>
<th>Intravenous solution</th>
<th>Sodium * (mmol/l)</th>
<th>In vitro osmolarity † (mOsm/l H₂O)</th>
<th>In vivo tonicity ‡ (mOsm/l H₂O)</th>
<th>Volume of EFW per litre infused</th>
</tr>
</thead>
<tbody>
<tr>
<td>5% dextrose</td>
<td>0</td>
<td>286</td>
<td>0</td>
<td>1000</td>
</tr>
<tr>
<td>0.18% saline in 4% dextrose</td>
<td>30</td>
<td>300</td>
<td>60</td>
<td>824</td>
</tr>
<tr>
<td>0.45% saline</td>
<td>75</td>
<td>150</td>
<td>154</td>
<td>500</td>
</tr>
<tr>
<td>0.45% saline in 5% dextrose</td>
<td>75</td>
<td>432</td>
<td>150</td>
<td>500</td>
</tr>
<tr>
<td>0.9% saline</td>
<td>1.54</td>
<td>308</td>
<td>308</td>
<td>0</td>
</tr>
<tr>
<td>0.9% saline in 5% dextrose</td>
<td>1.54</td>
<td>586</td>
<td>308</td>
<td>0</td>
</tr>
</tbody>
</table>

*The apparent discrepancy between the in vitro sodium concentration (0.9% saline) of 1.54 mmol/l and the in vivo plasma sodium of 1.44 mmol/l is due to the phenomenon of pseudohyponatraemia. In human plasma, approximately 7% of the plasma volume is occupied by albumin and lipid, falsely lower the true sodium concentration plasma by 10 mmol/l (7% of 1.55).
†In vitro osmolarity refers to the number of moles of solute per litre of solution.
‡In vivo tonicity refers to the total concentration of solutes which exert an osmotic force across a membrane in vivo (excludes the osmotic effect of dextrose because it is rapidly metabolised in blood).
§Calculated on the basis that electrolyte free water distributes to the intracellular and extracellular space in a ratio of 2:1.

THE RATIONALE FOR ISOTONIC MAINTENANCE FLUID

The paramount consideration in the choice of intravenous fluid is the requirement to maintain serum sodium at a normal level. The use of isotonic solutions such as 0.9% saline is more appropriate in acutely sick children as they do not theoretically expand the intracellular fluid space. Isotonic solutions preserve intracellular function and integrity, by minimising changes in plasma sodium concentration and tonicity.

Use of 0.9% saline as maintenance fluid, if combined with appropriate fluid restriction, will result in a two to threefold increase in daily sodium intake compared to the traditional regime. However, the concern that this may cause severe hypernatraemia is without foundation because the sodium concentration and tonicity of 0.9% saline is similar to plasma. Andersen et al showed a rise in plasma sodium only after intravenous administration of hypertonic 3% saline but not 0.9% saline, despite a temporary positive sodium balance.33 Heer et al showed chronic sodium loading in volunteers does not produce an increase in plasma sodium, body water, or weight as previously suggested.34 Many of the historical assumptions concerning sodium handling are based on salp depleted subjects. Indeed massive sodium loads from large volume resuscitation of infants and children with sepsis (80–180 ml/kg/day) using 0.9% saline did not produce hypernatraemia.33 Additionally and an epidemic of hypernatraemia has not been documented in hospitalised adults where isotonic maintenance fluids are routine. When present, the aetiology of hypernatraemia in this scenario is frequently due to well recognised factors such diabetis insipidus or over-use of loop diuretics.24

### CONCLUSION

We have shown a number of pitfalls in the Holliday and Segar approach to parenteral therapy, namely that it focuses on fluid and electrolyte requirements for healthy children. In acute disease or following surgery, caloric expenditure, insensible water losses, and urine output are frequently much less than in health (often 50–60% of the reference values). Furthermore, this approach fails to recognise the importance of tonicity with its central role in the distribution of water between fluid...
compartments (intracellular and extracellular space).

We therefore agree with Moritz and Ayus who advocate isotonic solutions such as 0.9% saline for routine fluid maintenance in children. Hypotonic solutions, such as 0.18% or even 0.45% saline, are potentially dangerous when renal water excretion is limited by ADH. This raises a significant ethical barrier to conducting a randomised control study as most acutely ill or postoperative patients have increased ADH levels. There are few occasions in medicine under such conditions admitted to hospital: retrospective analysis of factors contributing to its development and research in 1992:304:1218–22.


