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THE PERI-OPERATIVE FLUID THERAPY PROTOCOL FOR A PATIENT UNDERGOING A MAJOR SURGICAL PROCEDURE: A REVIEW ON AN IDEAL AND SAFE PERIOPERATIVE FLUID MANAGEMENT POLICY

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Abstract:

Surgery does not mean operation only. It is the total evaluation of the patient along with the appropriate and comprehensive management of the specific surgical condition altogether make the surgery an 'Art'. As surgeons we are immensely privileged that we are being trusted by people who often have no previous knowledge of us to make decisions on their behalf, carry out necessary measures or action, where someway or other slight lack of vigilance or any negligence at any step in the total process of management may result in various morbidities and might even cost their life.

This, on the other hand, imposes a huge responsibility upon the surgeons and that every surgeon must be very vigilant in his all and every step which starts pre-operatively and continues over the subsequent whole management process till the smooth and uneventful post-operative recovery period. It includes, establishment of a normal (or at least near normal) homeostatic status and it's maintenance is highly desirable in the whole peri-operative period. To assess the preoperative volumaeic status of the patient accurately and to replace any existing fluid or electrolyte deficiency as well as any other ongoing losses during the intra or per-operative as well as during the post-operative period, if any, it's proper and appropriate replacement or correction is of fundamental importance for every successful surgery.

Introduction :

Enormous honour and respect, sympathy and responsibility for each and every individual patient, is the unique quality to be possessed by any ideal surgeon. Even before a patient enters the operation theatre, a responsible, experienced and competent surgeon should be aware of the details of the patient that includes identification and the original disease process, latest state of the patient's disease status, the overall general and systemic conditions etc. and all. Depending on these criteria, he (the surgeon) works out a well planned, appropriate and unique surgical operation, often with some creative modification, as expected & only if needed. A responsible surgeon would start the process pre-operatively, ensuring that the correct patient has been brought to surgery in the best possible physiological, medical and psychological condition and when these criteria are satisfactory enough only then the surgeon should think of the next steps. However in relevance to the title of this review article, we would confine our discussion to only one but very important and vital topic of peri-operative fluid and electrolyte therapy — a safe and scientific protocol, which influences and is being intimately involved in each and every step of a successfully accomplished surgical operation. [1-3]

Understanding the basic patho – physiology of the disease process and the nature and extent of the planned surgery are important in outlining treatment, the mainstay of which is the Fluid Replacement Therapy consisting of : a) appropriate nature (blood or blood products, crystalloids or colloids etc, or other types), b) accurate (as close as possible) amount or volume, to be given over a defined period of time or rate.

Calculation of the daily prescription of fluid is actually like an arithmetic exercise to balance the input and output of water and electrolyte and the principles of it consist of :

- Replacement of normal maintenance requirements.
- Correction of pre-existing fluids deficits.
- Replacement of abnormal losses resulting from underlying pathology including surgical fluid losses (blood losses and other fluid losses).[3,4]

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And all that it need is a proper understanding of fluid and electrolyte management on the basis of the extent and composition of various body fluid compartments. It is to be noticed that for different practical purposes several self-evident but important generalizations have been there for different solutions for intravenous infusions. These bio-physiological patterns have been explained below by two rule for the convenience or better understanding of the subsequent discussion.

Rule-1

All infused Na+ remains in the ECF, Na+ cannot get access to the ICF because of the sodium pump. Thus, if saline 0.9% is infused, all Na+ remains in the ECF. As this is an isotonic solution, there is no change in ECF osmolality and therefore no water exchange occurs across the cell membrane. Thu, 0.9% expands ECFV only. However, if saline 1.8%is administrated, all Na+ remains in the ECF, its osmolality increases and water moves from ICF to ECF to maintain osmotic quality.

Rule-2

Water without sodium expands the TBW. After infusion of a solution of glucose 5%,the, glucose enters cells and is metabolized, The infused water enters both ICF and ECF in proportion to their initial volumes. Table 1.1 illustrates the results of infusion of 1 L of saline 9%, saline0.45% or glucose5% in a 70kg adult.

