

PERIOPERATIVE FLUID BALANCE

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Fluid balance is an important area of perioperative medicine. If managed incorrectly it is a significant cause of morbidity and mortality. This article will discuss:

- aims of adult perioperative fluid therapy
- fluid and electrolyte physiology
- assessment of hydration and volume status
- different fluid preparations
- controversies in fluid management
- guidelines for fluid management in surgical patients

AIMS OF FLUID THERAPY

Perioperative fluids are required to maintain adequate:

- hydration
- blood volume and oxygen delivery
- renal function
- electrolyte balance
- splanchnic and hepatic circulation

FLUID AND ELECTROLYTE PHYSIOLOGY

Fluids and electrolytes are present in a number of “compartments” in the body, according to their chemical composition. Plasma is the fluid component of the blood surrounding the red cells, intracellular fluid is the fluid within the body’s cells, and interstitial fluid is the fluid found between the cells, outside of blood vessels.

Water is present in plasma, interstitial and intracellular fluid volumes and passes freely between compartments, under the influence of osmotic pressure gradients. The interstitial fluid volume and plasma volume together make up the extracellular volume (ECF). Water accounts for 60% of adult body weight (total body water = 42 litres for a 70kg adult). Of the 42 litres, 3, 11 and 28 litres are found in the plasma, interstitial and intracellular compartments respectively. Osmolality is kept constant between all compartments by the movement of water by osmosis.

The ECF contains most of the sodium in the body, with equal sodium concentrations in the interstitial fluid and plasma. Sodium and water can pass freely through capillary membranes whilst albumin (the most important oncologically active constituent of the ECF) does not. Albumin is unequally distributed in the intravascular and interstitial compartments (normal concentrations of 40g/l and 10g/l respectively) and is excluded from the intracellular compartment. This distribution helps to retain fluid within the plasma due to the osmotic effect of albumin. The predominant intracellular anion is potassium.

This information predicts the distribution of infused fluid. Sodium free water e.g. glucose 5%, will be distributed throughout the total body water as it freely crosses cell membranes. Less than 10% of the infused volume remains in the plasma.

An infusion of a crystalloid solution, with a sodium concentration of approximately 140mmol/l, will be

distributed throughout the ECF as the sodium and water will move freely across the capillary membrane, but will not enter cells. Therefore around a third of infused normal 0.9% saline or Hartmann's solution remains in the intravascular volume. Colloid solutions are retained primarily within the plasma volume due to the effect of their albumin like content, providing an added osmotic (or oncotic) effect. However over time colloids leak across the capillary membrane entering the interstitial fluid space, or are metabolised.

NORMAL FLUID AND ELECTROLYTE REQUIREMENTS

Average adults in temperate climates lose between 2.5 and 3 litres of water per day (1300-1800mls urine, 1000mls insensible loss from lungs and skin, 100mls in the faeces). Normally fluid enters the body orally although around 200mls/day is produced from metabolic processes. Average adults lose about 1.5mmol/kg/day of sodium ions and 1 mmol/kg/day of potassium ions in the urine.

If a patient is nil by mouth then normal daily requirements may be provided by:

1000mls	Normal saline 0.9%
1500-2000mls	Dextrose 5%
60 mmol	KCl

ASSESSMENT OF HYDRATION STATUS AND INTRAVASCULAR VOLUME

Fluid management in the perioperative period involves maintaining the intracellular and extracellular fluid volumes.

Dehydration reflects loss of water. This may come from extracellular fluid (ECF) and intracellular fluid (ICF) depletion. Sodium is usually lost at the same time, giving rise to hyper- or hyponatraemia, depending on the relative degrees of loss. If ECF osmolality rises, water passes from the ICF into the ECF by osmosis. Predominantly water loss is therefore shared by ECF and ICF, whilst water and sodium loss is mainly from the ECF. This explains why fluid losses from fever and lack of intake (mainly water loss) may be tolerated for longer than severe vomiting or diarrhoea (water and sodium loss).

Hydration status and intravascular volume is assessed by the patient's history, examination, test results and response to intravenous fluid administration.

History may detail causes of perioperative dehydration and intravascular volume depletion such as inadequate oral intake, vomiting, diarrhoea, bowel preparation, haemorrhage, burns, drain losses and third space losses.

