The following account is intended as a guide to the management of intravenous fluid therapy in paediatric surgery. Essential biochemical and physiological data are quoted and important differences between children and adults emphasized. General guidance is given on how to determine the requisite amount and type of fluid to be administered and a chart included from which maintenance requirements of fluid and electrolytes can be rapidly ascertained. Only simple intravenous solutions are used; mass produced polyionic solutions are not recommended for routine use. Illustrative case reports, practical hints and comments on common avoidable errors supplement the general discussion. A list of references and a short bibliography are included as a guide to further reading.

There is general agreement that disturbances in body fluid and electrolyte balance can be harmful and often fatal. Yet, it is probably true to say that relatively few clinicians have more than a nodding acquaintance with the subject. There are good reasons why this should be so. In the first place the bewildering variety of scientific and pseudo-scientific terms used renders many publications on the subject virtually unintelligible. Additional confusion results from the employment of different terms of reference. For example, the fluid requirements of children may be expressed in one article as so many ml/kg body weight, while another authority may refer to fluid needs in terms of surface area, and yet a third equally authoritative pronouncement may insist on using basic energy expenditure as a term of reference, quoting fluid requirements as so many ml per 100 calories metabolized. Then again, the variable terminology used when referring to acid base regulation, for example, alkali reserve, carbon dioxide combining power, carbon dioxide content and plasma bicarbonate, and the different meaning attached by authors to such commonly used terms as "acid" and "base" only serve to render confusion worse confounded. Is it any wonder that clinicians tend to be perplexed? Yet, it is clearly imperative that they should acquaint themselves with the essentials of this subject since the survival of their patients could well depend on correctly administered intravenous fluids.

I have, therefore, elected to consider in the following account some of the more fundamental and practical aspects of intravenous therapy in children and especially in neonates.

BASIC DATA

Knowledge of the following three sets of data is essential:

- Composition of plasma.
- Distribution of body fluid.
- Twenty-four hour maintenance needs of fluid and electrolytes.

Composition of plasma.

It is necessary to know the concentrations of serum electrolytes (expressed in m.equiv/1.) and of certain other blood constituents, such as urea and proteins. These values are too well known to justify repetition. However, the differences which exist between babies and adults are less well appreciated. In this context three differences are of particular importance:

(a) The plasma carbon dioxide combining power is lower in infants than in adults, namely 22 m.equiv/l. as compared with 27 m.equiv/l.

Though in general use, the carbon dioxide combining power is of limited value since it does not enable the relative importance of respiratory and
metabolic factors to be differentiated. Astrup (1955) has reasoned that three measurements are necessary for a complete assessment to be made of acid base imbalances, namely, pH, Pco₂, and "base excess". Now that these measurements can be determined rapidly and reliably using microlitre techniques (Siggaard Andersen and Engel, 1960a; Siggaard Andersen et al., 1960b), these determinations are certain to be used increasingly in the future.

(b) The concentration of plasma proteins is significantly lower in infants than in older children and adults; average values are 5.5–6 g/100 ml under 6 months, 6–7 g/100 ml between 6 and 12 months, and 7–7.5 g/100 ml in children over 1 year of age. This fact is of importance should the plasma specific gravity be used as a guide in assessing dehydration.

The concentration of plasma protein determines the specific gravity of the plasma, the relationship being expressed by the formula: protein content of plasma (g/100 ml) = 365 x (plasma specific gravity - 1.007). Thus taking an average plasma protein concentration of 6 g/100 ml, the plasma specific gravity in a healthy infant will be only 1.023. In adults the normal value is usually taken to be 1.027; such a figure in an infant would clearly imply considerable dehydration.

(c) The blood urea, which is normally less than 30 mg per cent, can rise rapidly in babies to over 100 mg per cent as a result of dehydration (see Case 2). Great caution must therefore be exercised when interpreting high blood urea readings in this age group as evidence of intrinsic renal disease.

**Distribution of body fluid.**

In table I is shown the distribution of fluid within the body at different ages. Whilst the intracellular fluid represents a constant proportion of the body weight, about 45 per cent, the extracellular fluid (plasma and interstitial fluid) decreases relative to body weight from 30 per cent in the neonate to 20 per cent by 12 months of age, so that the total body fluid from representing about 75 per cent of the body weight in the neonate falls to about 65 per cent by 12 months. Hence, in a 4 kg neonate three-quarters of the weight will represent the weight of body fluid, that is 3 kg, which in terms of volume can be regarded as equivalent to 3 l. Similarly, in an older child the total body fluid approximates to two-thirds of the body weight and so will equal about 12 l in an 18 kg child.