Maintenance fluid therapy

Rubbing salt in the wound

M Hatherill

The case against isotonic parenteral maintenance solution

In a recent review, Moritz and Ayus have suggested that isotonic parenteral maintenance solution (PMS) should be used to prevent hospital acquired hyponatraemia in children. Hospital acquired hyponatraemia may be exacerbated by non-osmotic production of antidiuretic hormone (ADH) associated with conditions such as bronchiolitis (33%), pneumonia (31% and 45%), bacterial meningitis (50%), and postoperative pain or nausea. Although it has been termed a syndrome of inappropriate antidiuretic hormone secretion (SIADH), it may be more accurate to refer to non-osmotic ADH production, since haemodynamic baroreceptor stimuli, such as hypovolaemia, may be physiologically appropriate despite the adverse effect on sodium.1–4

The reported morbidity and mortality associated with hospital acquired hyponatraemia have given momentum to calls for increasing the tonicity of intravenous infusions in paediatric patients: rationale for using Ringer-lactate solution with low dextrose concentration. J Clin Pharm Ther 2003;28:31–40.

Therefore, if we contemplate a change in practice, we must consider whether
Electrolyte-free insensible water loss

Traditional volume recommendations should be a change to the electrolyte content, or the prescribed volume of PMS.

Issues:

Theoretical effects of variation in the volume of PMS

Both examples apply to a 10 kg child with non-osmotic ADH production, TBW = 6 l, estimated isotonic (Na + K = 154 mmol/l) urine output of 1 ml/kg/h, estimated IWL of 35 ml/kg/day, and initial sodium = 140 mmol/l.

Example 1

100 ml/kg/day hypotonic solution (0.2% sodium chloride equivalent, Na + K = 34 mmol/l).

| Input 100 ml/kg | = 1 l | Input (Na+K) | = 34 mmol |
| Urine output 25 ml/kg/day | = 0.25 l | Urine output (Na+K) | = 39 mmol |
| IWL output 35 ml/kg/day | = 0.35 l | Water balance | = -0.4 l |
| New Na = [(Na × TBW) + balance (Na+K)]/(TBW + water balance) | 19 | New Na | = 130 mmol/l |
| = [[140 × 6] – 5]/[6 + 0.4] |

Example 2

60 ml/kg/day hypotonic solution (0.2% sodium chloride equivalent, Na + K = 34 mmol/l)

| Input 60 ml/kg | = 0.6 l | Input (Na+K) | = 20 mmol |
| Urine output 25 ml/kg/day | = 0.25 l | Urine output (Na+K) | = 39 mmol |
| IWL output 35 ml/kg/day | = 0.35 l | Water balance | = 0 l |
| New Na | = 137 mmol/l |
| = [[140 × 6] – 19]/[6 + 0] |

- In the absence of randomised controlled trials, there is insufficient evidence to support the safety, effectiveness, or relative merit of isotonic PMS in children.

PRINCIPLES OF MAINTENANCE FLUID THERAPY

In order to avoid hyponatraemia (or hypernatraemia) a tonicity balance must be preserved, by matching input and output of both water and electrolytes to maintain an isotonic final product. Each input and output may be divided into two components, the volume of water, and the content of effective osmols (sodium and potassium), so that the net effect on tonicity may be calculated from the sum of these separate components.

A nephro-centric approach to maintenance fluid therapy that ignores IWL will contain an inherent error, since all inputs and all outputs need to be considered. Although such an approach might be acceptable in adults, children have greater proportional surface area, and the magnitude of error would increase with the proportion of IWL.

It is important to note that IWL, the “perspiratio insensibilis” of Santorio, represents loss of electrolyte-free water. Estimated IWL may be derived from data reported in hospitalised infants and smaller children, ranging from 29 to 54 ml/kg/day for a 10 kg infant. After endogenous water of oxidation (270 ml/m²/day) is subtracted, net IWL would amount to 30–35 ml/kg/day. Approximately one third of IWL occurs via the respiratory tract, and two thirds via insensible evaporation from the skin.

Since cutaneous IWL is determined by body surface area, net IWL varies with age, and may be as little as 520 ml/day in adults under basal conditions.

