OPEN ACCESS TEXTBOOK OF SURGERY

FLUIDS AND ELECTROLYTE ISSUES IN SURGICAL PATIENTS

E Panieri

A Boutall

INTRODUCTION

The majority of patients undergoing a surgical procedure receive intravenous fluids.

Changes in the serum electrolyte concentrations are common in the post operative period.

Understanding the principles of fluid therapy, and trouble shooting abnormal blood results are essential skills in surgical care.

In clinical practice intravenous fluids fluids are used for three indications:

1. for maintenance purposes (i.e the patient is unable to eat and drink, or absorb enteral intake)
2. for rehydration or replacement of previous losses (in the context of profuse vomiting, diarrhoea or stoma losses)
3. for resuscitation (in the shocked patient).

These indications frequently overlap, and patient management must always be individualised.

Remember you can harm the patient by

1. giving too much fluid
2. giving too little fluid
3. using the incorrect fluid

PHYSIOLOGY AND DAILY REQUIREMENTS

Fluid and electrolyte requirements

Water constitutes between 60-75% of lean tissue mass. In a 70 kg adult, the majority is found in the *intra-cellular compartment* (20-30l) and the rest in the *extra-cellular compartment*, which in turns is comprised by the plasma or intravascular space (4l) and interstitial fluid (10-12l).

The osmolality (total particle concentration) is the same across all fluid compartments (approximately 280-295 mosm/kg of water), but the specific electrolyte concentration is quite different. Potassium and Phosphate are the main intracellular electrolytes, whereas Sodium and Chloride are the main extracellular electrolytes. This is illustrated in Table 1.

It is important to remember that when measuring plasma levels of electrolytes, the laboratory results reflect extracellular concentration of these electroyes, and not necessarily overall concentration, nor are the plasma values proportional to daily requirements.

Table 1- electrolyte concentrations

Constituent	Extracellular (i.e plasma)	Intracellular
Cations		
Na^{2+}	142	10
K^+	4	150
Ca^{2+}	2.5	2
Mg^{2+}	1.5	20
Anions		
Cl^-	103	10
HCO_{3-}	27	10
SO_4^{2-}	1.5	70
PO_4^{2-}	1	45

The approximate daily requirements of water and electrolytes are shown in Table 2. There is significant variation between individuals, and excess is excreted by the kidneys, provided renal function is normal.

Table 2- daily requirements of water and electrolytes

Constituent	/kg of weight	Average for 70kg adult
Fluid		
water	25-35ml/kg	1750-2500ml
Cations		
Na^{2+}	1mmol/kg	70mmol
K^{+}	1mmol/kg	70 mmol
Ca^{2+}	0.1mmol/kg	7mmol
Mg^{2+}	0.1mmol/kg	7mmol
Anions		
Cl^{-}	1mmol/kg	70mmol
PO_4^{2-}	0.2mmol/kg	14mmol

Nutritional requirements- it is important to be mindful of concomitant caloric needs, since the majority of patients relying on IV fluids are unable to manage a sufficient enteral intake.

The caloric intake should consist of 25–35 kcal/kg/day of total energy (including that derived from protein, which should consist of 0.8–1.5 g protein/kg/day), in addition to the adequate volume of water and electrolytes described above, as well as minerals, micronutrients (allowing for any pre-existing deficits, excessive losses or increased demands) and fibre if appropriate.

As a clinician it is important to bear in mind that a **surgical event always results in a major catabolic deficit**, with rapid and significant depletion of glycogen, fat, and protein stores, and that these may take many months to fully recover.

Stress response to surgery

Major surgery, trauma and severe sepsis trigger a powerful cascade of physiological mechanisms designed to facilitate survival. These promote expansion of the blood volume, glucose availability, perfusion of vital organs, and inflammation.

● ADH – is secreted by the posterior pituitary gland in response to elevated plasma osmolality, low circulating blood volume, and stress. This results in water retention by the kidney, which expands the vascular volume.

● Aldosterone – The renin-angiotensin axis responds to volume contraction by stimulating aldosterone secretion in the adrenal gland. Aldosterone increases sodium and water retention by the kidney, thereby expanding the vascular volume.

