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RECENT ADVANCES IN SURGERY



Irving Taylor

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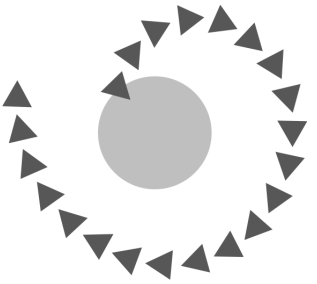

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4 Chapter An Update on Intravenous Fluids in Surgical Practice

Mike Stroud

INTRODUCTION

Decisions on intravenous (IV) fluid and electrolyte provision for surgical patients are often difficult yet usually delegated to junior doctors who lack relevant experience and specific training. In their recent 2013 guidance, NICE (National Institute for Health and Care Excellence) reported surveys that show the majority of IV fluid prescribers know neither the normal fluid and electrolyte needs of patients nor the specific composition of available fluids.[1] It is not therefore surprising that inappropriate IV fluids were identified as a significant contributor to morbidity and mortality in a UK National Confidential Enquiry into Perioperative Deaths[2] and although that report recommended making IV fluid prescribing equal in status to drug prescribing, this did not happen. Even if rarely reported, both inadequate and excessive IV fluids and/or electrolyte provision almost certainly continue to generate complications, prolonged hospital stay and increased cost.[1-7]

Poor IV fluid practice in surgery probably occurs more frequently in emergency departments, acute admission units and general wards than in operating theatres and intensive care. The 2013 NICE recommendations therefore concentrate on fluid prescribing for general settings, and this chapter has a similar focus. NICE also recognised that best fluid prescriptions were extremely variable and not really amenable to proscriptive rules. Their most important recommendations therefore revolve around the need for all IV fluid prescribers to understand the principles of fluid balance in health and disease and for all hospitals to organize appropriate training and to monitor adverse, IV fluid-related events.

PROBLEMS OF PRESCRIBING IV FLUIDS IN SURGERY

The aims of IV fluid therapy are to ensure that total fluid and electrolyte requirements are met and existing abnormalities are corrected if possible in patients where this cannot be achieved by oral or enteral routes. There are many reasons why providing optimal IV fluids is difficult in surgical cases, especially in ward type settings with less intensive monitoring. Reasonably detailed description of these problems can be found in the full

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NICE guidance,[1] and they are also covered in the NICE IV fluid training tool found at http://elearning.nice.org.uk/login/index.php. However, they are summarized below.

1. *Lack of evidence*:

   The evidence to determine best practice in general surgical settings is limited because:

   a. Many accepted IV fluid practices are based on historical, practical, production issues rather than randomised controlled trials (RCTs).
   b. IV fluid studies cannot easily be pooled for meta-analysis as they examine variable outcomes in heterogeneous groups using not only different types of fluid with differing electrolyte content but different volumes and rates of administration, sometimes with additional inotrope use.
   c. Most published RCTs were undertaken in intensive care or intraoperative settings, which particularly limit interpretation of best fluids for resuscitation as comparisons of different fluid types are made either after actual initial resuscitation has taken place (randomization occurs once patients have reached critical care) or are made in patients with anaesthesia-induced hypovolaemia—a situation, which does not closely mirror other causes of circulatory collapse.

2. *Problems with salt and water overload*:

   There are many reasons why surgical patients are prone to salt and water overload, particularly in the early postoperative phase:

   a. Humans have powerful sodium retention mechanisms regulated largely by renin–angiotensin (the kidney can reduce urinary Na+ concentration to < 5 mmol/L), but our capacity to excrete excess sodium is poor, probably because we evolved in the hot, low-sodium environment of Africa where excess natural intake would never occur. Illness or injury, particularly major surgery, further enhances sodium retention due to increases in antidiuretic hormone and cortisol as well as renin-triggered aldosterone, and simultaneously, the capacity to excrete excess sodium is markedly impaired.
   b. Perioperative responses increase the transcapillary albumin loss by up to 300% from about 5%/hour in health to 13–15%/hour[8] and subsequent falls in plasma albumin then reduce intravascular volume (with further stimulation of renin), whilst increased interstitial albumin promotes oedema.
   c. Many surgical patients start their postoperative course in very positive sodium and water balance because of high intraoperative IV fluid provision needed to compensate for anaesthetic-induced vasodilatation.
   d. Even healthy kidneys can only excrete a limited solute load—a capacity easily overwhelmed by catabolic release of solutes that is added to any iatrogenic solute excess.[9]

