Perioperative Fluid Manangement

18

Anirban Hom Choudhuri and Kiranlata Kiro

Contents

A. H. Choudhuri (✉) · K. Kiro
Department of Anesthesiology and Intensive Care, GB Pant Institute of Postgraduate Medical Education and Research, New Delhi, India

M. L. N. G. Malbrain et al. (eds.), *Rational Use of Intravenous Fluids in Critically Ill Patients*, https://doi.org/10.1007/978-3-031-42205-8_18

IFA Commentary (MLNGM)

This chapter provides a comprehensive overview of the importance of fluid management in the perioperative period. The authors highlight the significance of fluid regulation in determining the outcome after surgery and emphasizes the importance of understanding the physiology of body fluids and composition of parenteral fluids for perioperative physicians. This chapter outlines the key considerations for fluid management, including calculation of fluid requirement, monitoring of volume status, prevention of hypervolaemia and differences between crystalloid and colloid use. The authors also discuss the use of different fluid administration strategies, including the liberal and restrictive approaches, and note that the choice of strategy will depend on the patient's specific condition. This chapter concludes by highlighting the key take-home messages, including the importance of continuous monitoring of fluid intake and output, the need for individualized approaches to fluid management and the need for special precautions in high-risk patients. Overall, this chapter provides a thorough and informative overview of perioperative fluid management and would be useful for healthcare professionals who are involved in the care of surgical patients. It is well-written and concise and presents information in a clear and organized manner, making it easy to follow and understand.

Learning Objectives

After reading this chapter, you will:

1. Understand the calculation of fluid requirement in the perioperative period based upon the duration of preoperative fasting, type and duration of surgery and extent of blood loss.
2. Learn how to monitor volume status during perioperative period and early detection of hypovolaemia.
3. Study the prevention of hypervolaemia and its associated complications.
4. Appreciate differences between crystalloid and colloid use in the perioperative period.
5. Understand restrictive versus liberal fluid administration strategy.
6. Learn about fluid administration in special situations like elderly, paediatrics and pregnancy.

Case Vignette

Mr. A (aged 50 years, weighing 60 kg) is admitted following subacute intestinal obstruction. The patient has been fasting for the past 24 h. He does not have any comorbid illness. During physical examination, he exhibits signs of hypovolaemia. The plain abdominal X-ray reveals multiple air–fluid levels in the small bowel, and abdominal CT indicates the presence of a jejunal obstruction. He is planned for emergency laparotomy after quick optimization.

Questions

Q1. How should one plan his fluid management during the perioperative period?

Introduction

The outcome after any surgery is dependent on multiple factors among which fluid regulation is an important consideration. The type, amount and rate of fluid administration are primarily determined by the nature of surgery, requirements and losses and coexisting morbidities, if present. Any fluid either too much too little can be of unfavourable consequence. Therefore, knowledge about the physiology of body fluids and the composition of the parenteral fluids is of paramount importance for the perioperative physician. The fluid management in surgical patients is handled jointly by the anaesthetist during surgery and the team monitoring patients' postoperative care.

Rudolph Matas in 1924 first proposed the administration of an intravenous 'drip' during surgery and this has been validated and advanced manifold since then by Moore and Shires in the 1940s and 1950s and by Shoemaker in the 1970s [1, 2]. Classically, perioperative fluid requirement calculations have been practiced according to the '4-2-1 rule' based on the Holliday and Segar method [3]. Over the years, further appreciation of the metabolic stress responses to surgery and physiological principles governing fluid regulation have brought much consistency and conformity to the fluid management protocols. This chapter will focus on adult patients, and more information on fluid therapy in children can be found in Chap. 20. Some other chapters will discuss fluids in specific populations: sepsis (Chap. 14), heart failure (Chap. 15), trauma (Chap. 16), neurocritical care (Chap. 17), burns (Chap. 19), liver failure (Chap. 21), abdominal hypertension (Chap. 22), and COVID-19 (Chap. 26).

