Fluid management

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Abstract

Intravenous fluids are one of the most commonly prescribed medical therapies, with widespread effects on patient outcome, morbidity and mortality. They are often poorly understood and overseen by the most junior members of the healthcare team. Better knowledge of the appropriate choice, rate and volume of fluid, alongside the consequences of any prescription can therefore have a significant impact on patient care. This article reviews some of the basic concepts underpinning the use of fluid therapy, associated physiology, clinical application and evidence base in the perioperative setting. Suggested further reading is also provided.

Keywords Colloid; crystalloid; fluid; goal directed; haemodynamic; peri-operative

Introduction

Intravenous fluid (IvF) administration has been used as a medical therapy for hypovolaemia since the cholera epidemics of the 1800s.[1] Despite early successes, intravenous fluids did not enter routine practice for a further 100 years and to this day it still attracts conflicting evidence and opinion.[2]

Fluid management can influence every aspect of patient care, with inappropriate administration (e.g. incorrect rate, volume or type of fluid) having a significant impact on patient outcome. IvFs are one of the most commonly prescribed therapies in hospital, yet are often devolved to the most junior members of a medical team with little experience of what is being prescribed and the unforeseen consequences of inappropriate administration. Significant variation exists in clinical practice. It is important, therefore, that the basics of fluid physiology are understood in order to make consistent and safe IvF choices.

This article addresses the basics of fluid physiology and current evidence surrounding perioperative IvF management.

Physiology

Fluid compartments (Figure 1)

Water constitutes almost 60% of body weight and thus total body water (TBW) approximates to 42 L in a 70-kg individual. Of this, two-thirds is intracellular (28L) and one third extracellular (14 L). The extracellular component can be further divided into interstitial compartments (11 L) and the intravascular circulating volume (3 L).

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Administration of intravenous free water, as found in 5% glucose, will result in similar redistribution ratios. Approximately 70 ml of a 1000-ml bag remains intravascularly, as circulating volume constitutes just 7% of TBW (3 L of the 42 L TBW), with the remaining fluid being redistributed throughout the other fluid compartments. This is why 5% glucose is a poor resuscitation fluid.

IvF redistribution can be influenced by the presence of electrolytes, principally sodium, which cannot freely traverse cell membranes, and larger molecules such as those found in colloid solutions.

Daily requirements and fluid balance

In health, water requirements equate to 25–30 ml/kg/day (approximately 2 L for a 70-kg adult). Sodium, potassium and chloride requirements are each 1 mmol/kg/day (70 mmol) and 50–100 g/day of glucose is necessary to limit starvation ketosis.[3] Normally these requirements are met through dietary, enteral intake and metabolic oxidation reactions. In disease states, however, fluid and electrolyte requirements may alter significantly.

Classic Starling theory

Traditional theory dictating fluid shifts within the vasculature stem from work by Ernest Starling on capillary dynamics over 120 years ago. He postulated that movement of fluid across the capillary membrane is determined by a hydrostatic pressure gradient, osmotic pressure gradient and a filtration coefficient. In health, net transcapillary flow favours filtration into the interstitium at the arteriolar end of the capillary (due to predominance of capillary hydrostatic pressure) and reabsorption at the venous end (from predominant capillary oncotic pressure). More recently, however, this theory has been challenged. It has been established that most filtered fluid returns to the circulation as lymph and not through venules or capillaries. Capillaries are now believed to continue filtering intravascular fluid throughout their whole length and, as such, the Starling theory has had to be revised.[4]

The revised Starling/endothelial glycocalyx theory

Endothelial glycocalyx is a web of membrane-bound glycoproteins and proteoglycans, with associated glycosaminoglycans, on the luminal side of the endothelium. This acts as an active barrier between the blood and interstitial space, proving to be semi-permeable to anionic macromolecules (such as plasma proteins). Occasional large pores exist allowing large molecules to escape to the interstitium, with smaller pores regulating oncotic pressure gradients to reduce transcapillary flow. While some interstitial fluid can return to the vasculature via these pores, the principal mechanism by which it returns is as lymph. The structure and function of the glycocalyx layer differs between varying vascular beds, under altering physiological conditions and in disease states. The permeability of the layer can therefore be affected by a number of factors alongside direct injury.[2,4]