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e. 0.9% saline, containing 154-mmol/L sodium, is widely used despite the fact that normal maintenance needs are only 1 mmol/kg/day, which would be met in most cases by only 0.5 L of the fluid.
f. The intense sodium and water retentive responses described above imply that some postoperative oliguria is normal[10] and hence the common practice of meeting any degree of oliguria with a "give more fluids" reflex often worsens salt and water overload. Additional IV fluids should only be given if there are signs of intravascular volume deficit.
g. Since water as well as sodium is retained postoperatively, surgical patients easily develop dilutional hyponatraemia when given excess glucose or glucose/saline. This then encourages provision of 0.9% saline despite the fact that many hyponatraemic patients are oedematous with high total body sodium. Postoperative hyponatraemia is therefore best prevented or managed by decreasing total fluid provision rather than giving more sodium although this does not apply in some surgical cases where there are high, abnormal sodium losses (*see* below).
h. Potassium depletion is a poorly recognised cause of additional sodium retention. In the presence of deficiency, H+ ion reabsorption is impaired causing hypokalaemic alkalosis and decreased capacity to excrete sodium. Depletion of potassium is common in postoperative situations because the activation of aldosterone precipitates high urinary loss and the catabolic release of negatively charged intracellular amino acids causes simultaneous leakage of positively charged intracellular potassium ions. When catabolism is extreme, the latter process can lead to hyperkalaemia, especially if renal function is impaired, but in many postoperative patients, especially those with additional gastrointestinal (GI) tract potassium loss, hypokalaemia or at least whole body potassium depletion does occur and needs correction to help treat sodium and water excess.
i. Malnutrition is common in surgical patients and is often accompanied by reductions in cell membrane pumping with consequent movement of sodium and water into cells and simultaneous movement of potassium, magnesium, calcium and phosphate out which are then lost in the urine. Malnourished individuals therefore tend to have high total body sodium and water with low total body potassium, phosphate and magnesium (even if plasma levels are normal). This makes them even more prone to salt and water overload.
j. Malnourished patients are also vulnerable to refeeding syndrome with the delivery of IV glucose or food promoting insulin release, which not only stimulates cellular glucose uptake but reactivates the cell membrane pumps. This then leads plasma potassium, phosphate and

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magnesium moving back into cells with simultaneous movement of sodium and water back out into the circulation, effectively adding to any IV salt and water provision.[11] Furthermore, malnourished patients often have diminished cardiac and renal reserve and/or hidden infection with high capillary escape rates. Advice on the prevention and management of refeeding syndrome can be found in NICE guidance on Nutrition Support REF.

k. Although it is well recognized that hyperchloraemia can cause hyperchloraemic acidosis, the fact that high plasma chloride promotes ileus[12] and markedly reduces renal perfusion and glomerular filtration is less well known.[13] Administration of IV fluids with high chloride content must clearly predispose individuals to this although conversely, inadequate IV provision of chloride in patients with high GI salt losses can cause hypochloraemic alkalosis. Since 0.9% sodium chloride contains 154 mmol/L of chloride and normal plasma levels are only 95–105 mmol/L, prolonged saline use may also promote oedematous states and temporary intestinal failure via hyperchloraemia as well as other mechanisms.

3. *Problems in making accurate allowance for abnormal fluid and electrolyte losses*:

Many surgical patients have significant external losses of fluid and electrolytes, often from the GI or urinary tracts although high losses also occur with fever and burns. The presence of existing deficits from these losses and/or ongoing abnormal loss creates many problems for IV fluid prescribing:

a. The losses are usually difficult to measure in terms of both volume and electrolyte content.
b. High GI sodium loss is common, potentially causing hyponatraemia from total body sodium depletion. This must be distinguished from the hyponatraemia caused by excess low sodium fluid in patients with activated salt and water retention when total body sodium is high. In truly sodium depleted cases, proper assessment of likely sodium balance will often confirm high likely losses, e.g. from a high output, high GI stoma, coupled with clearly inadequate provision, and spot urinary measurement will usually shows very low sodium levels. However, spot urinary measures can only be interpreted if renal function is reasonable and the use of diuretics also confuses the picture.
c. Any deficits, which developed slowly, can be accompanied by compensatory adaptations and so must only be reversed slowly to limit risks of problems such as pontine demyelinosis.