Types Fluid

Based upon the patient's requirements, fluids can be of either *replacement* or *maintenance* type. *Replacement* fluids are necessary to treat existing deficits or compensate for ongoing losses during the perioperative period. The common replacement fluids used in the perioperative period include 0.9% sodium chloride (NaCl), Ringer's lactate, balanced salt solution and synthetic colloids. *Maintenance* fluids are those required for optimization of the ongoing losses due to physiological processes in order to maintain homeostasis. The common maintenance fluids are dextrose, dextrose–saline (5%D 0.9% NaCl%), dextrose–hypotonic saline (5%D 0.45%NaCl) and Isolyte solutions. Different crystalloids and synthetic colloids are discussed in more detail elsewhere in the book (see Chaps. 9, 10 and 11).

Calculation of Third-Space Loss

The loss occurring due to fluid shift from the intravascular to the extravascular compartment during surgery is known as third-space loss. This third-space loss follows oedema at the operative site and evaporation from surgical exposure. A lot of formulae are used to calculate third-space loss, although none can be claimed to be superior over the others. The simplest calculation is based upon the type of surgery:

(a) 4 mL/kg/h. for minor and moderate operations (e.g. hernia, hydrocele, cholecystectomy, plating and screwing for limb fractures)
(b) 8 mL/kg/h. for major and supra-major operations (e.g. abdominal hysterectomy, Whipple's procedure, craniotomy)
(c) The calculation may be also based on the amount of tissue handling or trauma during surgery as suggested in the following table (Table 18.1).

Table 18.1 Calculation of surgical third space loss based on tissue handling and/or trauma

Amount of tissue handling or trauma	Fluid requirement (mL/kg/h)
Mild (hernia repair/ophthalmic/otolaryngology procedures)	0–2
Moderate tissue handling (laparoscopic/gynaecologic/orthopaedic/neurosurgical procedures)	2–4
Major tissue handling (open abdominal surgery, e.g. bowel resection anastomosis)	4–8

Monitoring Intravascular Volume Status During the Perioperative Period

Since the purpose of fluid administration is to maintain optimal tissue perfusion, the intravascular volume status should be used to guide fluid therapy. Table 18.2 shows the common parameters (static and dynamic) used to guide fluid administration by determining the volume status.

Table 18.2 Monitoring volume status during the perioperative period with their advantages and disadvantages

Static parameters	CVP, PAOP, LVEDA, GEDV and ITBV
Advantages • Invaluable parameter in patient care • Marker of cardiac function and pressure gradient of organ perfusion	**Disadvantages** • Unable to differentiate between fluid responders and non-responders • Unable to predict effect of fluid administration prior to volume expansion • Only extreme values may be of some significance • Factors that increase intramural and transmural pressure (pump failure, valvular heart disease, dysrhythmias, PEEP, pneumothorax, asthma, intra-abdominal hypertension [IAH]) can affect values of CVP and PAOP. Volumetric indices are better in those conditions • Doppler- and echocardiography-mediated parameters need expert training
Dynamic parameters	**SVV, SPV, PPV, ABFV, PWV amplitude, SVC collapsibility and IVC distensibility index, EEO, tidal volume challenge**
Advantages • Useful indicators with high sensitivity and specificity in patients with stable cardiac rhythms having regular RR interval and undergoing elective mechanical ventilation with 8–10 mL/kg • Precede changes in cardiac output and blood pressure leading to earlier intervention	**Disadvantages** • Only reliable with tidal volume > 8 mL/kg because of non-linear relationship between chest wall compliance and intra thoracic pressure at lower tidal volumes • Increasing the number of breaths over which the dynamic indices are calculated can increase the values. This may be erroneous in many clinical devices that employs software to sample a defined time interval without identifying the number of breaths • Influenced by the presence of cardiac arrhythmias, viz. atrial fibrillation, premature ventricular contractions • Doppler- and echocardiography-mediated parameters need expert training