**Maintenance needs of fluid and electrolytes.**

The third set of essential data is that relating to maintenance needs of fluids and electrolytes. As previously stated, these requirements are variously derived from one of three basic units of measurement: surface area, metabolic expenditure, and weight. The advantage of basing calculations on surface area and metabolic expenditure is that fluid needs can be expressed by a single formula applicable to all patients irrespective of age, that is, 1,500 ml per square metre of body surface area or 150 ml per 100 calories metabolized. On the other hand, this advantage is more than outweighed by having to calculate these parameters from weight and height measurements using formulae, of which there are at least 37 to choose from, and nomograms. Moreover, claims that these methods are scientifically more accurate than using weight alone have recently been refuted by Oliver, Graham and Wilson (1958). These authors concluded that surface area possesses no particular merit over weight as a unit of physiological function. Thus, the third method in common use and the one which I prefer, namely that of using the patient's weight as a basis for calculations, while being as accurate as the previous procedures possesses the additional practical advantage that only one measurement is required; a measurement, moreover, which it is possible to record reasonably simply and accurately. The drawback with this system is that fluid requirements when expressed per unit of weight vary with the patient's age, thus 140 ml at 3 months, 100 ml at 12 months and 75 ml at Table I

<table>
<thead>
<tr>
<th>Birth to 1 month</th>
<th>1 month to 1 year</th>
<th>1 to 12 years</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intracellular fluid (% body weight)</td>
<td>45</td>
<td>45</td>
</tr>
<tr>
<td>Extracellular fluid (% body weight)</td>
<td>30</td>
<td>25</td>
</tr>
<tr>
<td>Total</td>
<td>75</td>
<td>70</td>
</tr>
</tbody>
</table>
5 years. This inconvenience can be readily overcome by using a chart. For such a chart to be of real practical value, however, it is necessary that it be of simple construction and include only essential data. A previously published chart (Carré, 1958) which has proved eminently satisfactory over the years is illustrated in figure 1. It must be re-emphasized that though formulae and charts afford a valuable guide to the fluid requirements of patients they merely augment and do not replace careful frequent clinical appraisal.

PRACTICAL CONSIDERATIONS

Next, it is necessary to consider the question of putting this information to practical use. It is impossible to lay down hard and fast rules regarding management—it is only possible to define certain guiding principles. Though absolute mathematical precision is neither possible nor, fortunately for the patient, necessary, nonetheless, much greater accuracy is necessary when treating infants than when treating older children or adults. This is fundamentally a matter of size. For example, in a newborn infant of 3.5 kg a blood loss of 60 ml would represent one fifth of its blood volume; a comparable fall in blood volume in an adult would approximate to a loss of 1 litre of blood.

When planning parenteral therapy it is usual to consider this under the headings: repair of

![Figure 1](https://academic.oup.com/bja/article-abstract/35/8/488/324810)

The chart enables a rapid assessment to be made of both 24-hour maintenance requirements of Na+, K+ and fluid (---) and of 24-hour extra renal fluid losses under conditions of bed rest in hospital (-----) in children over 10 days of age. The 24-hour urine output of a child receiving adequate fluids is approximately represented by the difference between these two curves.

For infants of under 10 days maintenance requirements, as derived from the chart, should be multiplied by the fraction age in days

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The chart may also be used to determine the average weight of children at various ages (Carré, 1958).
existing deficits, provision of maintenance requirements, and replacement of contemporary losses, for example, gastric aspirates, vomits.

**Repair of Existing Deficits.**

The primary aim of therapy during this phase is to correct harmful or potentially harmful fluid and electrolyte imbalances. This, in effect, means treating relatively severe disturbances only. I stress this point because I believe that many well-intentioned attempts at correcting mild to moderate disturbances constitute unnecessary interference and often result in more harm than good. This applies particularly to disorders in which, following a corrective operation, the body is enabled to effect whatever adjustments are required expeditiously and safely. Such is the case with hypertrophic pyloric stenosis, of which fewer than 5 per cent require parenteral fluids.

Having decided that intravenous therapy is necessary, the disorders to be corrected in order of priority are: the restoration of blood volume, the replacement of electrolyte deficits, and the correction of acid-base imbalances.