In 1956 Holliday and Segar devised a method for calculating maintenance fluid requirements, in which both insensible and urinary water losses were based on energy expenditure. Maintenance electrolyte needs of 3 mmol/kg/day sodium and 2 mmol/kg/day potassium were somewhat arbitrarily based on the amount delivered by human breast milk feeds (1 mmol/kg/day sodium and 2 mmol/kg/day potassium).

Caloric expenditure was estimated as 100 kcal/kg/day for an infant weighing up to 10 kg, so that water loss could be calculated per kg body weight. Using this approach, IWL for a 10 kg infant would be calculated as 50 ml/kg/day, with 16 ml/kg/day subtracted for endogenous water of oxidation, equating to net insensible loss of 34 ml/kg/day. Urinary losses, based on the water required to excrete the solute load of cows’ milk, would be calculated as 66 ml/kg/day, or 2.75 ml/kg/h.

The sum of the net IWL (34 ml/kg) and renal water loss (66 ml/kg) produced...
the arithmetically pleasing calculation of 100 ml/kg/day.\textsuperscript{11} Moritz and Ayus assert that this formula for calculating water needs "clearly has passed the test of time".\textsuperscript{1} However, even though almost half a century has passed, the formula has not been put to the test.

PROBLEMS WITH TRADITIONAL MAINTENANCE RECOMMENDATIONS

Urine output may be 1 ml/kg/h, or less, if determined by non-osmotic ADH production rather than solute load, and therefore children at risk of hyponatraemia may receive 40–50 ml/kg/day over and above their actual maintenance water needs.\textsuperscript{2} It is also notable that hospital acquired hyponatraemia may be associated not only with hypotonic PMS, but with amounts of fluid that exceed, by up to 50%, currently recommended maintenance volumes.\textsuperscript{2 3 10 32 33}

Individual maintenance water needs also depend on motor activity, temperature, and biological work.\textsuperscript{25 34} Since the energy expenditure of physically immobile, critically ill children may be less than 40 kcal/kg/day, their maintenance water requirement would be reduced.\textsuperscript{34 35} We might expect a further 30% reduction of IWL in patients breathing warmed humidified air through a ventilator circuit, which illustrates an important aspect of fluid balance in critically ill ventilated children.\textsuperscript{29} If their fluid requirement is dramatically reduced, by virtue of lower respiratory and cutaneous IWL, and the sodium requirement is unchanged, the concentration of PMS required to deliver that sodium increases.\textsuperscript{26 34 35} However, this consideration does not apply to the vast majority of hospitalised children with non-osmotic ADH production, whose reduction in fluid loss is predominantly urinary (high electrolyte content), rather than insensible (zero electrolyte content).\textsuperscript{1 3 6 20 34 35}

REDUCTION IN MAINTENANCE FLUID VOLUME

Previous authors have suggested a reduction of maintenance fluid volume in high risk patients, and fluid allowance of 50 ml/kg/day is standard practice for infants with bronchiolitis in some centres.\textsuperscript{2 4 12 17} The rationale for avoiding such "fluid restriction" is that it may be disadvantageous to children with hyponatraemia.\textsuperscript{12 36 37} Three prospective studies address this issue in meningitis.\textsuperscript{17 18 19} Powell et al showed that plasma vasopressin fell with the administration of additional fluid, suggesting an appropriate ADH response to hyponatraemia.\textsuperscript{7} Singhi et al showed that although (hypotonic) fluid restriction normalised serum sodium in hyponatraemic patients, it did not lead to a significant outcome advantage or disadvantage, except in post hoc sub-analyses.\textsuperscript{34} Duke et al compared oral fluid restriction and full intravenous maintenance, with no statistically significant difference in serum sodium or adverse outcome.\textsuperscript{37} Clearly, hyponatraemia and inadequate organ perfusion may be disadvantageous to patients with meningitis.\textsuperscript{72} However, neither the volume nor composition of maintenance fluid should be a consideration in the treatment of hyponatraemia, which should be corrected immediately with rapid infusion of resuscitation fluid.\textsuperscript{38} It has even been suggested that synthetic colloid, rather than saline, should be used to avoid sodium loading during resuscitation.\textsuperscript{39}