Discussion:

The basic idea behind determination of all these clinical as well as laboratory indices and their objectives as discussed aim at the determination of the pre-operative homeostatic or volumetric status of a patient which would in turn guide the subsequent pre-operative fluid therapy or practical fluid balance more scientifically.[2-5]

Table-1.1

Compartmental expansion resulting from infusion of I L of 0.9%, saline 0.45%or glucose 5%.

Intravenous infusion of 1000 ml	Change in Volume (ml) ECF	ICF	Remarks
Saline 0.9%	+1000	0	Na+ remains in ECF
Glucose 5%	+333	+666	66% of TBW is ICF
Saline 0.45%	+666	+333	33% of TBW is ECF

Normal Maintenance Needs :

Regardless of the disease process, water and electrolyte losses occur in urine and as evaporative losses from skin and lungs. It is evident from figure 1.1 that a normo-thermic 70 kg patient with a normal metabolic rate may lose 2500 ml of water per day. Allowing for a gain of 400ml from water of metabolism, hypothetical patient needs 2000 ml day-1 of water. As a rule of thumb, a volume of 30-35 ml kg -1 day-1 of water is a useful estimate for daily maintenance needs.[6-8]

Sodium. The normal requirement is 1 mmol kg-1 day-1 (50-80 mmol day-1) for adults.

Potassium. The normal requirement is 1 mmol kg-1 day-1 (50-80 mmol day-1) for adults.

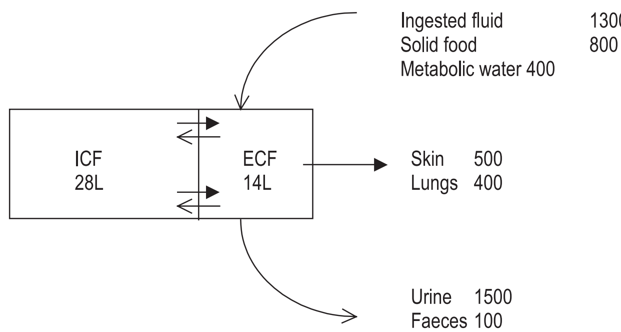

Fig.- 1.1 : *Daily water balance. Input and Output in ml.*

The basic physiology and the applied bio-physiological principle of commonly used intravenous fluids :

Table- 1.2

Composition [fluid & electrolyte content] and osmolality of the commonly used intravenous fluids.

Solution	Electrolyte content(mmol L-1)				Osmolality (mosmol kg-1)
Saline 0.9%	Na^+	154	C^{l-}	154	308
(“normal saline)					
Saline 0.45%(‘half-	77	Cl^-	77	154	
normal saline’)	Na^+				
Glucose 4%/saline0.18%	31	Cl^-	31	284	
(glucose-saline)	Na^+				
Glucose 5%		Nil			278
Compound sodium	Na^+	131	Cl^-	112	281
lactate (Hartmann’s	K+	5	HCO^-_3	29	
solution)	Ca^{2+}	4 As lactate			

Thus a 70kg patient requires daily provision of 2000-2500 ml of water and approximately 70 mmol each of Na^+ and K^+. This could be administered as one of the following:

- 2000 ml of glucose 5% +500 ml of saline 0.9%
- 2500 ml of glucose 4% saline 0.18%; plus potassium as KCL,

1g(13 mmol) added to each 500 ml of fluid. In Table 1.2 some commonly used intravenous fluid has been described.

Normal Maintenance Requirements :
In the absence of oral intake, fluid and electrolyte deficits can rapidly develop as a result of continued urine formation, gastrointestinal secretions, sweating and insensible losses from the skin and respiratory tract. Normal maintenance requirements can be estimated from table 1.3. Solutions such as $D_5{}^{1/4}$NS and $D_5{}^{1/2}$NS are most commonly used because these losses are normally hypotonic (more water loss than sodium loss).[4,5,9,10]

Table 1. 3
Estimating maintenance fluid requirements

Weight	Rate
For the first 10 kg	4ml/kg/h
For the next 10-20 kg	Add 2ml/kg/h
For each kg above 20 kg	Add 1ml/kg/h

Example: What are the maintenance fluid requirements for a 25-kg child?
Answer: 40+20+5=65 ml/h

Pre-Existing Deficits:
In elective surgical cases, patients present to surgery after an overnight fast without any fluid intake would have a preexisting deficit proportionate to the duration of the fast. This deficit can be estimated by multiplying the normal maintenance rate by the length of the fast.