**Restoration of Blood Volume.**

The blood volume must be promptly restored by replacing blood losses and correcting dehydration and electrolyte deficits. This will secondarily provide for the rapid re-establishment of renal function—a factor of major importance since normal kidney function is the most valuable ally of the therapist attempting correction of body fluid imbalances.

It is convenient to consider separately the indications for blood and plasma, and electrolyte solutions.

**Blood and Plasma.** Blood is required as replacement therapy whenever there has been appreciable blood loss. The quantity to be administered is calculated on the basis of estimated losses and knowledge of the patient's normal blood volume (the blood volume of a newborn infant corresponds to approximately 85 ml/kg body weight, at one month to 75 ml/kg and after this age to 70-75 ml/kg).

Whole blood and plasma are indicated in the immediate resuscitative treatment of children with burns. In these patients the following is a rough guide to initial requirements: 2-3 ml/kg body weight for each 1 per cent of body surface burned. The total volume to be transfused can be divided equally between blood or plasma, and an isotonic electrolyte solution; alternatively, it may be given solely as blood or plasma (Batchelor, Kirk and Sutherland, 1961). Thirty to 60 per cent of the total volume is given within the first 8 hours; the remainder is infused over a period of 16-40 hours (the greater the extent of the burn the smaller the initial percentage and the longer the duration of infusion).

**Fluid and Electrolytes.** Estimating replacement requirements of fluid and electrolytes can be difficult. There is no simple biochemical estimation which will provide the answer to this. The degree of dehydration and electrolyte loss can only be determined from an evaluation of all known facts.

(i) The nature and duration of the complaint—whether losses of fluid have been mainly as vomit or diarrhoea, approximate quantity of loss, etc.

(ii) Clinical assessment is one of the best ways of assessing dehydration in babies. It is usual to divide dehydration into three clinical degrees of severity.

**Clinical features.**

**Mild.** Irritability. Thirst. Dry tongue and mouth. Slightly sunken bright eyes. Flushed face and warm skin.


A guide to the volume of fluid needed to correct these degrees of dehydration is provided in table II. For example, a moderately dehydrated 4-month-old infant weighing 5½ kg (12 lb. 2 oz.) would need approximately 415 ml fluid (75 x 5½) to correct dehydration.

Though the above classification has great practical value it must be remembered that many of the clinical features listed relate to a deficiency of sodium rather than of fluid. This is particularly so of apathy, muscle hypotonia, loss of skin elasticity and peripheral circulatory disturbances.
TABLE II
Guide to correction of dehydration in children.

<table>
<thead>
<tr>
<th>Clinical assessment of dehydration</th>
<th>Severe</th>
<th>Moderate</th>
<th>Mild</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fluid deficit* expressed as percentage of extracellular fluid volume (all ages)</td>
<td>30</td>
<td>22.5</td>
<td>15</td>
</tr>
<tr>
<td>Fluid loss expressed as percentage of total body water</td>
<td>&lt;6 months</td>
<td>6-12 months</td>
<td></td>
</tr>
<tr>
<td>Infants</td>
<td>12</td>
<td>9</td>
<td>6</td>
</tr>
<tr>
<td>Children</td>
<td>10</td>
<td>8</td>
<td>5.5</td>
</tr>
<tr>
<td>Reduction in weight (%) resulting from fluid loss</td>
<td>&lt;6 months</td>
<td>6-12 months</td>
<td></td>
</tr>
<tr>
<td>Infants</td>
<td>9</td>
<td>7</td>
<td>5</td>
</tr>
<tr>
<td>Children</td>
<td>6</td>
<td>4.5</td>
<td>3</td>
</tr>
<tr>
<td>Volume of fluid per kg of actual body weight needed to correct patient's dehydration (ml)</td>
<td>&lt;6 months</td>
<td>6-12 months</td>
<td></td>
</tr>
<tr>
<td>Infants</td>
<td>100†</td>
<td>75</td>
<td>50</td>
</tr>
<tr>
<td>Children</td>
<td>80</td>
<td>60</td>
<td>40</td>
</tr>
</tbody>
</table>

* The reduction in body fluid is variously distributed between the extra- and intracellular fluids. By comparison with intracellular fluid the extracellular fluid suffers a relatively greater reduction in volume when sodium loss predominates and vice versa when the loss of water is proportionately greater than that of electrolytes.

† In the case of small severely dehydrated infants much larger quantities than those quoted may be required to correct dehydration, e.g. 120-150 ml/kg.