MECHANISMS OF HYponatraEMIA

ADH increases the permeability of the distal renal tubule and collecting duct, resulting in renal conservation of water and inappropriately high urinary sodium concentration, so that children who develop hyponatraemia may excrete urine isotonic to plasma.\textsuperscript{40 41} Excessive ADH production has also been termed a phenomenon of salt loss or "desalination", based on the secondary increase in net urinary sodium loss, possibly due to suppression of aldosterone, increased natriuretic peptide, or increased glomerular filtration, which occurs after over-expansion of the intravascular space.\textsuperscript{42 43 44}

Experimental models show that the acute hyponatraemia is primarily dilutional, while the secondary natriuresis contributes to the maintenance of ongoing hyponatraemia.\textsuperscript{45 17} In a model of 1-desamino-8-d-arginine vasopressin (DDAVP) infusion, two thirds of the acute hyponatraemia was ascribed to water retention, and one third to sodium depletion.\textsuperscript{46} In a similar experiment, rats infused with DDAVP (but not arginine vasopressin) maintained constant sodium balance, and hyponatraemia resulted from water retention alone.\textsuperscript{45}

It is important to note that the secondary "desalination" may be prevented by fluid restriction.\textsuperscript{47} In normal adults given pitressin, there was no increase in natriuresis if fluid intake were restricted to prevent over-expansion of the intravascular space.\textsuperscript{47} It follows that the administration of isotonic saline may be futile unless fluid volume is also reduced, since ongoing natriuresis may negate the effect of this intervention.\textsuperscript{46 47 48}

Studies in surgical patients show that while the fall in sodium is related to the volume of electrolyte-free water administered, the sodium falls even if isotonic fluid is administered to produce a net positive sodium balance, evidence of the primary dilutional nature of the hyponatraemia.\textsuperscript{44 45 47} Therefore, if the fundamental problem is anti-diuresis, rather than natriuresis, surely the principle of treatment should be less fluid, not more salt?

THEORETICAL EFFECTS OF VARIATION IN MAINTENANCE FLUID REGIMEN

It has been suggested that a toxicity balance should be used to predict changes in natraemia, rather than an electrolyte-free water approach.\textsuperscript{18} Changes in sodium are related to the ratio between effective osmols (sodium and potassium) and total body water, and the term "isotonic" refers to a solution in which the sum of both sodium and potassium amounts to 154 mmol/l.\textsuperscript{4} Changes in sodium may then be predicted by calculating a toxicity balance from the net gain or loss of effective osmols and water.\textsuperscript{49 50} Five per cent dextrose is considered necessary for maintenance of normoglycaemia and cerebral metabolism.\textsuperscript{50} However, although the additional dextrose increases the osmolality of PMS, we would not expect it to affect serum sodium, since glucose is not an effective osmol.\textsuperscript{1 51}

From the examples in the box, it is apparent that giving 100 ml/kg/day of hypotonic (0.2% saline equivalent) PMS to a child with non-osmotic ADH production might result in a clinically significant fall in sodium from 140 mmol/l to 130 mmol/l. It can be seen from the large positive fluid balance, and small negative sodium balance, that this fall would be primarily due to a fall in sodium. If tonicity were increased from 0.2% to 0.9% saline equivalent, with volume unchanged at 100 ml/kg/day, hyponatraemia might be prevented at the expense of a large positive fluid balance.

If instead of increasing sodium content, the amount of hypotonic PMS (0.2% saline equivalent) were decreased to 60 ml/kg/day, we might expect a clinically insignificant fall in sodium to 137 mmol/l over a period of 24 hours, but with no increase in total body water. This minor fall in sodium may not even occur if fluid restriction effectively reduces the natriuresis.\textsuperscript{17}

LACK OF EVIDENCE FOR ISOTONIC PARENTERAL MAINTENANCE SOLUTIONS

Changes in sodium may be predicted by theoretical manipulation of toxicity balance, but it should be emphasised that current recommendations for water and
electrolyte needs have not been rigorously tested, and are based on estimated values for energy expenditure and IWL derived from small historical studies.14-24-28 Although individual needs vary, recommendations for administration of PMS should be appropriate for the majority of all hospitalised children, while simultaneously safeguarding against hypotonicity and hypernatraemia in high risk conditions.13-14-15-51