Physical examination will include: pulse rate, arterial blood pressure, respiratory rate, urine output, JVP, capillary return and mucous membranes. The physical findings for various degrees of intravascular volume loss and dehydration are given in Tables 1 and 2. Table 1 also provides guidelines for the type of replacement fluids that should be used for each category of hypovolaemic shock. Choice of replacement fluid for dehydration will depend on which fluid compartments have been depleted. Initially electrolyte solutions such as normal saline or Hartmann's are used to replace ECF losses. Initial fluid boluses in moderate to severe dehydration should be 10-20ml/kg followed by reassessment of the patient and further fluids guided by clinical signs.

Clinical signs of hypovolaemia may be more difficult to determine during anaesthesia. The same physical variables should be measured, together with an estimation of ongoing intraoperative losses. Tachycardia alone is an insensitive marker of hypovolaemia. A normal pulse rate, blood pressure and CVP of 6-12mm Hg suggest adequate blood volume. Arterial blood pH and serum lactate are useful indicators of effective resuscitation. Urine output falls with hypovolaemia, and an output of 0.5 to 1.0ml/kg/hr during anaesthesia suggests adequate renal perfusion and intravascular volume. The physiological response to fluid administration, via repeated fluid challenges is a practical part of volume assessment.

Advanced monitoring of fluid status may be necessary for some patients with pre-existing pathology undergoing complex surgical interventions. Techniques utilised include CVP measurement, pulmonary artery catheterisation or newer cardiac output monitoring such as oesophageal Doppler ultrasound.

In perioperative care the emphasis is to use IV fluids to maintain the circulating volume and tissue oxygen delivery. There is good evidence that patients undergoing major surgery in a dehydrated, un-resuscitated state do worse than those who have received adequate IV fluid preoperatively. These patients are unable to react to the stress of the surgery and underlying illness, develop intracellular hypoxia and organ dysfunction.

In emergency patients, the time available for resuscitation is always limited, but early effective resuscitation may be lifesaving.

Laboratory investigations are useful, particularly the haematocrit, urea and electrolytes. An initially raised haematocrit (or Hb) may reduce substantially after fluid replacement.

FLUID PREPARATIONS

There are three types of intravenous fluids: crystalloids,

Table 1: Grades of hypovolaemic shock secondary to intravascular volume loss, their physical findings and suggested replacement fluids for a 70kg man

	Class I	Class II	Class III	Class IV
Blood loss (ml)	Up to 750	750-1500	1500-2000	> 2000
% blood volume lost	Up to 15%	15-30%	30-40%	> 40%
Pulse rate (/min)	<100	>100	>120	>14
Blood pressure	Normal	Normal	Decreased	Decreased
Pulse pressure	Normal	Decreased	Decreased	Decreased
Respiratory rate	Normal	Increased	Increased	Rapid
Urine output (ml/hr)	>30	20-30	5-15	Negligible
CNS / mental state	Slight anxiety	Mild anxiety	Anxious, confused	Confused, lethargic
Fluid replacement	Crystalloid	Crystalloid / colloid	Crystalloid / colloid and blood	Crystalloid / colloid and blood

Table 2: Grades of dehydration, relating to the % body weight lost and the resulting physical signs.

	Mild <5%	Moderate 5-10%	Severe >10%
Pulse rate	Normal	Increased	Increased
Blood pressure	Normal	Normal	Decreased
Respiratory rate	Normal	Normal	Rapid
Capillary return	<2 seconds	3-4 seconds	>5 seconds
Urine output	Normal	Decreased	Negligible / absent
Mucous membranes	Moist	Dry	Parched
CNS / mental state	Normal / restless	Drowsy	Lethargic / comatose

colloids and blood products. A useful principle is to “replace what is lost”. This requires knowledge of the constituents of both the fluids lost and of intravenous fluids. Tables 3 and 4 contain the relevant information.

Crystalloids

Crystalloids are solutions of crystalline solids in water. In general they contain sodium in similar concentrations as found in the plasma (e.g. normal saline, Hartmann’s). They are rapidly and evenly distributed throughout the extracellular space, with only 25-30% remaining in the intravascular compartment. When used to maintain circulating volume they are given in a volume equivalent to three times the estimated blood losses. Crystalloids which contain a lower concentration of sodium than plasma (i.e. 5% glucose or 0.18% saline with 4% glucose) are distributed throughout the total body water after the glucose has been metabolised.