Thus, an infant who has lost large quantities of fluid but little sodium (hypernatraemic dehydration) will appear deceptively well hydrated with relatively little peripheral circulatory disturbance and little loss of skin elasticity (the skin in these babies often has a doughy consistency on palpation).

An additional error to avoid is that of mistaking the underweight of malnutrition as evidence of dehydration since this can lead to an excessive quantity of electrolyte solution being given with resultant dangerous overhydration.

(iii) Recent weight records provide the most accurate means of calculating hydration fluid requirements (table II). Unfortunately, they are rarely available at this stage of a patient's illness.

(iv) Biochemical data. Plasma specific gravity and haematocrit readings are sometimes used to assist in determining the extent of a patient's dehydration. These values can be dangerously misleading and are not recommended for routine use.

It has already been pointed out that plasma specific gravity values are lower in babies than in adults. The importance of recognizing this fact is illustrated by Case 2. Haematocrit determinations are especially unreliable in small children. This is principally due to wide physiological variations during infancy (65 per cent at birth, 35 per cent at 3-6 months) and the common occurrence of anaemia in early childhood.

Replacement of electrolyte deficits.

Electrolyte requirements cannot be determined solely on the basis of serum concentrations since these give no guide to total needs; this applies particularly to potassium, which is mainly intracellular. Other factors, principally the degree of co-existing dehydration or water overloading, must also be considered.

The two electrolytes of major concern are sodium and potassium. Sodium is important because it accounts for most of the osmotic pressure of the extracellular fluid. When sodium is added to the extracellular fluid the osmotic pressure rises relative to that of the intracellular fluid and as a consequence a shift of water occurs from the intracellular to the extracellular fluid. Thus, although sodium is virtually confined to the extracellular compartment its osmotic effect is distributed throughout the body fluid and for this reason sodium deficits should be calculated on the basis of total body fluid and not on that of extracellular fluid volume. It is also worth noting that the daily maintenance needs of sodium, in terms of body weight, are for an infant about double those for an older child.
I emphasize these two points because of latter years there has developed a belief that since the infant's kidney cannot handle electrolytes as efficiently as the adult kidney, sodium must be given sparingly and to be on the safe side should not be administered in concentrations greater than one-fifth isotonic saline. This is a false doctrine and blind acceptance of this concept can lead to disastrous consequences. For not uncommonly, a considerable deficit of sodium may exist and a too timid approach in replacement therapy can rapidly lead to a hazardous state of water intoxication. This is particularly true of infants with hypertrophic pyloric stenosis in whom the vomiting of quantities of gastric mucus can result in large losses of Na⁺ as illustrated by the following patient:

**Case 1.** A 7-week-old male infant with hypertrophic pyloric stenosis was admitted to hospital with a 4-week history of vomiting. The baby weighed 3,740 g (8 lb. 4 oz.) (expected weight 5,190 g (10 lb. 11 oz.).) and was clinically severely dehydrated. Serum Na⁺ = 130 m.equiv/l; carbon dioxide combining power = 43.7 m.equiv/l.

The following intravenous fluids were given during the next 18 hours: 170 ml 1/2 N saline, 400 ml. 1/5 N saline.

Superficially this might appear rational and safe therapy. But is it? This therapy will provide only 25 m.equiv of Na⁺, i.e. less than one-third of the estimated sodium deficit.

Sixteen hours after starting intravenous therapy the resident medical officer wrote in the case notes "Hydration much improved . . .". Two hours later a second cryptic note stated "Baby convulsing and vomiting coffee ground material". Serum Na⁺ at this time was 108 m.equiv/l. and carbon dioxide combining power 36 m.equiv/l.

During the next 36 hours the baby was given 95 m.equiv Na⁺ (i.e. 615 ml. isotonic NaCl). This resulted in a rapid improvement and a rise in serum to Na⁺ 136 m.equiv/l. A Rammstedt operation was then performed and the baby's subsequent progress proved uneventful.

Though the serum level of K⁺ gives no indication of the total body deficit or excess of this ion, it is one substance where the actual concentration in the serum is of considerable clinical importance because of its potentially serious ill effects on the heart. Precautions to be observed in the giving of potassium intravenously are well known; these are, to give by slow intravenous drip only, to ensure that the patient is passing urine and, except under exceptional circumstances, not to give in a concentration exceeding 30 m.equiv/l.