4. *Problems from internal fluid redistribution*:

In addition to abnormal external losses, many surgical patients have marked internal fluid and electrolyte distribution changes especially

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after major interventions, when septic or critically ill, or with significant comorbidities. Most develop high transcapillary escape and whole body sodium and water excess with pulmonary and peripheral oedema, weight gain, compartment syndrome and poor wound healing, coupled with low intravascular volumes and renal dysfunction. IV fluid prescribing in such cases is not surprisingly extremely difficult.

5. *Problems of organ dysfunction*:

   Many surgical patients have specific organ or system dysfunction related to: their primary surgical problem; complications such as shock, sepsis or drug reactions or existing comorbidities. Cardiac, renal or hepatic dysfunction particularly increases vulnerability to salt and water overload.

6. *Problems of poor record keeping*:

   Even though regular, accurate monitoring of all relevant parameters must be considered as a standard of care for surgical patients on IV fluids, current measurement and recording of fluid and electrolyte inputs (especially those contained in other IV drugs) are often poor, as are recordings and summary additions of outputs from all sources. Accurate documentation of sequential weight, which is incredibly valuable in making optimal fluid provision choices, is rarely done well although it must be recognised that even with modern equipment, accurate weight measurement may be impractical in immobile patients with drains, etc. and interpretation of sequential weight is subject to many confounders including fluid loss into drains and dressings and the redistribution of fluid as oedema or fluid in non-functioning gut or natural body cavities.

Key Points

- The evidence to determine best practice in general surgical settings is limited.
- Many surgical patients have significant external losses of fluid and electrolytes, often from the GI or urinary tracts although high losses also occur with fever and burns.
- Surgical patients are prone to salt and water overload, particularly in the early postoperative phase.

ASSESSMENT OF IV FLUID AND ELECTROLYTE NEEDS IN SURGICAL PATIENTS

Any patient requiring IV fluids needs assessment revolving round 4 indications for fluids, which NICE designated as the "4Rs" and incorporated into prescribing algorithms along with a 5th R for reassessment (Flowchart 4.1). The algorithms that also include some guidance on volumes and types of fluid to use based on evidence discussed in the "Choice of fluid type" section below. The 4Rs are:

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1. Resuscitation—Some surgical patients have rapid external losses of circulatory volume from bleeding, drains, plasma loss or the GI tract whilst others have high internal loss to the extravascular space or internal body compartments. Urgent fluid resuscitation and other measures are needed if acute or chronic fluid loss has led to circulatory decompensation often accompanied by specific system dysfunction especially of the central nervous system with agitation, confusion or decreased consciousness or cardiac arrhythmias and renal dysfunction. There is, however, a problem in that fluid overload also precipitates most of the same symptoms and signs so inexperienced doctors may mistake overload for depletion. Furthermore, there is wide variability in patients' underlying fitness and those with significant comorbidities may decompensate with relatively little fluid depletion whilst the young, in particular, may maintain systolic blood pressure until suddenly severe shock ensues.
2. Routine maintenance—Advances in surgery, anaesthesia and perioperative care have reduced the period of postoperative GI dysfunction and early removal of nasogastric drains and commencement of reasonable oral intake is now the norm. The routine use of postoperative IV maintenance fluids has therefore declined and the consequent reduction in iatrogenic salt and water overload may well be an under recognised contributor to the success of early rehabilitation after surgery protocols. Nevertheless, many surgical patients still need IV fluids pre- or postoperatively for essentially routine maintenance purposes and prescribing for those with more complex fluid and electrolyte issues, needs to start with estimates of routine maintenance needs appropriate to body weight followed by adjustments either up or down.
3. Replacement—As discussed above, many surgical patients need additional IV fluids to treat previous and/or ongoing abnormal losses.
4. Redistribution—As also discussed above, many surgical patients have marked internal fluid distribution changes.

The "4Rs" approach demands careful, individual patient assessment by competent clinicians using all available information including: a focussed history; brief general examination with specific assessment of fluid status from trends in pulse and blood pressure, JVP and presence of oedema, and review of fluid balance and body weight charts. Recent laboratory results and trends are also needed.