CVP central venous pressure, *PAOP* pulmonary artery occlusion pressure, *LVEDA* left-ventricular end-diastolic area, *GEDV* global end-diastolic volume, *ITBV* intrathoracic blood volume, *SVV* stroke volume variability, *SPV* systolic pressure variation, *PPV* pulse pressure variation, *ABFV* aortic blood flow variation, *PWV* plethysomographic waveform variation amplitude, *SVC* superior vena cava, *IVC* inferior vena cava, *EEO* end-expiratory occlusion test

Choosing Between Crystalloids and Colloids

Extracellular fluid (ECF) replacement is better replenished by crystalloids. The distribution of crystalloids in the extracellular (interstitial) space is theoretically three times that of the intravascular space. Hence, after administration of 1 L of crystalloid and after checking the volumes after 1 h, about 250 mL will be present in the intravascular compartment and about 750 mL in the extravascular compartment (interstitial space). Only a negligible amount of isotonic fluid fills up the intracellular compartment. However, excessive crystalloids can dilute the plasma proteins thereby reducing plasma oncotic pressure causing fluid filtration from the intravascular to the interstitial compartment. This can lead to complications like interstitial pulmonary oedema.

Colloids on the contrary, being larger in size have difficulty crossing the capillary membrane and are returned easily via the lymphatics. They stay much longer in the intravascular compartment, exert colloid oncotic pressure (COP) and are needed in much smaller volumes. But if the vascular permeability is increased due to any cause, they can reach the interstitial space and produce interstitial COP. This can exacerbate pulmonary oedema. They can also cause allergic reactions and are costlier than crystalloids. Therefore, a good option in perioperative patients is to administer the maximum amount of fluid as crystalloids until there is any risk of overload. However, the choice is best decided by the physician on an individual basis (Table 18.3).

Table 18.3 Theoretical distribution after 1 h of 1 L of different types of fluid administered

	Intracellular space	Interstitial space	Intravascular space
1 L of (ab)normal saline (0.9% NaCl) or isotonic (balanced) crystalloid	0	750	250
1 L of 5% dextrose (hypotonic)	667	250	83
1 L of 3% hypertonic saline	Decrease	>750	>250
1 L of colloid	0	0	1000

'Restrictive' Versus 'Liberal' Strategy

The choice between restrictive and liberal strategies for fluid administration is blurred with discrepancies and disparities in the definition, methodology and outcome variables. However, it is generally accepted that when total administered fluid exceeds 5 L/day, there is a trend towards increased mortality and morbidity, especially in patients undergoing high-risk surgery. Whenever possible, fixed fluid regimens of varying composition not exceeding 3 L/day can be safe. The actual amounts can vary depending on the volume status and response to incremental boluses. In surgical procedures where the risk of oedema is high, e.g. lobectomy and pneumonectomy, restrictive fluid regimes are strongly advocated. Table 18.4 shows findings of the landmark studies on restrictive and liberal fluid administration during the perioperative period.

Table 18.4 Important studies comparing liberal versus restrictive fluid administration during the perioperative period

Author and year	Design	Population	Intervention	Conclusion
Lobo et al. 2002 [4]	RCT	20 colon cancer	LG ≥3 L fluid +154 mmol Na/ day; RG <2 L fluid +77 mmol Na/day	↑weight gain, delayed recovery and ↑LOS in LG
Brandstrup et al. 2003 [5]	Multicentric RCT	172 elective colorectal surgery	LG: Preload 6% HES 500 mL; third space 7, 5, 3 mL/kg/h for the first, second and third hours, respectively. Fasting 500 mL NS. Blood loss 500 mL; 1:3 crystalloid and thereby vol to vol colloid. >1.5 L blood component depending on HCT RG: No preload/ third-space adjustment. Fasting 5%D 500 mL Blood loss vol to vol 6% HES thereby for >1.5 L blood loss; blood component based on HCT	Reduced complications after elective colorectal resection in RG
MacKay et al. 2006 [6]	RCT	80 colorectal surgery	Median IV fluid intake LG–RG = 8.75:4.5 L	Gastrointestinal recovery and duration of stay in the hospital was similar in the groups