**Correction of acid-base imbalances.**

Of the three disturbances this is the least important clinically. It is commonly believed that the body is highly sensitive to changes in acid-base balance. However, by comparison with alterations in some other plasma constituents the body is, in fact, relatively tolerant to changes in the reaction of the serum. This fact tends to be obscured by the use of the pH notation. The range in serum pH compatible with life is usually stated to be between 7 and 7.8. In terms of H⁺ ions this represents a range of 2³ times to two-fifths of the normal H⁺ ion concentration (Robinson, 1961). A similar degree of change in the concentration of, say, K⁺ would imply a range of 2·125 m.equiv/l. and of Na⁺ of 55·350 m.equiv/l.—figures incompatible with life.

Should it be considered necessary to correct a patient's acidosis, at least in part, the following provides a guide to sodium lactate requirements: 4 ml of M/6 sodium lactate per kg body weight will raise the carbon dioxide combining power by 1 m.equiv/l.

Potassium depletion tends to induce a metabolic alkalosis and conversely an alkalosis predisposes to hypokalaemia. Thus, the possibility of potassium deficiency must always be considered whenever an alkalosis proves resistant to theoretically adequate corrective measures. In these instances the reaction of the urine is usually acid and not alkaline.

**Case 2.** L.S., a 26-day-old girl with pyloric stenosis, birth weight 4,055 g (8 lb. 15 oz.), was admitted to hospital with a history of persistent vomiting since the tenth day. During the two weeks preceding her admission she had been fed virtually on glucose water. She was desperately ill, malnourished and grossly dehydrated with peripheral circulatory failure and convulsions. An immediate intravenous infusion of isotonic saline was set up and hydrocortisone 25 mg given intravenously. Biochemical examination of a blood specimen taken after 120 ml isotonic saline had been given yielded the following results: Na⁺ 120 m.equiv/l., K⁺ 2·4 m.equiv/l., Cl⁻ 53 m.equiv/l., carbon dioxide combining power 59 m.equiv/l., plasma specific gravity 1·026 and blood urea 300 mg per cent.

Within the first 60 hours in hospital she was given 1880 ml fluid, 120 m.equiv Na⁺, 35 m.equiv K⁺ and 155 m.equiv Cl⁻. Following this period of rehydration her weight was 3,320 g (7 lb. 5 oz.) and the serum electrolytes Na⁺ 130 m.equiv/l., K⁺ 3·6 m.equiv/l., Cl⁻ 85 m.equiv/l., carbon dioxide combining power 41 m.equiv/l., urea 106 mg per cent. A Rammstedt operation was performed and a routine postoperative oral feeding schedule instituted. However, vomiting continued, and 3 days after operation the serum elec-
trolyte concentrations were practically unchanged though there had been a further fall in blood urea (Na⁺ 143 m.equiv/l, K⁺ 3.4 m.equiv/l, Cl⁻ 87 m.equiv/l, carbon dioxide combining power 42 m.equiv/l and urea 60 mg per cent.). The persistence of an alkalosis was attributed to an insufficient replacement of potassium, a view supported by the observation that a freshly passed specimen of urine was acid in reaction (pH 6.5). Milk feeds with added 7.5 per cent potassium chloride were retained when given by continuous gastric drip. Forty-eight hours later, after a further 80 m.equiv K⁺ had been given, the relevant serum electrolytes were K⁺ 4.9 m.equiv/l, carbon dioxide combining power 29 m.equiv/l and Cl⁻ 100 m.equiv/l. Subsequent progress was uneventful and 12 days after operation the blood urea was 32 mg per cent. When seen at 18 months the child appeared perfectly healthy and there was no evidence of either neurological or renal disturbance.

Comment. This case history is instructive for a number of reasons.

The serum specific gravity of 1.026 in the presence of gross clinical dehydration demonstrates the folly of interpreting serum specific gravity results in babies in terms of adult values. The blood urea of 300 mg per cent recorded during the early stages of treatment illustrates the height to which blood urea values may rise in babies secondary to dehydration. That more than 110 m.equiv K⁺ were required to correct this patient's hypokalaemia emphasizes the large potassium deficits which can arise in vomiting babies. The importance of hypokalaemia as a potentiating factor in alkalosis and the therapeutic value of a gastric drip in overcoming troublesome vomiting and ensuring an adequate potassium intake is clearly demonstrated. Finally, this small infant's complete recovery vividly illustrates the well-nigh miraculous results which can follow intravenous therapy.