Colloids

Colloids are suspensions of high molecular weight particles, derived from gelatin (gelifusine, haemaccel), protein (albumin solutions) or starch (hetastarch) and are prepared in solutions of saline or glucose. Colloid solutions remain longer intravascularly than crystalloids prior to being metabolised or excreted (plasma half-lives: gelifusine or haemaccel 4 hours, hetastarch 24 hours, albumin solutions 5-10 days). They should be given in a volume equivalent to the estimated blood loss. Potential disadvantages of their use include increased cost, anaphylactic reactions and risk of infection with human albumin.

Blood

Oxygen delivery to the tissues is primarily a function of haemoglobin level, haemoglobin oxygen saturation and cardiac output. Ensuring an adequate haemoglobin level and intravascular volume is therefore vital for

Table 3: Composition of body fluids

Types of fluid	Na (mmol/l)	K (mmol/l)	Protein (g/l)
Serum	135-145	3.5-5.3	70
NG losses and vomit	60-120	5-10	Minimal
Diarrhoea	80	25-40	Minimal
Third space losses	135-145	3.5-5.3	10-20

Table 4: Composition of various intravenous fluids

(Concentrations are given in mmol/l, molecular weights are given in Daltons)

Fluid	mOsm/l	Na	Cl	Lactate	Ca	K	Solute	pH
N saline 0.9%	308	154	154					5
4% glucose 0.18% saline	284	30	30				40g/l glucose	4.5
5% glucose	278						50g/l glucose	4.2
Hartmann's	278	131	111	29	2	5		6
Gelofusine	274	154	120		0.4	0.4	40g/l gelatin MW 30,000	7.4
Haemaccel	301	145	145		6	5	35g/l gelatin MW 35,000	7.3
HAES 6%	308		154	154			60g/l starch MW 130,000	5.5
HAES 10%	308		154	154			100g/l starch MW 200,000	5.5
HAS 4.5%	270-300	100-160	100-160		2	2	45g/l albumin MW 64,000	6.8
HAS 20%	135	50-120	<40			2	200g/l albumin MW 64,000	6.8
Dextran 40	278						100g/l dextran MW 40,000 50g/l glucose	5

oxygen delivery. Transfusion of red cells is indicated when haemoglobin levels fall, or are expected to fall, to around 7.5 g/dl in fit patients. Patients with underlying ischaemic heart disease may need higher levels (>9g/dl). Transfusion of one unit of packed red cells (volume 300ml Hct 60-70%) will raise Hb by 1 to 1.5g/dl.

Other Blood Products - Update in Anaesthesia No 14

FLUID CONTROVERSIES

Crystalloids versus colloids

Controversy still exists about the roles of crystalloids and colloids in perioperative fluid therapy. In 2004 a well designed randomised controlled trial involving nearly 7000 ICU patients was published comparing the effect of fluid resuscitation with albumin or saline on mortality¹. No significant difference was demonstrated between the albumin and saline groups for the primary outcome

measure of 28 day all cause mortality. The study concluded that albumin can be considered safe in the heterogeneous population of adult ICU patients, but no clear advantage over saline was identified.

Potential advantages of colloids. If membrane permeability is intact, colloids preferentially expand plasma volume rather than interstitial fluid volume which may result in lower fluid requirement and less peripheral and pulmonary oedema.

Potential disadvantages of colloids. These include greater expense, allergic reactions (gelatins), infection risk (HAS), coagulopathy (dextrans and starches), impaired cross matching (dextrans), and reduction in ionised calcium (HAS).

All colloids leave the plasma volume to enter the interstitial space and the long term benefits of colloids are unclear. In disease states associated with increased alveolar capillary permeability (sepsis, ARDS), infusion of colloid may aggravate pulmonary oedema. Similarly capillary leak of infused colloid in head injuries may cause increased cerebral oedema and increased intracranial pressure.