Once an estimate of total fluid volume and electrolytes requirements has been made, a common prescribing error is to fail to allow for fluid and electrolyte intakes from all other sources. These may include oral or enteral tube provision as well as any other IV therapies. Blood products, in particular, contain large amounts of electrolytes as do many IV drugs, especially when given frequently in large volume diluents, e.g. the sodium content of some IV antibiotics easily exceeds daily sodium needs. Most patients on artificial

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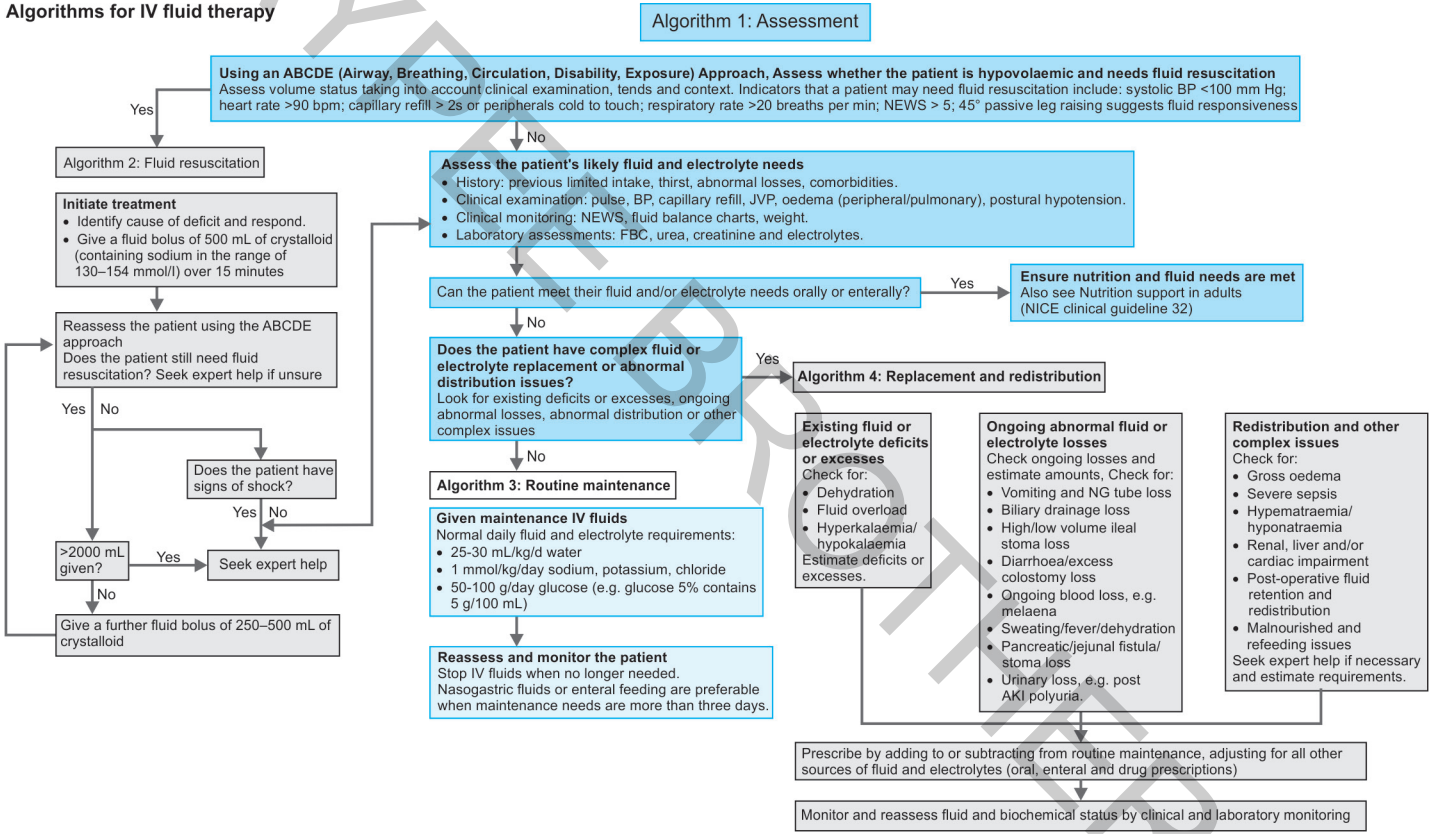
Flowchart 4.1: National Institute for Health and Care Excellence algorithms for intravenous fluid therapy.



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nutrition also receive adequate fluid and electrolytes to meet at least their routine maintenance needs, yet prescription of inappropriate additional IV fluids is frequent.