It is also important to note that other layers of the capillary wall contribute to transcapillary flow. The basement membrane (composed of type IV collagen and laminin) and extracellular matrix (collagen fibres upon which glycoproteins and proteoglycans are arranged) constitute additional layers through which fluid must flow. They are also believed to have a

significant role in modulating the inflammatory response and altering the hydrostatic pressure gradient through conformational changes and glycosaminoglycan hydration. Moreover, the vascular endothelial cells themselves may form sinusoids or fenestrated capillaries which will alter fluid dynamics. These cells may undergo phenotypic changes in response to stressors, further contributing to endothelial dysfunction and clinical oedema.[4]

Clinical applications

Assessment of fluid state

Assessment of a patient's fluid state revolves around the fundamental principles of history taking, clinical examination and investigation (Figure 2). It is complicated, however, by the dynamic nature of a patient's physiology, which can rapidly alter in response to underlying disease processes and medications. It is important to reassess the impact of IvF therapy in a timely manner, adapting the fluid plan to the individual patient circumstances. The correct choice of IvF can be extremely difficult to interpret at times, and may require additional expertise or invasive monitoring such as that offered by the critical care unit.

History

Clinical history is important in determining a patient's fluid state and can help elicit causes of dehydration and hypovolaemia. Key points to consider are included in Figure 2.

Examination

Thorough physical examination should be undertaken in addition to assessment of vital signs (e.g. Early Warning Scores (EWS), observation charts, input–output charts). Administration of a fluid challenge (a 250–500 ml bolus over 15–30 min) with close observation of parameters, such as mean arterial pressure (MAP) or urine output, can be useful in determining a patient's fluid responsiveness. Passive leg raising (PLR) involves sitting a patient at 45°, before lowering their upper torso to supine while simultaneously raising their legs to 45° for 60 seconds. This creates a transient reversible autotransfusion from the lower extremities that may predict fluid administration response. The patient is then returned to their initial position, with changes in haemodynamic parameters assessed to determine the likely IvF responsiveness.

Investigations

Determining trends in urea, creatinine, sodium, urinary sodium, urinary osmolality, lactate, haematocrit and haemoglobin are useful measures of fluid status and tissue perfusion. Other modalities that may help in assessing a patient's fluid state or possible cause for abnormality, include urinalysis, electrocardiograms, chest x-rays, advanced imaging techniques such as echocardiography and advanced cardiac monitoring techniques (e.g. LiDCo, oesophageal Doppler, PiCCO).[5]

Fluid management

The National Institute for Health and Care Excellence (NICE) UK have produced guidelines to assist clinicians in the use of IvF for hospital inpatients. They advocate assessment and management of a patient's fluid need as part of every review, using protocols aimed at stopping parenteral IvF as soon as possible. Prescription of IvF should constitute part of a 24-hour fluid management plan, including the type, rate and volume of IvF while considering the 5 Rs:

- Resuscitation – administer a bolus of 500 ml crystalloid over <15 min containing 130–154 mmol/L of sodium. Consider 4–5% human albumin solution (HAS) in severe sepsis and avoid tetrastarch for resuscitation.
- Routine maintenance – prescribe IvF containing 25–30 ml/kg/day of water and approximately 1 mmol/kg/day of sodium, potassium and chloride. 50–100 g/day of glucose should also be included to limit starvation ketosis, however this will not meet nutritional requirements. Reduced