Provision of Maintenance Requirements.

Daily maintenance needs of fluid and electrolytes can be quickly ascertained from the chart (fig. 1). It is important, however, that these estimates be modified according to circumstances.

Age. Fluid requirements during the early days of life are less than the recommended 155 ml/kg/24 hours for older babies. Due allowance must therefore be made for this fact.

It is particularly important in the case of neonates that precautions be taken to avoid excessive insensible losses both during operation and at other times, for example, small premature newborn babies should be nursed naked in incubators at a temperature of 90-95°F and a humidity of 90-100 per cent.

The nature of the complaint. It is clear that special care will be needed in patients with either renal or cardiac disorders.

Fluid and electrolyte disturbances may occur secondarily to cerebral disease. In these cases, interference with the output of antidiuretic hormone may cause either water retention or conversely diabetes insipidus. Cerebral dysfunction may also occasionally result in a salt-losing syndrome due to an uncontrolled loss of urinary sodium.

The effect of surgery and anaesthesia. It will be recalled that following surgical procedures and anaesthesia there occurs a reduction in urine output and retention of sodium. It is thus essential to curtail the intake of fluids and sodium during the immediate postoperative period.

Great care must be exercised when interpreting the significance of carbon dioxide combining power values recorded during or immediately following operation. A raised carbon dioxide combining power might reflect a respiratory acidosis resulting from either inadequate pulmonary ventilation or inadequate carbon dioxide removal during closed circuit anaesthesia. Conversely, a low carbon dioxide combining power might indicate a respiratory alkalosis caused by, for example, excessive pulmonary ventilation during anaesthesia.

Drugs. Corticosteroids are the most important of these because of their profound effect on sodium and potassium metabolism.

Replacement of Contemporary Losses.

This is most accurately done by having all aspirates and other losses measured and their electrolyte content determined. When such information is not available calculation of the replacement quantities will have to be based on intelligent guesswork. However, the risk of serious error can be greatly minimized by having dressings and napkins weighed and by referring to a table listing the average composition of gastro-intestinal secretions (table III).

| TABLE III Composition of gastro-intestinal fluids (m.equiv/l) |
|-----------------|-----------------|-----------------|-----------------|
|                  | Na⁺             | K⁺             | Cl⁻             | HCO₃⁻             |
| Saliva           | 15-20           | 20-30           | 20              | 20                |
| Gastric          | 20-80           | 5-20            | 100-150         | —                 |
| Small bowel      | 100-140         | 5-15            | 90-130          | 20-40             |
The patient's fluid and electrolyte balance must be critically re-evaluated at frequent intervals (every 6-12 hours); children on intravenous fluids should never be left for as long as 24 hours without careful reassessment (see Case 4). The calculated requirements for each interval of time are derived from the following:

**Intake and output records.** These must be sufficiently detailed to enable the electrolyte as well as fluid intake by all routes to be determined. Output records should list separately all losses from the renal and alimentary tracts, the time at which these occurred and relevant qualitative information, for example, dark concentrated or pale dilute urine.

**Daily weight records** should be kept whenever practicable as they provide the most accurate means of measuring fluctuations in hydration. Periodic serum electrolyte estimations are essentials.

**Clinical assessment.** The above data, while of undeniable worth, are no substitute for sound clinical judgment and can be misleading unless correctly interpreted. The following case report is instructive.

**CASE 3.** A 14-year-old girl with portal hypertension had a mesenterico-caval anastomosis performed. During the following 2 weeks she became increasingly ill and lethargic with anorexia, vomiting and oliguria. Calculation of her fluid balance for this period revealed an average daily intake of only 870 ml. The patient's fluid intake was increased to an average of 2100 ml per day by supplementing her oral intake with intravenous fluids. As a result, her urinary output increased rapidly to an average of 1100 ml per day; this was associated with a dramatic clinical improvement and subsequent uneventful recovery.