Potential advantages of crystalloids. Crystalloids are inexpensive and non-allergic. They are more effective at replacing depleted ECF and are not associated with transmission of infection, impairment of coagulation or cross matching.

Disadvantages of crystalloids. Crystalloids exert short lived haemodynamic effects in comparison to colloids. When used for massive fluid resuscitation they invariably produce peripheral oedema and occasionally pulmonary oedema.

Most anaesthetists use a mixture of crystalloids and colloids based on the individual patient being managed and the clinical situation.

Normal saline versus Hartmann's solution.

Normal saline contains a higher concentration of chloride than plasma (154 versus 135-145mmol/l). As a consequence of this high chloride load, large volumes of normal saline may cause a hyperchloraemic metabolic acidosis. Whilst the dangers of this temporary saline induced metabolic acidosis are probably minor, it causes a base deficit on arterial blood gases, which may be misinterpreted as a metabolic problem. A recent study confirmed that hyperchloraemic metabolic acidosis can be prevented by using balanced solutions containing physiological concentrations of chloride such as Hartmann's solution².

PERIOPERATIVE FLUID MANAGEMENT

Fasting Policy

Current preoperative fasting guidelines for elective surgical patients state that elective patients may take clear

oral fluids until two hours prior to the anaesthetic and surgery. Oral fluids alone are suitable for many patients undergoing anaesthesia and surgery. The Association of Anaesthetists of Great Britain and Ireland recommends these minimum fasting periods based on the American society of Anaesthesiologists (ASA) guidelines:

- 6 hours for solid food, infant formula, or other milk.
- 4 hours for breast milk
- 2 hours for clear (non particulate) and non-carbonated fluids.

Intravenous fluid

Perioperative fluid therapy is divided into replacement of pre-existing losses, provision of maintenance fluids and replacement of intraoperative and postoperative losses. Many factors alter the amount of fluid required in the perioperative period (Table 5). Wide variations in the impact of these factors exist between individuals. Fluid regimes must therefore be individualised for each patient.

REPLACEMENT OF PRE-EXISTING LOSSES

The fluid deficit to be replaced is the maintenance fluid requirement (multiplied by the hours since last oral intake) added to preoperative external and third space losses.

Table 5: Factors affecting perioperative fluid requirements

- | |
|---|
| <ul style="list-style-type: none"> ● Patient size, weight, body composition ● Preoperative fluid losses, hydration and volume status ● Co-morbid diseases, particularly sepsis, renal, cardiac and hepatic impairment ● Normal maintenance requirements ● Fever ● Temperature of environment ● Anaesthetic technique ● Type of operation ● Duration of operation ● Operative losses ● Neuro-hormonal stress response ● Postoperative losses ● Speed of return to oral intake |
|---|

Using the information in Tables 3 and 4 choose the most appropriate replacement fluid.

Normal maintenance requirement of fluid and electrolyte can be estimated at 1.5ml/kg/hr and is usually

replaced with normal saline or Hartmann's and 5% glucose. 4% glucose plus 0.18% saline is a satisfactory alternative.

Abnormal insensible losses must be included. Pyrexia increases insensible loss by 20% per degree Celsius rise in body temperature. Note normal insensible loss for an adult in a temperate climate is 1000ml/day. Fluid lost in this way is exhaled water vapour and electrolyte rich sweat.

Abnormal preoperative external losses are often from the gastrointestinal tract. As shown in Table 3 this fluid contains electrolytes and depletes the ECF. It is best replaced with crystalloid of similar composition, either normal saline or Hartmann's. Diarrhoeal losses may contain high concentrations of potassium.

Third space losses describes the loss of fluid from the intravascular compartment secondary to increased capillary permeability found in conditions such as sepsis and trauma. Some of this fluid forms oedema in the surgical field, some is lost into the bowel lumen and some into the peritoneal cavity. These losses contain equivalent electrolyte concentrations but a lower protein concentration compared to extracellular fluid. These losses are best replaced during resuscitation by a combination of normal saline or Hartmann's and colloids.

The fluid volume required to replace pre-existing losses is difficult to estimate as the losses are hard to measure accurately. Third space losses are notoriously difficult to assess and may continue to increase until the patient starts improving. Therefore fluid replacement must be dynamic, based on the patient's response, and not simply based on one set of observations or predictions. Rate and volume of fluid administration must be adjusted to achieve physiological goals that suggest correction of intravascular volume and hydration status (refer to tables 1 and 2).