REASSESSMENT AND MONITORING

Even when taking a structured "4Rs" approach, estimates of IV fluid and electrolyte need will often prove incorrect, especially as clinical states are usually changing. There is therefore a need for constant clinical and laboratory. *Reassessment* (the 5th R) with regimens altered or stopped as appropriate. This should initially include at least daily reassessments of clinical fluid status and fluid balance charts and weight measurement twice weekly if at all possible. In complex or vulnerable patients, clinical reassessment will need to be even more frequent.

Laboratory monitoring of urea, creatinine and electrolytes is also needed daily during initial IV fluid therapy and, as noted above, additional intermittent monitoring of urinary sodium may be helpful. Chloride should also be measured in patients receiving significant amounts of high chloride (>120 mmol/L) fluids (*see* discussions below).

Importantly, the need for continuing IV fluids is not always questioned by junior trainees who may be inclined simply to repeat previous days' IV fluid prescriptions rather than properly reassess patients. They should therefore be encouraged to seek advice from more senior colleagues and proper review of IV fluids *must* be an integral part of every surgical ward round.

Key Point

- Any patient requiring IV fluids needs assessment revolving round 4 indications for fluids, which NICE designated as the "4Rs" resuscitation, routine maintenance, replacement and redistribution. A "5th R" reassessment and monitoring is also essential.

CHOICE OF IV FLUID TYPE

The problems of inadequate RCT evidence mentioned above have led to much debate about the best regimens to use for resuscitation and routine maintenance, and since there are virtually no RCTs relevant to best replacement and redistribution issues, there is also uncertainty when prescribing for those indications.

The Best Regimens for Resuscitation

A variety of crystalloids, artificial colloids and human albumin solutions have been used for fluid resuscitation. Although traditional teaching suggested colloids had advantages, the idea that they are much better at

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expanding and maintaining intravascular volume is now doubted and they are much more expensive than crystalloids. Although in theory, colloids that are iso-oncotic with plasma should expand blood volume by the volume infused, in practice the figure is closer to 60–80%[14,15] and probably much less in sick patients with high transcapillary leakage. Furthermore, studies showing that circulatory stability is better maintained by colloid rather than crystalloid in anaesthetic-induced hypovolaemia may not be relevant to ward patients with illness/injury-induced hypovolaemia and abnormal fluid distribution and handling.

Any advantage of colloids are also offset by potential problems of renal dysfunction, disturbed coagulation and allergic responses and since nearly all currently available semi-synthetic colloids contain 140–154 mmol/L sodium chloride, their use may also contribute to excess sodium and chloride provision.

In the United Kingdom sodium chloride 0.9%, Ringer's lactate/acetate, Hartmann's solution, gelatins, hydroxyethyl starch, and albumin are all used for resuscitation in general surgical areas whilst the use of dextrans or high molecular weight penta- and hexa starches is usually confined to intraoperative and ICU usage. NICE therefore only evaluated studies comparing those used in general areas to each other. The evaluations showed:

Key Points

- Gelatins had no clear advantage over other colloids or crystalloids.[15-22]
- Tetrastarch had no clear advantage over other colloids or crystalloids,[23-27] and three large studies in critical care suggested it may increase acute kidney injury (AKI) compared to 0.9% saline or Ringer's lactate with one suggesting increased mortality.
- Albumin 4% had no clear advantage compared to 0.9% saline although there was a trend towards decreased mortality in one study examining its use in a pre-defined sepsis subgroup.[28,29]
- No studies compared colloids made up in balanced physiological solutions to those made up in sodium chloride 0.9%.
- Studies of factors such as timing, administration rates and best total volume of fluids to give for resuscitation[30-34] showed apparently important differences between early versus late, and fast versus slow fluid provision but the direction of benefit was not always the same in different studies.

The NICE concluded that crystalloids containing sodium in the range 130–154 mmol/L should be used for resuscitation rather than colloids and that an initial bolus of 500 mL should be given over < 15 minutes. They also recommended that tetrastarches should no longer be used and that albumin could be considered severe sepsis although in reality, the cost implications of this will surely confine its use to experts in critical or high-care settings.

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The Best Regimen for Routine Maintenance

Sodium chloride 0.9% with or without additional potassium is the most commonly used IV fluid in UK surgical patients, but it may contribute to excessive sodium and water retention. There is therefore interest in "balanced fluids", which contain less sodium and chloride and variable amounts of potassium, calcium and magnesium at levels approximating to normal needs.