Thus following the above mentioned 2nd protocol for determining the normal maintenance fluid requirements, for the average 70kg person fasting for 8hours, this amounts to =(40+20+50)ml/hour X 8hours = 880ml (In reality this deficit will be somewhat less as a result of renal conservation)

However in surgical emergencies the amount of pre existing deficit might be huge due to the amount of abnormal losses in addition to normal sensible and insensible losses. Like in cases of intestinal obstruction fluid and electrolyte losses due to

- vomiting
- Defective absorption (in addition to ingested fluid and contents of saliva, gastric juice, bile, pancreatic juice.and intestinal secretion itself) all of which are rich in fluid and electrolytes.
- Increased secretion and sequestration (as intestinal secretion is stimulated with the distension of the guts) into the bowel. and other factors.
- Third space loss due to oedamatous thickening of the intestinal wall itself.
- In advanced cases, leakage of fluids from gut wall to pathological increase in permeability and loss of normally protective gut wall barrier due to strangulation.[11-13]

Table 1.4
Electrolyte content of body fluids.

Fluid		Na^+(mEq/L)	K^+(mEq/L)	Cl (mEq/L)	HCO_3(mEq/L)
Sweat		30-50	5	15-55	
Saliva		2-40	10-30	6-30	30
Gastric Juice	High acidity	10-30	5-40	80-150	5-25
	Low acidity	70-140	5-40	55-95	
Pancreatic secretions		115-180	5	55-95	60-110
Billiary secretions		130-160	5	90-120	30-40
Ileal fluid		40-135	5-30	20-90	20-30
Diarrhoeal stool		20-160	10-40	30-120	30-50

Similarly in cases of perforation of duodenal ulcer or inflammation of intra abdominal viscera like appendix, gall bladder and particularly acute pancreatitis offer would also be huge abnormal losses and therefore, preexisting deficit as clinico-pathogeological feature of the patient. In acute surgical emergencies like the above mentioned conditions,variable sources of abnormal (often massive) fluid losses definitely contribute to the pre-existing deficits.[14]

In other pre-operative cases, bleeding (source upper or lower gastro-intestinal tract), Vomiting (acute cholecystitis, acute pancreatitis, acute peptic ulcer or gastritis), diuresis (diuretic phase of renal failure) or diarrhea in (acute Chrons' disease, acute ulcerative colitis, pelvic abscess, ca-rectum, villous adenoma), in addition invisible losses due to fluid sequestration, 3rd space losses in traumatized or inflammed/infected/ gangrenous tissues and ascitis (mostly exudative often transudative) etc can also produce substantial pre existing losses and these losses is usually directly proportional to the duration i.e. time of onset of the acute episode, type of the pathology, previous replacement therapy etc, etc. and as the surgical emergency remains untreated (properly) and the pathological process proceeds, subsequently to SIRS ultimately shock supervene which may initially be hypovolumic and, if not treated, invariably proceeds to septicaemia, septic shock syndrome and finally definitive septicaemic shock supervene.As they do so increased insensible losses like toxaemic fever, hyperventilation, sweating would add to the pre-existing deficit that should not be overlooked. The usual insensible loss of.5 ml/kg/hour increases by 12% for each degree Celsius rise in body temperature.[15]

The difficulty in correcting these deficits relates to an inability to quantify (also qualify) their magnitude accurately. The earlier topic of "Determination of the Homeostatic or Volumetric Status(ICF or ECF) would come into appropriate application here and would give the surgeon some confidence in outlining the fluid loss in terms of :

- Fluid loss expressed as percentage of body weight
- Clinical indices of extent of Intravascular (Blood) loss.
- Indices of extent of loss of Extra cellular fluid

Assessment of dehydration

This is a clinical assessment based upon the followings: History: how long the patient had abnormal loss of fluid? How much has occurred, e.g. frequency of vomiting?