● Cortisol – The hypothalamic-pituitary axis responds to stress by stimulating cortisol release from the adrenal gland. This promotes gluconeogenesis and muscle breakdown and results in hyperglycemia.

● Catecholamines – Epinephrine and norepinephrine are released from the adrenal gland in response to sympathetic nervous system stimulation, resulting in vasoconstriction, tachycardia, and catabolism. This combination leads to increased cardiac output, hypertension, and hyperglycemia.

● Cytokines – Acute phase reactants (eg, interleukins 1 and 6) generate a local inflammatory response at the site of injury, facilitating healing at sites of tissue disruption.

The stress response to tissue injury helps the body to compensate for hypovolemia. However, if excessive or dysregulated, the same inflammatory response may lead to vasodilation, deranged coagulation, systemic capillary leak, and systemic organ dysfunction.

Fluid losses in the post operative period

Surgery and surgical conditions commonly cause additional fluid losses- these have to be understood and considered.

There are four types of fluid losses- Blood, insensible and third space losses are primarily relevant within the first 24 hours of surgery and are usually managed by the anaesthesiologist pre- and –intraoperatively; external losses (particularly from the GIT) can be relevant for much longer.

Blood — bleeding from trauma or surgery results in hypovolaemic shock, and needs active management. This is primarily a consideration in the pre-operative resuscitation process or intra-operatively. It can occasionally occur as a post operative mishap.

Insensible losses — evaporative loss can be related to prolonged exposure during laparotomy or thoracotomy, or prolonged exposure of burn wounds during skin grafting. It is estimated that the losses from open abdominal exposure are approximately 0.5 to 1 mL/kg/hour; however, the amount varies with the degree of organ exposure and the severity of the illness. Insensible losses associated with ventilator support (intraoperative, postoperative) are limited.

Third space losses — this refers to capillary leak and extravasation of protein-rich serum into the interstitial spaces of the soft tissues (eg, skin, fat, muscle), organs, deep space cavities (eg, chest, abdomen), or retroperitoneum. It typically occurs during the first 72 hours following major surgery and is associated with a heightened stress response. Clinical manifestations include edema, ascites or pleural effusions.

Hypoalbuminemia (commonly found in many surgical conditions) contributes to third-spacing; the decreased intravascular oncotic pressure caused by hypoalbuminemia facilitates fluid shifts.

External losses — Gastrointestinal losses (nasogastric tube, or via vomiting, diarrhoea, stomas or fistulae) are a major source of fluid loss and electrolyte derangements in the post operative period and need to be monitored and replaced actively.

Table3- GIT losses

Site	Volume (l/day)	Na	K	HCO
Stomach	1-2.5	80	15	10
Bile	1.5	150	5	35
Pancreas	1	150	5	80
Small bowel	2-5	110	5	30
Large bowel	variable	120	25	45

Table 3 gives an indication of the potential volume loss, and electrolyte deficit, depending on the level of the GIT that is obstructed or leaking.

TYPES OF FLUIDS

The prescribing clinician must be very clear in the goals of IV fluid therapy. Fluids are designed for a specific purpose, and when used for the incorrect indication can be harmful. For example maintenance fluids are very poor resuscitation fluids, and replacement fluids are not correct for maintenance needs.

Maintenance fluids

The goal of maintenance fluid therapy is to administer to the patient the equivalent of the daily requirements of water, electrolyte and caloric needs, whilst they are unable to eat and drink normally.

Normal oral intake of fluids, electrolyte and nutrition determined by the patient's own hunger and thirst mechanism is ALWAYS superior to IV fluids for this purpose.

GMS (General Maintenance Solution) is the commonest fluid available for maintenance purposes. The concentration of electrolytes in this product is based on the assumption that the patient will receive 3l fluid per day, so each litre contains one third of the daily requirements of electrolytes. 5% Dextrose is added to prevent hypoglycaemia, but this amount is not sufficient to meet daily caloric requirements.

Be mindful that 3l of fluid a day is a lot! Current practice is for most patients to receive 1.5l to 2l of GMS per day.