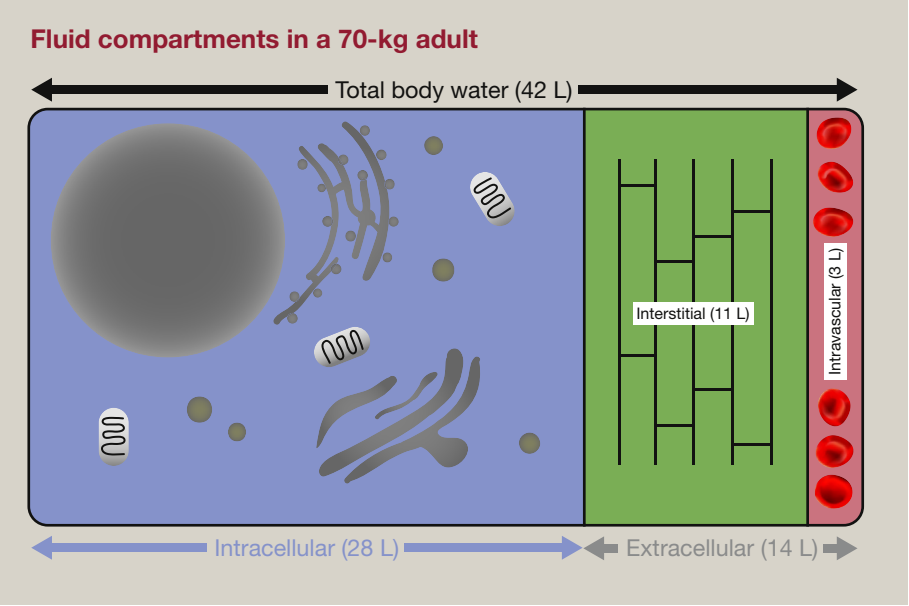

Figure 1

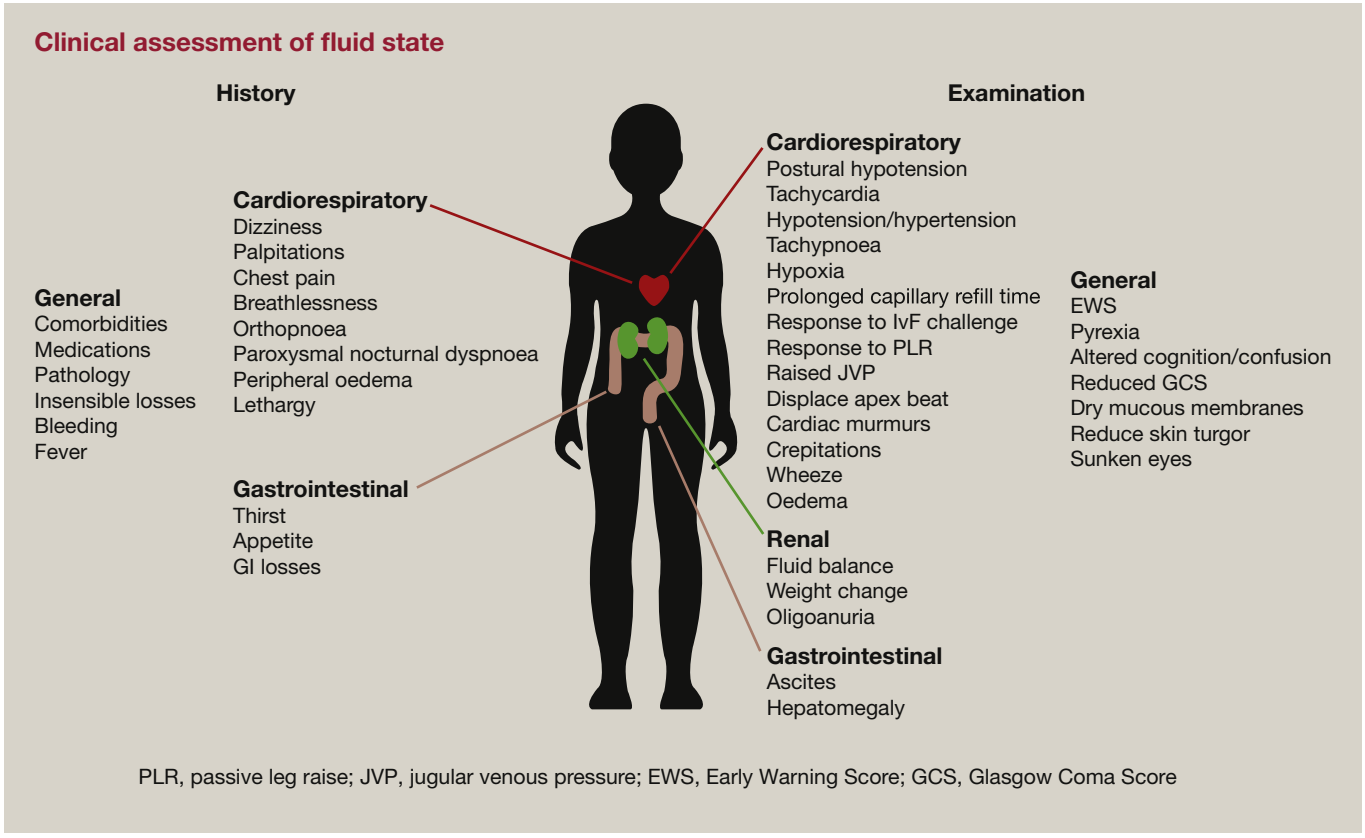

Figure 2

volumes should be considered for patients who are elderly or suffer from renal/cardiac impairment.

- Replacement — account for existing or ongoing fluid and electrolyte losses in addition to maintenance needs.
- Redistribution — account for abnormal fluid distribution (e.g. third space losses).
- Reassessment — fluid status should be re-evaluated at least daily and following any patient transfer or deterioration. Appropriate history, examination and investigation skills should be utilized, alongside twice weekly weights. Monitoring can, however, be adjusted depending on the patient's haemodynamic stability. Patients receiving IvF containing >120 mmol/L of chloride should have daily chloride level monitoring. If hyperchloraemia or acidaemia develop, fluid therapy and acid:base status should be reviewed.[3]

Similar guidelines have been produced by other agencies, such as the British Consensus Guidelines on Intravenous Fluid Therapy for Adult Surgical Patients (GIFTASUP).[6] Examples of recommendations include the use of balanced crystalloid solutions to avoid hyperchloraemic acidosis, avoidance of prolonged preoperative starvation times or routine use of bowel preparation, advocation of goal directed haemodynamic therapy and recommendations for patients suffering from acute kidney injury (AKI). While many of these recommendations are already in current practice, there is a variable quality of evidence base and limited generalizability of many of the results.

The Goldilocks principle

Approximately 300 million patients undergo a surgical procedure worldwide each year, most of whom receive perioperative IvF. Many factors can influence fluid shifts or deficits including preoperative fasting, gastrointestinal losses, haemorrhage, insensible losses, capillary leak, 3rd space accumulation, tissue oedema and anaesthesia induced vasodilatation. Occult hypovolaemia may often be missed, and can account for the traditionally generous volumes of fluid administered by clinicians to date. Some recent evidence has suggested benefit in certain patient populations from a more restrictive, individualized approach to fluid therapy, with enhanced recovery protocols now incorporating such approaches.[7]

Too little fluid can result in thirst, decreased patient satisfaction, dehydration, confusion, falls, venous thromboembolism, poor wound healing and AKI. Too much fluid may cause greater cardiorespiratory compromise, reduced tissue oxygenation, falls (peripheral oedema), poor wound healing, pressure sores, electrolyte derangement, intrabdominal oedema contributing to ileus, anastomotic leak, compartment syndrome and AKI.