**Comment.** The reasons underlying the development of dehydration in this child are informative. After operation the patient's fluid intake was restricted in view of the postoperative risk of fluid retention and overhydration. Fluid restriction, however, was unduly prolonged; for example, on the ninth postoperative day her fluid intake was still only 960 ml; as a result the urine output remained low. At this time a second error of judgment occurred for the reduced urine output was misinterpreted as evidence of primary renal damage. Accordingly, the patient's daily fluid intake was adjusted to an amount equal to the calculated daily extra renal losses plus a quantity equal to the previous 24-hour urine output. Unfortunately, data relating to insensible fluid loss under experimental basal conditions were used to calculate the patient's extra renal losses, for example, 0.3 ml/kg/hour (= 380 ml/day). In fact, these amounts are only about half the observed extra renal losses of patients under conditions of bed rest in hospital (Heeley and Talbot, 1955; Carré and Squire, 1956). Thus, three errors of judgment were primarily responsible for this patient's enforced fluid restriction and subsequent dehydration: an overzealous and prolonged post-operative fluid restriction; misinterpretation of the patient's low urine output as evidence of intrinsic renal damage; and the use of the wrong data to calculate the patient's extra renal fluid losses.

The length of time a patient is maintained on intravenous fluid should be kept to a minimum. Feeding with protein foods should be reintroduced as soon as practicable, if necessary by gastric tube.

**ADMINISTRATION**

I dislike using mass-produced ready-mixed polyionic electrolyte solutions. These are now so numerous that they tend to lead to confusion and in any case they rarely provide electrolytes in the correct amount and proportion required by any one patient. In my opinion, an additional very serious disadvantage is that their use discourages logical constructive thought in the planning of intravenous therapy.

Other than whole blood, the "standard" solutions listed in table IV are all that are required for paediatric intravenous use.

Having calculated the quantity of fluid and electrolytes to be given in any specified period of time, then by reference to this table it is a simple matter to mix an "electrolyte cocktail" which will provide precisely the calculated requirements of both fluid and electrolytes.

For example, suppose that requirements during a 12-hour period have been assessed as:

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
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<th></th>
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</thead>
<tbody>
<tr>
<td>450 ml</td>
<td>fluid</td>
<td></td>
</tr>
<tr>
<td>15 m.equiv Na⁺</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5 m.equiv K⁺</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

these will be provided by mixing together in a flask:

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>100 ml</td>
<td>isotonic saline (15 m.equiv Na⁺)</td>
<td></td>
</tr>
<tr>
<td>5 ml</td>
<td>7.45 per cent KCl (5 m.equiv K⁺)</td>
<td></td>
</tr>
<tr>
<td>345 ml</td>
<td>5 per cent glucose</td>
<td></td>
</tr>
<tr>
<td>450 ml</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The desired rate of infusion, expressed in drops/min can be rapidly deduced since this equals about one-quarter of the rate expressed in ml/hour. Thus, in the above example, to deliver...
required. Additionally, it is often mistakenly believed that the subcutaneous route of administration is “safer” and for this reason also is preferable. That this is untrue is illustrated by the following case history.

CASE 4. E.G., a baby of birth weight 2,040 g (4 lb. 8 oz.) started vomiting on the fourth day due to gastro-oesophageal incompetence. By the sixteenth day he had become severely dehydrated (weight 1,700 g, 3 lb. 12 oz.); serum electrolytes were Na+ 100 m.equiv/1., K+ 3.4 m.equiv/l. and Cl- 66 m.equiv/l. While awaiting these electrolyte results a subcutaneous infusion of isotonic saline was commenced. This was discontinued after 180 ml had been given because of gross subcutaneous oedema at the site of infusion and an alarming deterioration in the baby’s clinical state. An intravenous drip of isotonic saline was substituted after first giving 50 ml of 2.7% glucose solution. After 48 hours on parenteral fluids, during which a total of 970 ml fluid and electrolytes had been given, the baby appeared greatly improved and the subcutaneous collection of fluid had resolved; serum electrolytes were Na+ 127 m.equiv/l., K+ 2.6 m.equiv/l. and Cl- 99 m.equiv/l. Within the next 48 hours, 1,150 ml fluid, 50 m.equiv Na+ and 22 m.equiv K+ were given intravenously. This volume of fluid represented about 500 ml more than the calculated requirements and not surprisingly was associated with clinical deterioration and signs of overhydration (serum electrolytes Na+ 122 m.equiv/l., K+ 4.5 m.equiv/l. and Cl- 94 m.equiv/l.). After a period on restricted oral fluids the baby improved and an estimation of the serum electrolytes 2 days later revealed a normal pattern. Vomiting ceased with postural treatment and the baby’s subsequent progress proved uneventful.