Fluid	Na	K	Cl	Dext
GMS	26	27	52	5%

Patients on IV maintenance fluids are never receiving sufficient caloric support, and GMS simply supplies short term fluid and electrolyte support on the assumption that the patient will re-establish enteral intake within a few days of surgery. Patients who have prolonged gut dysfunction must receive total parenteral nutrition instead of maintenance fluids.

Patients should be encouraged to reintroduce normal enteral intake as soon as they are ready to tolerate it in almost all post operative circumstance.

Rehydration & replacement fluids

These fluids are administered to the patient who is clinically dehydrated (i.e. with bowel obstruction or profuse diarrhoea) or those who have ongoing excessive GIT losses. The characteristic of these fluids is a relatively high sodium content to counteract the high sodium losses typically associated with these clinical problems.

Fluid	**Na**	**K**	**Cl**	**Dext**
Rehydration	77	-	77	5%
Replacement	108	15	117	5%
Dextrose/ Saline	154	-	154	5%

Resuscitation fluids

These are used in the active resuscitation of a shocked patient or intra-operatively. They are seldom used in the routine post operative care of a surgical patient.

Fluid	**Na**	**K**	**Cl**	**Dext**
PlasmalyteB	130	4	110	nil
Ringers lactate	135	5.4	108	nil
Voluven	154	0	154	nil

Harms of incorrect fluid therapy

Insufficient fluids- this predisposes to dehydration and pre-renal failure, which in high risk cases (pre-existing renal dysfunction, cholestatic jaundice, use of nephrotoxic drugs) may be irreversible. The typical clinical features are lethargy, postural hypotension, and dry mucosal membranes. It is important to note that the thirst reflex is largely driven by sodium content, if dehydration is due to high ileostomy output (which is high in sodium) for example the patient will not feel thirsty.

Excessive fluids — patients may develop pulmonary and peripheral edema, have impaired wound healing, face an increased risk of sepsis and eelectrolyte derangements, develop gut edema and prolonged post operative ileus, ARDS and face a longer hospital stay.

Incorrect fluids — using the incorrect fluid type can exacerbate pre-existing electrolyte derangement- i.e. giving a hyponatraemic patient 5% dextrose will worsen the hyponatraemia! Or giving a patient with hyperkalaemia a potassium containing fluid like replacement fluid will risk precipitating a hyperkalaemic crisis.

Harms of unnecessary "nil per os" orders

Preoperative fasting is routinely advised in patients who are undergoing any form of general anaesthesia. This is to reduce gastric contents, and the harm they may cause if aspirated during induction of anaesthesia, or in the post-operative recovery period.

In reality most patients awaiting surgery fast excessively, often in excess of 18 hours, which places them at risk of dehydration and hypoglycaemia. Not only is this extremely unpleasant it is also associated with adverse outcomes.

It is an incorrect dogma that preoperative starvation should be of a minimum of 6 hours. It is well established that it is safe for patients to have an oral intake of carbohydrate containing clear liquids up to 2 hours before surgery; this needs to be enocuraged in routine peri-operative planning.

Oral intake of fluids, if the gut is functional, is always better than intravenous fluid administration.

PATIENT ASSESSMENT

Evaluating a patient's hydration, electrolyte deficit and nutritional need is a daily routine of clinical hospital care.

Patients should eat and drink independently of IV fluids as soon as possible, and IV fuids must be discontinued at the earliest opportunity.

Examine the patient and look at the fluid and nursing charts twice per day. Consider if the patient needs

- **Resuscitation** — is the patient shocked?
- **Rehydration** — is the patient dehydrated? Do you have to catch up with previous losses?
- **Replacement** — of monitored GIT losses (what was lost from NGT, stoma, drain, etc); if in excess of 500ml replace them.
- **Maintenance** — can the patient eat and drink normally? If not use GMS in a volume appropriate to the patient weight and co-morbidity until gut function resumes.

The simplest parameter used to evaluate adequate hydration urine output: if the patient produces more than 1 ml/kg/hr, hydration is likley to be adequate. A urine output of less than 0.5ml/kg/hr is a marker of pre-renal failure and should prompt re-evaluation of the case and intravenous fluid regime.

ELECTROLYTE DERANGEMENTS IN SURGICAL PATIENTS

Post operative electrolyte derangements are common, and are multifactorial in aetiology.