(continued)

Table 18.4 (continued)

Author and year	Design	Population	Intervention	Conclusion
Holte et al. 2007 [7]	RCT	32 colonic surgery	Preload: LG 10 mL/kg/h, RG none Fluid protocol: LG 18 mL/kg RL in first hour followed by starch 7 mg/kg; PACU 10 mL/kg/h RL RG 7 mL/kg RL first hour followed by 5 mL/kg in subsequent hours; starch 7 mg/kg; PACU no fluids	Significant improvement in pulmonary function and postoperative hypoxaemia in RG group
Holte et al. 2007 [8]	RCT	48 knee arthroplasty	Preload: LG 10 mL/kg/h, RG none Fluid protocol: LG 30 mL/kg, RG 10 mL/kg with similar colloid and postoperative fluid orders	Significant weight gain, reduced incidence of nausea and hypercoagulability were observed in LG
Kabon et al. 2005 [9]	RCT	256 colonic resection	LG 16–18 mL/kg RG 8 mL/kg	No correlation with wound infection
Nisanevich et al. 2005 [10]	RCT	152 abdominal surgery	LG 10–12 mL/kg/h, RG 4 mL/kg/h RL	Episodes of hypotension > in RG treated by fluid bolus Weight gain observed in LG Delayed postoperative recovery and ↑ duration of stay in hospital in LG
Holte 2004 [11]	RCT	48 laparoscopic cholycystectomy	LG 40 mL/kg RL RG 15 mL/kg RL	Better pulmonary function, exercise capacity, reduced stress response, low nausea dizziness, fatigue, thirst and early discharge were observed in LG
Maharaj 2005 [12]	RCT	80 diagnostic laparoscopy	LG 2 mL/kg/h RG 3 mL/kg	Frequency of mild moderate or severe PONV was significantly less in LG Mean postop pain scores was less in LG

Table 18.4 (continued)

Author and year	Design	Population	Intervention	Conclusion
RELIEF trial 2018 [13]	RCT	3000 major abdominal surgery	LG–RG = 6100 mL: 3700 mL LG crystalloid 10 mL/kg followed by 8 mL/kg/h (may be reduced further after 4 h if required), 1.5 mL/kg/h for 24 h postoperative period RG ≤5 mL/kg at induction, followed by 5 mL/kg/h (esophageal Doppler or pulse wave analyser for fluid bolus in hypotension) and 0.8 mL/kg/h in first 24 h postoperative period preference of inotrope over fluids to treat hypotension if no evidence of hypovolaemia	No difference in rate of one-yr disability free survival between groups Higher rate AKI in RG (8.6% vs. 5%) Septic complication RRT similar in both groups Surgical site infection and RRT more in RG

RCT randomised control trial, *LG* liberal fluid group, *RG* restrictive fluid group, *PONV* postoperative nausea and vomiting, *AKI* acute kidney injury, *PACU* post-anaesthesia care unit, *RRT* renal replacement therapy, *HCT* haematocrit, *RL* Ringer's lactate, *NS* 0.9%sodium chloride, *5%D* 5% dextrose

Fluid Requirements in Special Situations

Neurosurgery [14]

Neurosurgical patients frequently receive diuretics in the preoperative period for reduction of intracranial pressure (ICP) and often have hypovolaemia intraoperatively following blood loss. All hypo-osmolar fluids like 0.45% saline or 5% glucose in water cause a reduction in plasma osmolality and water movement across the blood–brain barrier (BBB) into the brain tissue. Besides, glucose administration increases local and global ischaemia leading to neurological damage. Therefore, salt-free solutions containing glucose are best avoided in patients with brain and spinal cord injuries. During resuscitation of traumatic brain-injured (TBI) patients, hypertonic saline solutions are useful in reducing ICP and maintain cerebral perfusion pressure without producing an osmotic diuresis. This is discussed more into detail in Chap. 17.