Five per cent glucose and glucose/salines with or without potassium cannot be used for rapid administration but once the glucose is metabolised, they are distributed through total body water with limited effects on blood volume. They are therefore appropriate for preventing or correcting simple dehydration and also help limit starvation ketosis, although they make little contribution to meeting patients' overall nutritional needs.

The NICE found no studies that simply compared different maintenance fluid choices to one another but four RCTs[35-38] compared "restricted" IV fluid maintenance regimens (with reduced sodium chloride and fluid volumes) with more "standard" regimens in postoperative patients. Two RCTs suggested that restricted regimens reduced mortality and hospital stays whilst the other two showed no difference in mortality with one suggesting restricted regimens prolonged hospital stays. However, the four studies varied enormously with restricted groups given fluid volumes ranging from 1.5–2.5 L/day with sodium chloride provision ranging from 62–231 mmol/day, whereas the standard regimen groups received fluid volumes of 2–4 L/day with sodium chloride provision ranging from 154–231 mmol/day. This not only prevented meaningful meta-analysis but probably explains the differences in results with adverse outcomes seen if either too much or too little fluid and too much or too little sodium chloride is given. Importantly, all four RCTs suggested no clinically important difference in the risks of developing AKI when using restricted IV fluid regimens and none reported significant problems of hyponatraemia even though sodium chloride provision was at low levels that have traditionally been thought of as likely to precipitate hyponatraemic risks.

The NICE also reviewed studies in which surgical patients received IV fluids with chloride >120 mmol/L with those receiving fluids with chloride < 120 mmol/L[1] and concluded that provision of lower chloride fluids was probably associated with lower mortality and morbidity. In a separate review of studies examining associations between serum chloride input, plasma levels and clinical outcome[1] suggested that hyperchloraemia occurred more frequently if high chloride fluids were given but that both hyper- and hypo-chloraemia had adverse outcome effects. These considerations led to NICE recommending that serum chloride should initially be monitored daily when using regimens based on fluids containing >120 mmol/L

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chloride and that if chloride levels rise, hyperchloraemic acidosis should be considered. Low chloride levels are most likely to reflect true saline depletion.

The conclusion of all of the above findings was a NICE recommendation that for routine maintenance an appropriate initial prescription should deliver approximately: 25–30 mL/kg/day of water; 1 mmol/kg/day of potassium, sodium and chloride; and 50–100 g/day of glucose. NICE also suggested that this could be achieved by using 25–30 mL/kg/day of sodium chloride 0.18% in 4% glucose with 27 mmol/L potassium—a fluid that became very unpopular with surgeons because of its association with hyponatraemia. However, NICE felt that hyponatraemic risks were small if <2.5 L/day is used and explicitly pointed out that these were only initial prescriptions with further prescribing needing to be guided by monitoring. They also recommended that less fluid (e.g. 20–25 mL/kg/day) should be considered in patients who are older or frail and those with renal impairment, cardiac failure or malnutrition.

The Best Fluid for Replacement

If patients need IV fluids and electrolytes for replacement purposes, it is important to recognize that these will usually be in addition to their routine maintenance requirements. Replacement for blood loss is generally by the use of 0.9% sodium chloride or balanced crystalloids with packed red cells as necessary, whilst replacement for other losses, e.g. GI or urinary, will usually depend on estimates of their composition but 0.9% sodium chloride, glucose 5% and glucose with saline solutions and balanced crystalloids can all be used with or without additional potassium as appropriate. Although it is sometimes possible to measure the volumes and electrolyte content of abnormal losses (e.g. with high urinary loss), more often it is only possible to measure volumes and not infrequently both volume and likely content must be estimated, predicting likely electrolyte losses from the nature of the loss (Fig. 4.1). Since these estimates will be subject to wide errors, particularly close clinical and laboratory monitoring will be needed.

The Best Fluids for Fluid Redistribution Problems

Prescribing appropriate IV fluids for patients with redistribution type problems is particularly difficult since too little leads to intravascular hypovolaemia, low blood pressure, poor urine output and poor tissue perfusion, whilst too much may promote even more oedema. Furthermore, as such patients get better, transcapillary leakage will decrease and the redistribution problems may effectively operate in reverse. It may therefore important to reduce overall IV fluid and electrolyte provision to permit a net negative sodium and water balance, to aid oedema resolution.