Examination: Specific features are thirst, dryness of mucous membrane, loss of skin turgor, orthostatic hypotension or central jugular venous pressure (JVP) or central venous pressure (CVP) and decreased urine output. In the presence of normal renal function, dehydration is associated usually with a urine output of less than 0.5 ml kg-1h-1. The severity of dehydration may be described clinically as mild, moderate or severe and each category is associated with the following water loss relative to body weight.

- Mild: loss of 4% body weight (approximately 3 L in a 70 kg patient) – reduced skin turgor, sunken eyes, dry mucous membrane.
- Moderate: loss of 5-8% body weight (approximately 4-6 L in a 70 kg patient) – oliguria, orthostatic hypotension and tachycardia in addition to the above.
- Severe: loss of 8-10% body weight (approximately 7L in a 70kg patient) – profound oliguria and compromised cardiovascular function.

Laboratory assessment:

The degree of haemoconcentration and increase in albumin concentration may be helpful in the absence of anaemia hypoproteinaemia. Increased blood area concentration and urine osmolality (>630 mosmol kg-1) confirm the clinical diagnosis. [4-6,11]

The history (in details) physical/clinical examination along with the mentioned Laboratory investigation and haemodynamic studies are the basic in outlining the corrections.[4-6,11]

Most of the preexisting deficit or losses are from the gut in surgery. Although the compositions of gastrointestinal secretions are variable (Table 1.4), replacement should be with

- Saline (0.9% NaCL)
- 13-26 mmol of K^+/L

However, if the losses are considerable (>1000ml/day) a sample of the appropriate fluid should be sent for biochemical analysis so that the electrolyte replacement may be rationalized.

Also to be remembered that in most of the surgical losses (GIT), fluid and electrolyte deficit occur directly from the ECF. If the fluid lost is isotonic, only ECFV is reduced; if however, water alone or hypotonic fluid is lost, redistribution of the remaining TBW occurs from ICF to ECF to equalize the osmotic forces.(Rule-1 & 2). However, in general, dehydration with accompanying salt loss is the common disorder in surgical patients.

Ideally, all pre existing deficits should be replaced preoperatively in all patients. The fluids used should be similar in composition of the fluid lost as assessed from the table –1.4.

Intra Or Per-Operative Fluid Loss And It's Correction :

Intra operative Fluid (mainly blood) loss and it's replacement indication : the protocol of blood transfusion

Ideally, blood loss should be replaced with crystalloid or colloid solution to maintain intravascular volume (normovolemia) until the danger of anemia outweighs the risk of transfusion. At that point, further blood loss is replaced with transfusion of red blood cells to maintain hemoglobin concentration (or haematocrit) at that level. For most patients, that point corresponds to a hemoglobin between 7 and 8 g/dL (or a haematocrit of 21 -. 24%).

Below a hemoglobin concentration of 7 g/dL, the resting cardiac output has to increase greatly to maintain a normal oxygen delivery. A level of 10 g/dL is generally used for elderly patients and those with significant cardiac or pulmonary disease. Higher limits may be used if continuing rapid blood loss is expected.

In practice, most clinicians give lactated Ringer's solution in approximately three to four times the volume of the blood lost, or colloid in a 1:1 ratio, until the transfusion point is reached. At that time, blood is replaced unit for unit as it is lost, with reconstituted packed red blood cells.

The transfusion point can be determined preoperatively from the haematocrit and by estimating blood volume (table. 1.5) Patients with a normal haematocrit should generally be transfused only after losses greater than 10-20% of their blood volume. The exact point is based on the patient's medical condition and the surgical procedure.

Table-1.5

Average blood volumes.

AGE	BLOOD VOLUMES.
Neonates	85 to 95 ml/kg.
Infants	80 ml/kg
Adults :	
Men	75ml/kg.
Women	65ml/kg.