Blood loss is replaced initially with 3ml of normal saline or Hartmann's per ml of blood lost. Colloid may also be used in a ratio of 1ml colloid per ml blood lost. After the Hb falls to less than 7.5g/dl blood transfusion may be required.

PERIOPERATIVE LOSSES

During the operation, anaesthesia and surgery affect fluid balance. General anaesthesia causes significant vasodilatation and varying degrees of myocardial suppression. Positive pressure ventilation will reduce venous return and cardiac output. Vasodilatation produced by sympathetic blockade following spinal and epidural anaesthesia will also reduce preload and blood pressure.

Surgery has a number of influences on intraoperative and postoperative fluid balance. These include bleeding, third space losses, evaporative losses from exposed surfaces, fluid sequestration in obstructed or adynamic bowel, patient

positioning, and the neuro-hormonal or stress response. The physiological stress response to surgery or trauma causes a rise in the levels of circulating catecholamines, aldosterone, cortisol and antidiuretic hormone (ADH). This catecholamine and steroid release results in water and sodium retention post-operatively. Because relatively more water is retained than sodium there is a risk of post-operative hyponatraemia, particularly if an excess of non-sodium containing fluids are given.

Third space losses caused by alterations in endothelial function leading to fluid extravasation are very variable. Major influences are the extent of the surgery and the presence of any complications such as sepsis.

PLANNING A FLUID REGIME

Minor body surface surgery

Patients undergoing elective minor surgery often do not need supplementary intravenous fluids perioperatively unless there are additional factors suggesting a delay in return to oral intake or poor preoperative hydration. Some anaesthetists start IV fluids even in this group to ensure optimum hydration and as a route for drug administration, but there is no clear benefit.

Intermediate surgery (*eg bilateral inguinal herniae*)

More significant surgery is associated with a longer postoperative recovery and in some patients significant delays in re-establishing oral intake, particularly in the elderly and those with postoperative nausea and vomiting. Fluids may be given only during surgery or continued for a few hours postoperatively.

Major surgery (*including all laparotomies*)

All patients require supplementary IV fluid during and after surgery. The amount required is dependent on the patient's condition, the type of surgery, anaesthesia and the degree of the stress response. Estimate the preoperative losses and perioperative maintenance requirements and then add an amount to replace additional losses in theatre (estimated blood loss, third space, evaporation etc). Construct a regime which should then be adjusted according to physiological targets.

Long, complex bowel surgery will require much more intravenous fluid replacement than a simple hysterectomy. Blood loss may be similar in both operations, but the bowel surgery is likely to be followed by more tissue swelling, oedema and bowel dysfunction (third space). A large wound will result in more evaporative losses (and cooling), and further third space losses. Giving exact figures for specific operations is not possible.

All laparotomies will require replacement of preoperative losses, and then an estimated volume added for intraoperative replacement. Most laparotomies will therefore receive 10 - 20 mls/kg/hour of Hartmann's

during surgery as a baseline, increased for larger operations (20-30mls/kg/hr). This fluid replaces maintenance, third space losses and evaporative losses, but estimated blood loss will need to be replaced in addition. Fluids must be targeted against physiological parameters.

During straightforward surgery in fit patients physical assessment combined with measurement of blood loss is sufficient to guide fluid therapy (i.e. pulse rate, arterial blood pressure, respiratory rate, urine output, JVP and capillary return). Measurement of haemoglobin concentration using a HaemoCue is also useful.

Patients with significant underlying disease, or those undergoing operations during which large volume shifts are anticipated, should have supplemental invasive monitoring. Suggested physiological goals to be achieved are given below:

- Normal pulse rate (<100/min)
- Normal blood pressure (within 20% of normal)
- Urine output 0.5-1ml/kg/hr
- CVP 6-12 cm H₂O
- Normal pH, PaO₂, base excess, serum lactate
- Haemoglobin > 7.5 g/dl - fit patients; >9g/dl in patients with ischaemic cardiac disease.
- Where advanced monitoring, such as oesophageal Doppler is used, measurement of flow is possible and fluids may be targeted to maintain cardiac output.