Open-Heart Surgery [15]

Cardiac surgery, particularly procedures involving cardiopulmonary bypass (CPB), is associated with the activation of many complex physiological and biochemical pathways, making volume replacement complicated. The patient's underlying electrolyte status must be reviewed before choosing the fluid; potassium-containing fluids must be avoided in presence of hyperkalaemia. Excessive crystalloid administration is associated with volume overload and pulmonary oedema which are more likely in patients with a low ejection fraction. Colloids with the exception of albumin have the disadvantage of causing coagulation abnormalities (which is already deranged in CPB patients) and anaphylactic reactions and are only used in the pre-bypass period. In infants and children undergoing cardiac surgery, blood volume replacements are preferred over non-blood volume replacement regimens. Some studies have shown benefits in priming the CPB pump with colloids (plasma, albumin) to elevate the colloid oncotic pressure (COP).

Kidney [16] and Liver Transplant Surgery [17]

The determination of volume status in patients undergoing kidney transplant is a challenge and the conventional monitors can be misleading. The compensatory mechanisms that maintain effective vascular volume and tissue perfusion are obtunded in patients with end-stage kidney disease. The mean arterial pressure which adequately preserves the renal microcirculation is also difficult to ascertain. One approach is to follow the 'goal-directed therapy' (GDT) based upon dynamic indices. Another approach is the administration of fluid based on 'triggers' and is known as 'flow-directed theray' (FDT). In both cases, the change in cardiac output (CO) is used as an indicator to assess the effectiveness of therapy. After a given volume is administered, usually 500 ml of crystalloid, the CO response is checked; a 15% increase in CO with a CVP rise of at least 2 mmHg constitutes a positive response. When there is no positive response, other therapies can be tried (i.e. vasopressor and/or inotropic therapy to treat hypotension) (See also Chap. 14).

The patient undergoing liver transplant surgery has end-stage liver disease (ESLD) which is associated with low systemic vascular resistance (SVR) causing sodium and water retention by the kidneys. This increases the amount of total body fluid. But the presence of portal hypertension expands the splanchnic circulation leading to a fall in the relative amount of fluid in the systemic circulation. There is movement of protein-rich fluid into the body cavities causing ascites and pleural effusions. Moreover, the cross-clamping of inferior vena cava during surgery contributes to hypotension and renal dysfunction. Preoperative coagulopathy is common and haemorrhage can occur at any stage of the operation. Therefore, any excess of fluid administration should be avoided during surgery and a low CVP is desirable. The use of fresh frozen plasma, platelets and cryoprecipitate is commonly advocated to prevent coagulopathy and reduce risk of volume overload (See also Chap. 21).

Obstetric Surgery

Perioperative maintenance of adequate intravascular volume status is very important in pregnant patients. Usually, these patients are exposed to rapid volume fluctuations during caesarean section. Since spinal anaesthesia is commonly chosen for its rapid onset, minimal patient risk and negligible risk of fetal drug transfer, preloading is particularly important. Wollman and Marx [18] first described the concept of preloading, by administering 10–20 mL/kg of intravenous crystalloids in pregnant females around 15–20 min prior to spinal anaesthesia. But later studies showed that preloading can induce the release of atrial natriuretic peptide (ANP) which can damage the endothelial glycocalyx and lead to increased excretion of preload fluid from the intravascular compartment. To address these inconsistencies, the concept of co-loading gained acceptance. Co-loading is more appropriate physiologically as fluid administration coincides exactly with the time of maximal vasodilatory effect of spinal anaesthesia.

Pediatric Surgery [19]

Since children are very sensitive to even minor fluctuations in volume status, the clinical assessment is of greater significance. The losses in paediatrics can range from 1 mL/kg/h for a minor surgical procedure to as high as 15–20 mL/kg/h for major abdominal procedures. It may even go up to 50 mL/kg/h for surgery for necrotizing enterocolitis in premature infants. The younger the child, the greater is the relative proportion of losses because of the large ECF volume when compared with older children and adults. Third-space losses should be replaced with crystalloids (0.9% NaCL or LR). Box 18.1 shows the guidelines for administration of balanced salt solutions according to the child's age and extent of tissue trauma (See also Chap. 20).