The amount of blood loss necessary for the haematocrit to fall to 30% can be calculated as follows:

(1) Estimate blood volume from Table 1.5.

(2) Estimate the red blood cell volume (RBCV) at the preoperative haematocrit ($RBCV_{preop}$).

(3) Estimate red cell volume at a haematocrit of 30% ($RBCV_{30\%)}$, assuming normal blood volume is maintained.

(4) Calculate the red cell volume lost when the haematocrit is 30%; $RBCV_{lost} = RBCV_{preop} - RBCV_{30\%}$.

(5) Allowable blood loss = $RBCV_{lost}$ X 3.

Example:

An 85 kg woman has a preoperative haematocrit of 35%. How much blood loss will decrease her haematocrit to 30%?

Estimated blood volume = 65mL/kg x 85 kg=5525 mL.

$RBCV_{35\% =}$ 5525x35%=1934mL.

$RBCV_{30\%}$ = 5525 x 30% = 1658 mL.

Red cell loss at 30% = 1934-1658=276mL

Allowable blood loss= 3 x 276mL=828mL

Therefore, transfusion should only be considered when this patient's blood loss exceeds 800mL. Increasingly, transfusions are not recommended until the haematocrit decreases to 24% (hemoglobin < 8.0 g/dL), but one must take into account the rate of blood loss and co-morbid conditions, i.e. cardiac disease in which case transfusion might be indicated if only 800mL of blood is lost.

Other useful guidelines commonly used are as follows:

(1) one unit of red blood cell will increase hemoglobin 1g/dL and the haematocrit 2-3% (in adult); and

(2) a 10-mL/kg transfusion of red blood cells will increase hemoglobin concentration by 3 g/dL and the haematocrit by 10%.[7,8,10]

Replacing Redistributive & Evaporative Loss :

Since these losses are primarily related to wound size and the extent of surgical dissections and manipulations, procedures can be classified according to the degree of tissue trauma. These additional fluid losses can be replaced according to Table 1.6, based on whether tissue trauma is minimal, moderate or severe. [1,5,7,10]

Table 1.6[3,5,7,15]

Redistribution and evaporative surgical fluid losses

Degree of tissue trauma	Additional fluid requirement
Minimal (e.g. herniorraphy)	0 – 2 mL / kg
Moderate (e.g. cholecystectomy)	2 – 4 ml / kg
Severe (e.g. bowel resection)	4 – 8 ml / kg

Haematocrits of hemoglobin concentration reflect the ratio of blood cells or plasma, not necessarily blood loss; moreover, rapid fluid shifts and intravenous replacement after measurements. Haematocrit may be useful during long procedures or when estimates are difficult.

Other Fluid Losses:

Many surgical procedures are associated with obligatory losses of fluids other than blood. Such losses are due mainly to evaporation and internal redistribution of body fluids. Evaporative losses are most apparent with large wound and directly proportionate to the surface area exposed and the duration of the surgical procedure.

Sequestration of fluid at the site of operative trauma is a form of fluid loss which is common in surgical patients. Plasma-like fluid is sequestered in any area of tissue injury; its volume is proportional to the extent of trauma. This fluid is frequently referred to as 'third space' loss because it ceases to take part in normal metabolic processes. It represents an expansion of ECFV. Third-space losses are not measured easily. Sequestered fluid is reabsorbed after 48-72 h.

Internal redistribution of fluids –often called "third spacing" — can cause massive fluid shifts and severe intravascular depletion. Traumatized, inflamed, or infected tissue (as occurs with burns, extensive injuries, surgical dissections, or peritonitis) can sequester large amount of fluid in its interstitial space and can translocate fluid across serosal surfaces (ascitis) or into bowel lumen. The result is an obligatory increase in a non-functional component of the extra cellular compartment, as this fluid does not readily equilibrate with the rest of the compartments. This fluid shift can not be prevented by fluid restriction and is at the expense of both the functional extra cellular and the intracellular fluid compartments.