POSTOPERATIVE LOSSES

Postoperative losses should be replaced in a similar way to preoperative losses. Maintenance requirements, abnormal insensible losses, visible external losses (via NG tube, vomiting, lower GI tract, urinary tract and drains), third space loss and concealed blood loss should all be measured or estimated. Because of the risk of hyponatraemia during this phase, Hartmann's solution or a combination of 2 litres of normal saline with 1 litre of glucose per day are appropriate maintenance regimens. As during other times in the perioperative period, fluid administration should be regularly reassessed and adjusted according to physiological goals.

COMMONLY ENCOUNTERED POSTOPERATIVE PROBLEMS

Hypotension

Postoperative hypotension is most commonly due to hypovolaemia but may also be caused by sepsis or cardiac dysfunction. Early treatment is needed to prevent subsequent vital organ dysfunction. Initial steps in management of patients with postoperative hypotension are assessment of the intravascular volume status and fluid replacement where appropriate.

Fluid resuscitation should be titrated to clinical end points of arterial blood pressure, heart rate, urine output, skin perfusion, together with indices of tissue perfusion such as blood lactate concentrations. Invasive monitoring may be required.

Once fluid resuscitation is adequate, if hypotension is still an issue, inotropic or vasopressor therapy may be required. If sepsis is suspected noradrenaline (0.02 - 0.8 microgram/kg/min) is the first line agent for increasing blood pressure in a patient with clinical signs of shock and hypotension not responsive to aggressive fluid challenge. Dopamine (2 - 10microgram/kg/min) and adrenaline (0.02 - 0.8 microgram/kg/min) are alternatives. Adverse effects of gut hypoperfusion and lactic acidosis are common with adrenaline. Prior to commencing vasopressors, patients must be fully volume resuscitated with the CVP within the normal range. For patients with cardiac failure dobutamine (2 - 15microgram/kg/min) is an alternative, but if used during anaesthesia often results in vasodilatation and hypotension.

Low urine output

Postoperative urine output should be at least 0.5ml/kg/hr. Oliguria and renal impairment may be caused by pre-renal, renal or post-renal problems.

Pre-renal and post-renal problems predominate in the postoperative period. Common pre-renal causes include hypovolaemia, cardiac dysfunction and septic shock. Post-renal causes of urethral prostatic and bladder neck obstruction are all relieved by urethral catheterisation. Renal failure may be caused by renal disease such as acute tubular necrosis, glomerular or interstitial nephritis, and diabetic nephropathy. It is also caused by toxicity from myoglobin, radio contrast media and certain drugs (NSAIDS, ACE inhibitors and aminoglycoside antibiotics).

Management of low postoperative urine output is aimed at treating or removing any underlying cause of renal impairment and ensuring adequacy of intravascular volume and renal perfusion via restoration of adequate blood pressure and volume. Complications of renal impairment include fluid retention, causing peripheral and pulmonary oedema, hyperkalaemia and metabolic acidosis. These may be severe enough to warrant renal replacement therapy.

Hyponatraemia

Extracellular water and electrolytes are under hypothalamic control. Osmoreceptors in the anterior hypothalamus maintain plasma osmolality between 280 - 295mmol/kg by secretion of ADH. ADH or vasopressin reduce renal diuresis and cause retention of water. Hyponatraemia is a serum sodium of less than 135mmol/l and confusion

followed by convulsions and coma occurs in severe cases ($<115\text{mmol/l}$).

Preoperative low serum sodium may be the result of sodium loss or water excess. Hyponatraemia with decreased extracellular volume is caused by sodium and water loss through the kidneys (i.e. during the diuretic phase of renal failure, diuretic excess, osmotic diuresis secondary to hyperglycaemia and Addison's disease.). Other routes causing water and sodium loss include diarrhoea, vomit, small bowel obstruction and burns.

Postoperatively hyponatraemia is mostly associated with water overload due to an over reliance on dextrose-containing fluids and ADH secretion as part of the stress response to surgery. It may also be a feature of nephrotic syndrome, cardiac failure and hepatic failure. The syndrome of inappropriate ADH secretion (SIADH) is diagnosed by finding a concentrated urine (sodium $> 20\text{mmol/l}$) in the presence of hyponatraemia (serum sodium $< 125\text{mmol/l}$), or low plasma osmolality ($<260\text{mmol/l}$) and the absence of hypovolaemia.