Box 18.1 Guidelines for Fluid Administration in Children According to Age and Extent of Tissue Trauma

First hour (*plus* item 3 if applicable)

- 25 mL/kg in children ≤3 years.
- 15 mL/kg in children ≥4 years.

All other hours (*plus* item 3)

- Maintenance plus extent of tissue trauma (as per item 3).

Maintenance volume = 4 mL/kg/h.

Item 3

Mild tissue trauma (e.g. hernia, hydrocele, circumcision, tonsillectomy) → 2 mL/kg/h.

Moderate tissue trauma (appendicectomy, obstructed inguinal hernia, etc.) → 4 mL/kg/h.

Severe tissue trauma (tracheo-esophageal fistula, congenital diaphragmatic hernia, etc.) → 6 mL/kg/h.

Both hypo- and hyperglycaemia can have serious adverse effects in paediatric patients and the general consensus is to selectively administer dextrose only in children at high risk for hypoglycaemia and to even consider the use of lower dextrose-containing fluids. The highest risk of hypoglycaemia is in neonates, children receiving hyper alimentation and those with endocrinopathies, in whom monitoring blood glucose levels and adjusting the rate of infusion are also important. The rate of glucose infusion can start at 120–300 mg/kg/h (compared to adults 1–1.5 g/kg/day) to maintain an acceptable blood glucose level after which it can be titrated as per need. The idea is also to prevent lipid mobilization in hypoglycaemia-prone infants.

As compared to adults, children are more susceptible to hospital acquired hyponatraemia which has been attributed to use of hypotonic IVFs (0.2%/0.45% NaCl) in elevated AVP situation: acutely ill patients, postsurgical state, hypovolaemia, medications, pneumonia, meningitis. A suspicion of hyponatraemia in paediatric patients can be difficult due to very nonspecific symptoms like headache, nausea, vomiting, confusion, lethargy and muscle cramps often confused with the generalized irritability frequently observed in a hospitalized child. With larger brain/skull size ratio and with rapid fall in sodium levels, a child's brain gets very little time to adapt and may precipitate hyponatraemic encephalopathy as seen in high-risk patients [20]. Dysnatremia-induced neurological complications following minor surgical procedures in apparently healthy children raise serious concerns regarding safety of hyponatraemic IVFs in paediatric patients [21]. Evidence-based guidelines now recommend isotonic fluids (sodium concentration similar to Plasma-Lyte or 0.9% saline) in children who are acutely ill or require maintenance IVFs [22, 23] (barring neonates <28 days, cases like DI, severe diarrhoea, burns, congenital or acquired renal, hepatic or cardiac diseases, traumatic brain injury where fluid requirements have been attended more specifically). Concerns of hypernatraemia, fluid overload with oedema and hypertension and hyperchloraemic acidosis have been raised with use of isotonic fluids in paediatric patients, but there is no available data of higher risk with use of isotonic in comparison to hypotonic IVFs in patients aged 28 days to 18 years.

Outpatient and Day-Care Surgery

The choice of fluid in outpatient and day-care surgery is highly variable depending on the nature of surgery. Some procedures like liposuction are associated with considerable fluid shifts, while some dental procedures may have minimal fluid loss. However, administration of 'liberal' doses of fluid minimizes certain undesirable effects like postoperative nausea and vomiting (PONV), pain and dizziness. Some advocate early feeding during the postoperative period to minimize the risk of unwarranted hypovolaemia.

Case Vignette

Box 18.2 shows the maintenance and replacement fluid requirements of the patient in the case vignette.

Box 18.2 Calculation of Fluid Requirements

Hourly maintenance requirement M (mL) = (A+ B + C).

A (mL) = 4 × first 10 kg body weight.

B (mL) = 2 × next 10 kg of body weight.

C (mL) = remaining kg of body weight.

Fasting requirement F (mL) = (A+ B + C) × h (where h is the number of hours of fasting).