Intraoperative Fluid Replacement :

Intra-operative fluid therapy should include supplying basic fluid requirement and replacing residual preoperative deficit as well as intra-operative losses (blood, fluid redistribution, and evaporation). Selection of the type of intravenous solution depends upon the surgical procedure and the expected blood loss. For procedures involving minimal blood loss and fluid shifts, maintenance solution can be used. For all other procedures, lactated Ringer's solution or fluid is generally used even for maintenance requirements.

In addition to normal maintenance requirements of water and electrolytes, patients may require fluid in the peri-operative period to restore TBW after a period of fasting and to replace small blood losses, loss of ECF into the 'third space' and losses of water from the skin, gut and lungs.

Blood losses in excess of 15% of blood volume in the adult are usually replaced by infusion of stored blood. Smaller blood losses may be replaced by a crystalloid electrolyte solution such as compound sodium lactate; however, because these solutions are distributed throughout ECF, blood volume is maintained only if at least three times the volume o the blood loss is infused. Alternatively, a colloid solution (human albumin solution or a synthetic substitute) may be infused in a volume equal to that of the estimated loss.

Third space losses are usually replaced as compound sodium lactate. In abdominal surgery (e.g. cholecystectomy), a volume of 5 ml kg^{-1} h^{-1} during operation, in addition to normal maintenance requirements(approximately 1.5 ml kg-1h-1) and blood loss replacement, is usually sufficient larger volumes may be required in more major procedure, but should be guided by measurement of CVP.[1,5,7,10]

Post Operative Fluid Replacement:

In the postoperative period, normal maintenance fluid should be administered (see above). Additional fluid (given as saline 0.9% or compound sodium lactate) may be required in the following circumstances:

- If blood or serum is lost from drains (colloid solution should be used if losses exceeds 500ml)
- If gastrointestinal losses continue, e.g. from a nasogastric tube or a fistula
- After major surgery (e.g. total gastrectomy, repair of aortic aneurysm), when additional water and electrolytes may be required for 24-48 h to replace continuing third space losses
- During rewarming if the patient has become hypothermic during surgery.

Normally, potassium is not administered in the first 24 h after surgery as endogenous release of potassium from the tissue trauma and catabolism warrants restriction. The post operative patient differs from the ‘normal’ patient in that the stress reaction modifies homeostatic mechanisms; stress-induced release of ADH, aldosterone and cortisol causes retention of Na+ and water and increased renal excretion of potassium. However, restriction of fluid and sodium in the post operative period is inappropriate because of increased losses by evaporation and into the ‘third space’.

The syndrome of inappropriate ADH secretion may persist for several days in elderly patient, who are at risk of symptomatic hyponatraemia if given hypotonic fluid in the preoperative period. Elderly, orthopedic patients taking long-term thiazide diuretics are especially at risk if given 5% dextrose postoperatively. Such patient can develop water intoxication and permanent brain damage as a result of relatively modest reductions in serum sodium.

After major surgery, assessment of fluid and electrolyte requirements is achieved best by measurement of CVP and serum electrolytic concentrations. Fluid and electrolyte requirements in infants and small children differ from those in the adult.

Patients with renal failure require fluid replacement for abnormal losses, although the total volume of fluid infused should be reduced to a degree determined by the urine output.

Conclusion :

The basic idea behind determination of all these clinical as well as laboratory indices and their objectives as discussed aim at the determination of the pre-operative homeostatic or volumetric status of a patient which would in turn guide the subsequent fluid therapy or practical fluid balance more scientifically. Also important is, regardless of the method employed serial evaluations are necessary to confirm initial impression and guide the subsequent fluid therapy. Moreover, modalities should complement one another, because all parameters are indirect, non-specific measures of volume; reliance on any one parameter may be erroneous and, therefore, hazardous.

In the modern scientific era, there is no scope of lagging for us, specially with a basic and simple thing like this. Even within the constraining factors, we can start the scientific method of “ Determining the volumetric Homeostatic Status of the pre-operative – elective or emergency patient”, at least selectively initially (severely ill routine or emergency patients and patients of paying beds or cabins i.e. in one group where it is necessary and the other group who can afford financially). Later on this acadaemic practice/ culture may hopefully be carried out in all indicated patients – even can be made mandatory for all.

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