Comment. Two fundamental therapeutic errors were made in this case. The initial use of subcutaneous isotonic saline was clearly a wrong decision since the immediate effect was quite the reverse of that intended. For the subcutaneous administration of a fluid (Na+ 155 m.equiv/l.) which was hypertonic relative to the baby’s extracellular fluid (Na+ 100 m.equiv/l.) promptly caused a fluid shift from the patient’s extracellular compartment into the depot of subcutaneous saline, thereby causing a further reduction in the volume of extracellular fluid.

The second fundamental error was the intravenous administration within a period of 48 hours of 500 ml more fluid than the calculated requirements. This near fatal mistake could easily have been avoided had the patient’s fluid balance been critically re-evaluated every 6 or 12 hours.

One additional aspect of this patient’s therapy is of interest. Not until about 200 m.equiv Na+ had been given was the baby’s electrolyte imbalance corrected. This is another example of the enormous sodium deficits which can occur in babies as a result of persistent vomiting.

**SOME AVOIDABLE ERRORS**

The subcutaneous administration of fluid is occasionally preferred to intravenous therapy, especially in babies, since less technical skill is required. Additionally, it is often mistakenly believed that the subcutaneous route of administration is “safer” and for this reason also is preferable. That this is untrue is illustrated by the following case history.

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**TABLE IV**

<table>
<thead>
<tr>
<th>Solution</th>
<th>Electrolyte composition (m.equiv/l.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Isotonic saline (0.9% NaCl)</td>
<td>155 - 155 -</td>
</tr>
<tr>
<td>M/6 Sodium lactate (1.85% solution)</td>
<td>165 - 165 -</td>
</tr>
<tr>
<td>5% Glucose solution</td>
<td>- - 165</td>
</tr>
<tr>
<td>Reconstituted plasma</td>
<td>150 5 105</td>
</tr>
<tr>
<td>7.45% KCl: 1 ml provides 1 m.equiv K+</td>
<td></td>
</tr>
<tr>
<td>5.8% NaCl: 1 ml provides 1 m.equiv Na+</td>
<td></td>
</tr>
</tbody>
</table>

It is still common practice for infants to be sent to the operating theatre with an intravenous drip attached to a full 500-ml or 1000-ml flask. This is potentially extremely dangerous since it is a simple matter for more fluid to be run in than is either desirable or safe. I would recommend that no child be permitted to go to theatre with an intravenous drip connected to a flask containing more than the next 6 hours’ estimated needs of fluid and electrolytes.

The management of intravenous therapy in surgical patients is often shared between the surgeon, an anaesthetist and a physician, their respective registrars and house staff. This divided responsibility is inherently bad. Ideally, responsibility for such therapy should be vested in one person—someone experienced not only in parenteral fluid therapy but also in the care of small babies.

In conclusion, it is important to recall that whilst correctly administered intravenous fluids can do inestimable good, unwarranted intravenous therapy can prove equally injurious. The need to give fluids intravenously must be carefully evaluated in each instance and the temptation to “put up a drip” simply because the patient is suffering from a particular disorder or has some relatively mild biochemical imbalance must be resisted.

**ACKNOWLEDGMENTS**

I wish to thank the editor of The Practitioner for permission to reproduce the chart illustrated in figure 1.
A great deal of the information presented has been obtained from publications not specifically acknowledged in the text. These are listed as a short bibliography and guide to further reading.

REFERENCES

BIBLIOGRAPHY

LIQUIDES ADMINISTRES PAR VOIE PARENTERALE EN CHIRURGIE INFANTILE

SOMMAIRE
Ce compte-rendu voudrait servir de guide des modes d'administration intra-veineuse des liquides utilisés en chirurgie infantile. L'auteur rappelle les données principales biochimiques et physiologiques et il fait ressortir les différences importantes existant à ce sujet entre enfants et adultes. Il indique le mode de calcul des doses des liquides requis et le type de liquide que l'on devrait administrer; à ce sujet il publie un tableau permettant de calculer rapidement les quantités de liquide et d'électrolytes nécessaires.
Il n'utilise que de solutions intraveineuses simples et il s'abstient des solutions poly-ioniques mis actuellement sur le marché. Il ne recommande pas ces dernières pour emploi dans la routine normale. L'étude est complétée par le compte-rendu de cas typiques, par des renseignements pratiques et par des commentaires concernant des erreurs commises couramment mais évitables. Une liste de références et une brève bibliographie guident le lecteur.

PARENTERALE FLÜSSIGKEITSZUFUHR IN DER PÄDIATRISCHEN CHIRURGIE

ZUSAMMENFASSUNG