Half of the calculated fasting requirement is administered in the first hour and the remaining half is administered in the second and third hours.

Our case vignette mentions a 50-year-old patient of 60 kg body weight with 24 h of fasting.

Hourly maintenance requirement M(mL) in our patient = (40 mL + 20 mL +40 mL),i.e. 100 mL.

Fasting requirement (mL) = 100 × 24 i.e. 2400 mL.

Third space loss (mL) = 8 × 60 i.e. 480 mL/h.

First hour fluid requirement =100 mL + (50% of 2400) mL + 480 mL i.e. 100 + 120 0 + 480 mL = 1780 mL + F.

Second hour fluid requirement = 100+ (25% of 2400) + 480 i.e. 100 + 600 + 480 = 1180 mL + F.

Third hour fluid requirement = 100+ (25% of 2400) + 480 i.e. 100 + 660 + 480 = 1180 mL + F.

Subsequent hours = 480 mL + F.

Where F is the surgical loss (*surgical blood loss to be replaced by crystalloid 1:3, Colloid/blood – 1:1 ratio*).

Conclusion

There has been an increase in the use of a highly individualized and goal-directed approach for restoring near-normal fluid balance in the perioperative period. It is appreciated that the static parameters (CVP, heart rate, etc.) are not reliable in accurately assessing volume status and 'fluid responsiveness' guided by dynamic parameters is a better option. However, the suitability of a parameter is linked to its availability and comfort of use in the operative setting to expect the desired benefits.

Both 'liberal' and 'restrictive' approaches have been found to be useful in different conditions, the former in low-risk and ambulatory patients and the latter in high-risk patients. Crystalloids have been found to be reliable and safe, and the use of balanced salt solutions along with the older fluids has been found to be better than colloids in patients with kidney diseases without much difference in outcome.

Take Home Messages

- Fluid administration during the perioperative period is both an art and science.
- The predicted calculations are based upon body weight, duration of fasting, extent of blood loss, etc., but such calculations may be inadequate and imprecise.
- It is necessary to continuously monitor the fluid intake and output with help of appropriate monitoring tools. There is no single monitor that performs best in all circumstances.
- Both 'restrictive' and 'liberal' strategies for fluid administration are useful in specific conditions.
- Both crystalloids and colloids can be used although the former is preferred over the latter as the first choice.
- Special precautions should be adopted in high-risk patients with reduced threshold for tolerating hypo- or hypervolaemia especially the paediatric age group, elderly, those with accompanying kidney diseases, etc.

References

1. Matas R. The continued intravenous "drip" with remarks on the value of continued gastric drainage and irrigation by nasal intubation with a gastroduodenal tube (Jutte) in surgical practice. Ann Surg. 1924;79:643–61.
2. Srinivasa S, Hill AG. Perioperative fluid administration: historical highlights and implications for practice. Ann Surg. 2012;256:1113–8.
3. Holiday MA, Segar WE. The maintenance need for water in parenteral fluid therapy. Pediatrics. 1957;19:823–32.