If we consider increasing the tonicity of PMS to prevent hypotonicity, several fundamental questions are yet to be answered.1 Would isotonic PMS be safe?41-51 Crucially, does it work? Is isotonic PMS actually effective in reducing the incidence of hypotonicity? Would reducing the maintenance volume of hypotonic PMS be equally effective?41-2 Given that hyponatraemia can occur despite isotonic fluid administration, and despite a positive sodium balance, isotonic PMS may not be effective in preventing hypotonicity, unless fluid volume is also reduced.44-47

A large multicentre randomised trial is needed to compare the current standard of care (hypotonic PMS) with (a) isotonic PMS, (b) isotonic PMS at reduced volume, and (c) hypotonic PMS at reduced volume, in children at risk of hypotonicity. A recent review considers the ethical aspects of such a trial, in which equipoise must be maintained.52 Clearly, it would be unethical to perform a study in which the balance of evidence suggests that one treatment arm is inferior to the other. It would be equally unethical to perform a study in which lack of scientific rigour jeopardises the validity of the findings.52 The morbidity and mortality associated with hypotonic PMS is not disputed, but also underlines the pitfalls of adopting a standard of care without robust evaluation.13-14-15-41-42-43 For the reasons outlined above, we may not assume that isotonic PMS would be superior to the current regimen, nor that isotonic PMS is without potential disadvantages.41-51 A prospective trial to compare the effect of different maintenance fluid regimens on sodium and IWL while simultaneously safeguarding the maintenance fluid regimens on sodium and IWL would be both feasible, and ethically acceptable, if serial measurement of sodium and effective data safety monitoring could be ensured. Therefore, until it can be shown that isotonic maintenance fluid is both safe, and effective, in preventing hospital acquired hypotonia, calls for widespread change in practice are premature.11-12

SUMMARY
The morbidity and mortality associated with hospital acquired hypotonia should prompt re-evaluation of measured energy expenditure, water loss, and electrolyte needs in hospitalised children. Traditional recommendations for maintenance fluid volume exceed actual requirements and contribute to the development of hypotonia in children at risk of non-osmotic ADH production. Reducing the volume of maintenance fluid may be a more effective prophylactic measure than an increase in sodium content, and a prospective clinical trial should be performed to resolve this issue. Unless the evidence of such a trial were to support the use of isotonic maintenance fluid in children, an injudicious change in clinical practice may not correct the errors of the past 50 years, but compound them.


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NEWS AND NOTES FROM THE UK

When I did resident on-call, every now and then a colleague would discover me in front of children’s TV on a Saturday or Sunday morning, usually consuming a hurried on-call breakfast. The excuse “It was on when I came in’’ wore a bit thin, but fortunately now I have another, much better one should I need it. I’m doing market research. It is the same thing that a previous boss would claim he was doing when he read the local newspaper—a rag of doubtful value and variable accuracy. “This is part of my job” he’d say, and believe. “This is our constituency—a fact we forget at our peril. This is what the people who pay our wages think. Or what they are being told to think.”

Back to the weekend morning, and if you haven’t tried this recently, you should. Watch television as an anthropologist. Count the adverts and examine their strange internal logic. Look at the link between the adverts and the programme content. Find out what our children are being told to think. I’m told that the best way to advertise to children is to pitch the message just beyond their level of understanding. My guess is that this somehow appeals to both their and their parents’ sense of premature ability, or it confuses the child while appealing to the parent, or maybe it just confuses both. I do know that after about 20 minutes of watching I’m at least 10 IQ points the poorer.

The next thing to do is to pick up a teen magazine. As I’ve said, it is market research, so you have a perfect excuse. Look at the seamless segue between content and advertisement. Look at the lifestyle articles telling our teens what they should be buying and where, how they should look and feel, what they should do and when. Actually, it is on this last issue that I find the single redeeming feature of some of these magazines. The problem pages often offer such sensible, down to earth, useful advice that I’m left wondering whether the agony aunts and uncles inhabit a different planet to the rest of the content providers.

How is this excuse for how I spend the occasional 20 minutes on a Saturday morning at all relevant to being a paediatrician? Well, it must be part of our role as child advocates to see that young people at least have a fighting chance of interpreting this deluge of information in a sensible manner. Our response could be to bring up our children in isolation—in a hut in the Scottish Highlands or Australian Outback. We could deny them access to television, magazines, and no unvetted book written since, say, 1950. This is part of our constituency—a fact we forget at our peril. This is what the people who pay our wages think. Or what they are being told to think.”

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Pouring salt on troubled waters

D Taylor and A Durward

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