Treatment of hyponatraemia is of the underlying cause. If a patient is not dehydrated and renal function is normal, then sodium of more than 125mmol/l rarely requires treatment. If the serum sodium is less than 125mmol/l and the patient is not dehydrated, then water restriction of 0.5 - 1 litre per day is indicated. If the patient is dehydrated, then normal saline is normally used. Gradual increase in serum sodium helps to avoid heart failure and neurological complications (central pontine myelinosis).

Hyperkalaemia

Hyperkalaemia ($\text{K}^+ > 5.3\text{mmol/l}$) occurs in severe dehydration, renal failure, diabetic ketoacidosis, excess potassium therapy, transfusion of large volumes of old blood, severe tissue damage (rhabdomyolysis, burns) and malignant hyperthermia. $\text{K}^+ > 6.5\text{mmol/l}$ may cause fatal cardiac arrhythmias and therefore needs urgent treatment. Temporary treatment measures include:

- Intravenous fluids if the patient is dehydrated.
- 10mls 10% calcium gluconate to improve cardiac rhythm stability.
- 25 units of actrapid insulin IV with 50mls of 50% dextrose to increase the transport of potassium into cells - monitor blood sugar regularly)
- Sodium bicarbonate 50mls of 8.4% to correct any acidosis and shift potassium into cells.
- 5mg nebulised salbutamol
- Sulphonate resins 15g orally 6 hourly or 30g rectally to aid excretion of potassium by intestinal route.

These measures provide a temporary reduction in K^+ . Management priority is to try to treat the underlying cause and ensure optimal hydration. A minority of patients require urgent renal replacement therapy in the form of dialysis or haemofiltration.

Hypokalaemia

Hypokalaemia is often due to diuretics or diarrhoea. Other common causes in the post operative period include GI dysfunction and insufficient intake (normal daily requirement is 1mmol/kg). Symptoms are lethargy, weakness, ileus and cardiac arrhythmias. Treatment is with potassium chloride supplementation, preferably given orally if tolerated. Intravenous therapy should be given at a rate no more than 40mmol/hr with a concentration no more than 40mmol/l , unless given via a CVP line with ECG monitoring in place.

CASE HISTORIES

The three case histories given below illustrate some of the principles and variations in perioperative fluid requirements. For each case a brief description is given including relevant background information.

Fluid management for an elective laparoscopic cholecystectomy

- Fit 43 year old female, weighing 80kg.
- Clear oral fluids until 2 hours preoperatively.
- Total blood loss approximately 30mls.
- Operation duration 1 hour.

Fluid regime

During surgery there was no significant blood loss and tissue oedema and third space losses are minimal. Therefore fluid replacement only needs to cover pre-operative deficit and maintenance requirements. These are approximately:

- Normal hourly maintenance = $1.5\text{ml/kg/hr} = 120\text{mls/hr}$
- Pre-operative deficit = 2 hours $\times 120\text{mls} = 240\text{mls}$
- Maintenance fluid during operation = 1 hour = 120mls
- Allowance for third space loss / evaporation $5\text{mls/kg} = 400\text{mls}$
- Total: maintenance + replacement = 760mls Hartmann's
- Ongoing postoperative maintenance fluids (until tolerating oral fluids) = 120mls/hour.

In most operations of this type fluid balance is not exact and most anaesthetists would give a litre of Hartmann's (or saline 0.9%) during surgery followed by a further litre of Hartmann's and then glucose 5%, both at 120mls/hour. However the method of calculating a suitable fluid regime is demonstrated.

Fluid management for an elective bowel resection

- Fit 70 year old man, weight 80kgs
- Preoperative Hb 12g/dl
- Has been nauseated overnight and had no oral intake for 8 hours.
- Received enema to prepare bowel resulting in diarrhoea overnight.
- Total blood loss: 1000mls
- Operation duration 3hours.