4. Lobo DN, Bostock KA, Neal KR, Perkins AC, Rowlands BJ, Allison SP. Effect of salt and water balance on recovery of gastrointestinal function after elective colonic resection: a randomised controlled trial. Lancet. 2002;25: 359(9320):1812–8.
5. Brandstrup B, Tonnesen H, Beier-Holgersen R, et al. Effects of intravenous fluid restriction on postoperative complications: comparison of two perioperative fluid regimens: a randomized assessor-blinded multicenter trial. Ann Surg. 2003;238:641–8.
6. MacKay G, Fearon K, McConnachie A, Serpell MG, Molloy RG, O'Dwyer PJ. Randomized clinical trial of the effect of postoperative intravenous fluid restriction on recovery after elective colorectal surgery. Br J Surg. 2006;93(12):1469–74.
7. Holte K, Foss NB, Andersen J, Valentiner L, Lund C, Bie P, Kehlet H. Liberal or restrictive fluid administration in fast-track colonic surgery: a randomized, double-blind study. Br J Anaesth. 2007;99(4):500–8.
8. Holte K, Kristensen BB, Valentiner L, Foss NB, Husted H, Kehlet H. Liberal versus restrictive fluid management in knee arthroplasty: a randomized, double-blind study. Anesth Analg. 2007;105(2):465–74.
9. Kabon B, Akça O, Taguchi A, Nagele A, Jebadurai R, Arkilic CF, Sharma N, Ahluwalia A, Galandiuk S, Fleshman J, Sessler DI, Kurz A. Supplemental intravenous crystalloid administration does not reduce the risk of surgical wound infection. Anesth Analg. 2005;101(5):1546–53.
10. Nisanevich V, Felsenstein I, Almogy G, Weissman C, Einav S, Matot I. Effect of intraoperative fluid management on outcome after intraabdominal surgery. Anesthesiology. 2005;103(1):25–32.
11. Holte K, Klarskov B, Christensen DS, Lund C, Nielsen KG, Bie P, Kehlet H. Liberal versus restrictive fluid administration to improve recovery after laparoscopic cholecystectomy: a randomized, double-blind study. Ann Surg. 2004;240(5):892–9.
12. Maharaj CH, Kallam SR, Malik A, Hassett P, Grady D, Laffey JG. Preoperative intravenous fluid therapy decreases postoperative nausea and pain in high risk patients. Anesth Analg. 2005;100(3):675–82.
13. Myles PS, Bellomo R, Corcoran T, Forbes A, Peyton P, Story D, Christophi C, Leslie K, McGuinness S, Parke R, Serpell J, Chan MTV, Painter T, McCluskey S, Minto G, Wallace S. Australian and New Zealand College of Anaesthetists clinical trials network and the Australian and New Zealand Intensive Care Society clinical trials group. Restrictive versus liberal fluid therapy for major abdominal surgery. N Engl J Med. 2018;378(24):2263–74.
14. Oddo M, Poole D, Helbok R, et al. Fluid therapy in neurointensive care patients: ESICM consensus and clinical practice recommendations. Intensive Care Med. 2018;44:449–63.
15. Young R. Perioperative fluid and electrolyte management in cardiac surgery: a review. J Extra Corpor Technol. 2012;44:20–6.
16. Calixto Fernandes MH, Schricker T, Magder S, Hatzakorzian R. Perioperative fluid management in kidney transplantation: a black box. Crit Care. 2018;22(1):14.
17. Fayed NA, Yassen KA, Abdulla AR. Comparison between 2 strategies of fluid management on blood loss and transfusion requirements during liver transplantation. J Cardiothorac Vasc Anesth. 2017;31(5):1741–50. https://doi.org/10.1053/j.jvca.2017.02.177. Epub 2017 Feb 22. PMID: 28552297.
18. Wollman S, Marx C. Acute hydration for prevention of hypotension of spinal anesthesia in parturients. Anesthesiology. 1968;29:374–80.
19. Langer T, Limuti R, Tommasino C, van Regenmortel N, Duval E, Caironi P, et al. Anaesthesiol Intensive Ther. 2018;50:49–58.
20. Moritz ML, Ayus JC. Prevention of hospital-acquired hyponatremia: a case for using isotonic saline. Pediatrics. 2003;111(2):227–30.

21. Langer T, Malbrain L, Van Regenmortel N. Hypotonic or isotonic maintenance fluids for paediatric patients: the never-ending story. Anaesthesiol Intensive Ther. 2020;52(5):357–8.
22. Feld LG, Neuspiel DR, Foster BA, et al. Clinical practice guideline: maintenance intravenous fluids in children. Pediatrics. 2018;142(6):e20183083.
23. National Institute for Health and Care Excellence. Intravenous fluid therapy in children and young people in hospital. London: National Institute for Health and Care Excellence; 2020. (NICE Guideline, No. 29). https://www.ncbi.nlm.nih.gov/books/NBK563449