Minor derangements will typically normalise spontaneously provided the recovery period is uncomplicated and the patient resumes an enteral intake without undue delay.

A simple approach to remebering the possible causes of electrolyte abnormalities is the following.

Causes of low electrolyte levels (hypo-):

- excessive loss of electrolyte
- water retention or excess administration
- Shift of the electrolyte in the intracellular space

Causes of high electrolyte levels (hyper-):

- excessive loss of water
- electrolyte retention or excess administration
- shift of the electrolyte in the extracellular space

The sections below highlight the surgical contexts of the commonest electroloyte derangements, are are not an exhaustive review of all possible causes.

Hyponatraemia

Low sodium is very common. It causes brain edema, and patients experience tiredness, nausea, confusion, muscle cramps; in severe cases it may lead to coma and death.

Commonest causes: in the early post-operative period hyponatraemia is caused by ADH secretion as well as by an intracellular shift of sodium related to third space fluid shifts. This often accompanied by hypokalaemia.

More severe hyponatraemia is caused by excess sodium loss from the gastrointestinal tract (particularly biliary losses), iatrogenic excess administration of hyponatraemic fluid, and some diuretics, or syndrome of inappropriate ADH secretion in head injuries or following neurosurgical procedures. Transurethral prostate resection is also often accompanied by hyponatraemia. Excess water retention in congestive cardiac failure or renal disease is a less common issue in surgical patients.

In patients with marginal post-operative hyponatraemia, the sodium corrects spontaneously as the patient recovers from surgery, and IV fluids are stopped.

More severe cases (Na < 125 mmol/l) need active treatment.

Hypernatraemia

This is much less common than hyponatraemia. Frequent causes are severe dehydration, excess administration of hypernatraemic fluids, or diabetes insipidus

Hypokalaemia

This causes muscle weakness, gut dysfunction with ileus and constipation, and arrhythmias.

Commonest causes: use of diuretics, loss of potassium from the gut, particularly in diarrhea, and third space shifting.

Treatment is aimed at providing oral or IV postassium supplementation and correcting the underlying cause.

Hyperkalaemia

An elevated potassium level is the most lethal of electrolytes derangements and can lead to arrhythmias and sudden cardiac arrest.

The **commonest causes** include acute tubular necrosis, rhabdomyolisis, and severe acidosis. Beware of prescribing potassium containing fluids in high-risk patients.

Treatment is aimed at stopping any IV postassium fluid, administering potassium binders orally, insulin/ dextrose infusion or urgent dialysis. Always correct the underlying cause.

Hypocalcaemia

Symptoms of hypocalcaemia are typically peri-oral tingling and paeaethesias, and carpopedal spasms and muscle cramps.

Hypocalcamia is commonly noted in patients undergoing third space fluid shifts, and is a specific complication following total thyroidectomy and parathyroid surgery.

Hypercalcaemia

Marginal elevation of serum calcium is usually asymptomatic. Severe hypercalcaemia can lead to confusion, seizures, coma and intractable arrhythmia.

Borderline elevations in hospitalized patients can be spurious and related to prolonged immobilization or incorrect blood letting.

Persistent hypercalcaemia or significant elevation is most commonly caused by primary hyperparathyroidism or meatstaic disease.

Refeeding syndrome

Refeeding syndrome is a collection of electrolyte derangements associated with a massive intracellular shift of electrolytes.

Many surgical diseases are associated with preoperative malnutrition, such as GIT malignancies, chronic organ dysfunction, or small bowel fistulae. As malnourished patients recover from surgery and resume dietary intake, they are at risk.

Hypophosphatemia is commonly observed as extracellular phosphate is rapidly taken into the cells to generate adenosine triphosphate (ATP). ***Hypokalemia, hypomagnesaemia*** are also commonly observed.

The clinical implications of refeeding syndrome range from congestive heart failure, peripheral edema, rhabdomyolysis, seizures, hemolysis, and sudden cardiac arrest. Patients are often extremely weak, and may struggle to mobilize, ambulate or when weaning off mechanical ventilation.

Malnourished patients should be closely monitored for clinical and laboratory evidence of refeeding syndrome when oral or intravenous nutrition is started.