Fluid regime

Preoperative deficits and maintenance fluids need replacing, but in addition there has been significant blood loss and third space losses. As only one third of infused crystalloids remain in the intravascular compartment, crystalloid replacement volume should be 3 times the blood volume lost. This patient would have a blood volume of around (70mls X 80kg = 5600mls). Measured blood lost is around 20% of the blood volume and so the postoperative Hb will be around 9 - 9.5g/dl which is acceptable.

- Normal maintenance rate = 80kg x 1.5ml/hr = 120ml/hr
- Pre-operative deficit = 8 hours x 120mls = 960mls
- Maintenance fluid during operation = 120mls x 3 hours = 360mls
- Other losses include diarrhoea of an unknown amount - estimate 1000mls.
- Replacement of 1000mls blood loss
 - can be with 1000mls of colloid or 3000mls of Hartmann's.
- Third space losses estimated = 10ml/kg/hr for first hour then reducing to 5mls/kg/hr thereafter = 1600mls
- Total - approximately 6000mls over 3 hours

As can be seen this patient requires a substantial volume of IV fluid and it is difficult to replace volumes accurately. Following trends in clinical signs as described above will assist fluid therapy. Inadequate volume replacement results in hypotension, poor tissue perfusion and cellular dysfunction. Although it is important not to fluid overload patients, this is rarely a problem perioperatively. In unfit patients undergoing this degree of surgery, CVP monitoring is useful.

Postoperatively the patient will require higher than normal fluid volumes as fluid will tend to gather in the bowel which will not function, and oedema in the area of surgery will sequester fluid. Fluid replacement should be primarily with Hartmann's or saline 0.9% during the first 24 hours and K⁺ should be added on the following day. Fluid replacement should be reassessed every 4 hours using the clinical signs described earlier.

Fluid management for an emergency laparotomy

- 65 year old female with occasional angina weighing 70kgs
- Pain for 24 hours, no oral intake during this time
- Pulse 120/min, BP 90/60, poor capillary refill
- Preoperative Hb: 16g/dl, Na 143, K5.4, creatinine 153, Urea 10.4
- Scheduled operation: laparotomy and bowel resection for faecal peritonitis.

This patient is very complex and fluid management will be difficult. Estimating preoperative losses is difficult as she has had no fluid for 24 hours and also will have a lot of intra-abdominal fluid due to her faecal peritonitis. Her Hb and urea are raised with her existing fluid deficit. Fluid replacement will be based on her clinical signs, invasive monitoring and the response to volume loading.

Preoperative intervention: 1 litre colloid and 2 litres crystalloid over 2 hours.
Two large IV cannulae
CVP line
Urinary catheter
Arterial line

Intraoperative blood loss: 700mls
Operation duration 2 hours

Calculations

This is a complex case and calculations will be very inaccurate. In addition to maintenance fluids and replacement of blood loss, there are uncertain preoperative deficits and significant third space losses relating to the surgery and sepsis (estimate as 10-20 mls/kg/hr)

Titrate fluids to restore HR, BP, capillary refill, CVP and urine output to normal levels. Watch the Hb level as resuscitation continues as it is likely to drop. Postoperatively this lady will require increased fluids, and with a recovering peritonitis will have large fluid shifts due to loss of fluid into the abdomen.

- Preoperative deficit = uncertain. Management as described under preoperative resuscitation, based on physiological response of patient.
- Maintenance rate over the 2 hours of surgery titrated to maintain observations at a normal level.
- Replacement of 700ml intraoperative blood loss = replaced by colloid or crystalloid.
- Replacement of third space losses during the 2 hour operation will depend on the physiological signs intraoperatively.

- Postoperatively the losses will continue and fluid requirements will be high and difficult to assess, but are likely to add 50% to the maintenance requirements for the first 2 days.

SUMMARY

Fluid balance is an important area of perioperative medicine. The primary goals are to maintain an effective circulating volume, preserve oxygen delivery to the tissues and maintain electrolyte homeostasis. Appropriate management requires careful consideration of pre-, per- and post-operative factors on an individual patient basis. Basic knowledge of the physiology relevant to fluid management is required. This includes the constituents

and features of commonly used intravenous fluids and an understanding of the neuro-hormonal response and third space fluid loss. Well-informed decisions and management plans made on an individual patient basis reduce patient morbidity and mortality.

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