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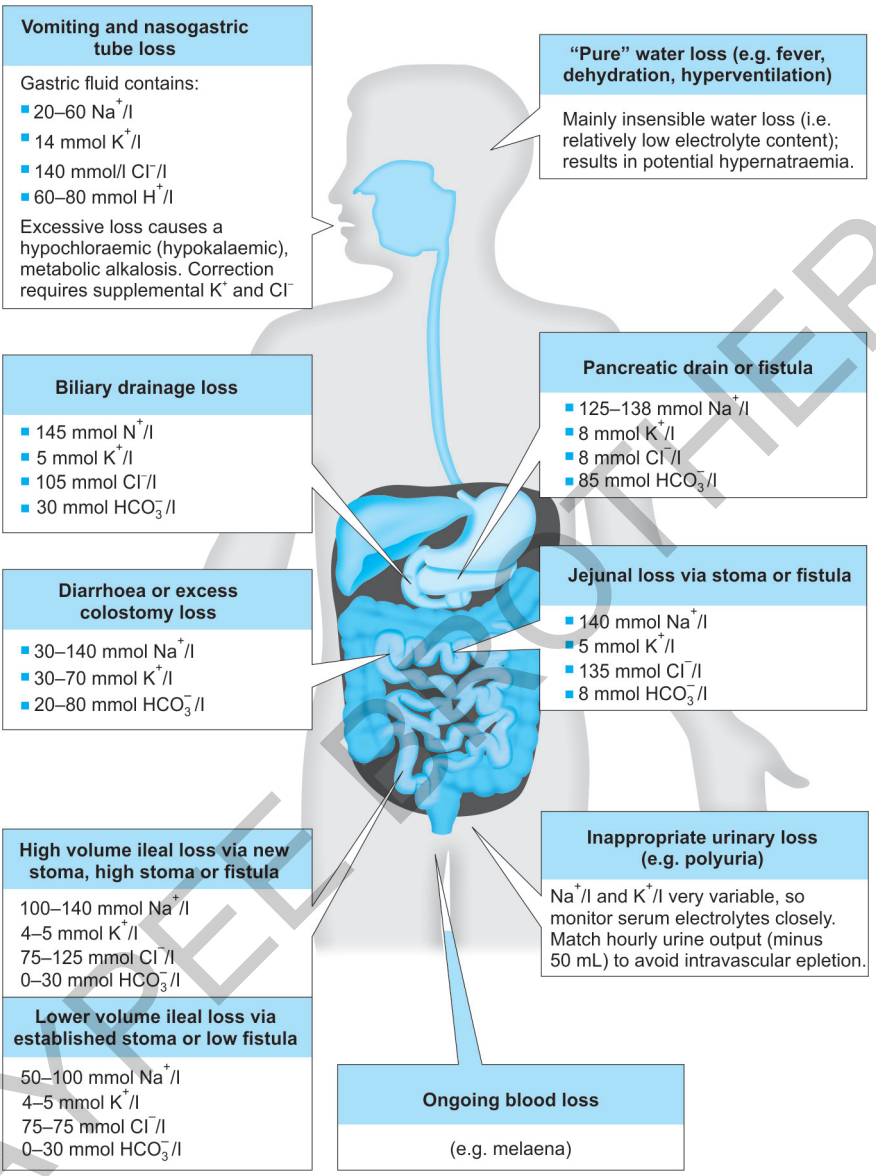

Fig. 4.1: The likely nature of abnormal external losses.
Source: Copyright-National Clinical Guideline Centre.

The overall approach is to treat intravascular hypovolaemia as one would for resuscitation but aim for a negative overall fluid and sodium balance as soon as possible. In severe cases, balance can be assessed by comparing total sodium intake (accounting for all sources including other IV fluids, IV drugs and their diluents) with total losses from urinary measurements and estimates of sodium in other external losses. Excretion should exceed intake.

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RECENT ADVANCES IN SURGERY 37

Recent Advances in Surgery 37 once again provides the reader with a comprehensive up-to-date review of developments in the general field of surgical practice as well as in important specialised areas. The editors have carefully chosen topics in which important innovations have recently been incorporated into clinical usage. Each chapter is written by a recognised expert in the field and a relevant reference list is provided to assist with further reading.

The book is designed both for surgical trainees undertaking surgical examinations and established Consultants wishing to keep abreast of recent developments in surgical practice.



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