The correct fluid, volume and rate for a given patient, administered precisely for the specific patient circumstance represents a Goldilocks scenario and must be 'just right'. Often the most junior members of a medical team are assigned the role of fluid prescription, and yet most may have little understanding of the consequences of their fluid prescription choices. A complete

hospital culture change is required, from the most junior nurses to consultants, before fluid therapy outcomes will be improved.[7]

Crystalloids (Table 1)

In medical use, crystalloids describe solutions containing ions or sugars that may cross semipermeable membranes. Solutions may be balanced, containing multiple ions aiming to replicate the constituents of plasma (e.g. PlasmaLyte 148), or contain single solutes that contribute to the tonicity and osmolality of the solution (e.g. 0.9% saline). Once administered, these physiochemical properties, alongside the sodium content of the solutions, determine the volume remaining intravascularly and their redistribution to the interstitium. Crystalloids are relatively cheap, easily available and have a long shelf life accounting for their use as the most common IvF worldwide. Conversely, however, they can contribute to electrolyte derangement, acid:-base disturbances and may have unfavourable constituents in particular disease states.[2,5]

Two recent studies (one ward based,[8] the other in critical care[9]) comparing saline with balanced crystalloid (Ringer's lactate) found no significant difference between groups, however patients receiving balanced IvF demonstrated a lower incidence of major adverse kidney events within 30 days.

Colloids (Table 1)

Colloid solutions produce non-crystallizable gummy products when evaporated and, owing to their large molecular mass, do not easily cross cellular membranes. They can be classified into plasma derivatives (e.g. albumin) and semisynthetics (e.g. gelatins). Colloids are believed to remain intravascular for a longer duration than crystalloids, theoretically reducing the overall fluid requirements for a similar clinical effect. Indeed, this has long been considered to equate to a ratio of 1 L colloid to 3 L crystalloid. More recently a ratio nearer to 1:1.4 has been demonstrated, suggesting less of a volume sparing effect than previously thought. Colloids are generally more expensive than crystalloids and risk precipitating renal impairment, coagulopathy and anaphylaxis. Some evidence exists to suggest that their use in critically ill patients may even cause harm, leading the Medicines and Healthcare Products Regulatory Agency (MHRA) to withdraw the license for all hydroxyethyl starches (HES) in the UK.[2,5]

Table 2 references some of the seminal papers relating to intravenous fluid therapy produced over the last two decades.

Goal-directed haemodynamic therapy

Goal-directed haemodynamic therapy (GDHT), also known as goal-directed therapy, is a complex group of interventions aimed at improving oxygen delivery and tissue perfusion. These interventions can be used both in the operating department & intensive care unit. By improving oxygen delivery perioperatively, to address periods of increased demand, mortality and adverse outcome rates may benefit.

Multiple techniques exist to facilitate GDHT, the details of which are beyond the scope of this article. These essentially comprise of some form of non-invasive or minimally invasive cardiac output monitor allowing the measurement of various haemodynamic values, which can be targeted to predefined goals through titration of IvF and vasoactive drugs.

Commonly available intravenous fluids, with crystalloid compositions[2,5]

Crystalloids

	Non-balanced	Balanced
Hypertonic	2.7% saline	
Isotonic	0.9% saline	Plasma-Lyte 148
		Plasma-Lyte A
		Sodium lactate (Hartmann's)
		Ringer's acetate
		Ringer's lactate
Hypotonic	5% dextrose	
	0.45% saline	
	0.18% saline +4% dextrose	

Colloids

Semisynthetics	Hydroxyethyl starches
	Gelatins
	Dextrans
Plasma derivatives	Human albumin solution

Compositions

Fluid	Composition (mmol/L)
2.7% saline	Na^+ 462, Cl^- 462
0.9% saline	Na^+ 154, Cl^- 154
0.45% saline	Na^+ 78, Cl^- 78
0.18% saline +4% dextrose	Na^+ 30, Cl^- 30, glucose 40 g
5% dextrose	Glucose 50 g
Plasma-Lyte 148	Na^+ 140, Cl^- 98, K^+ 5, Mg^{2+} 1.5, acetate 27, gluconate 23
Plasma-Lyte A	Na^+ 140, Cl^- 98, K^+ 5, Mg^{2+} 1.5, acetate 27, gluconate 23
Sodium lactate (Hartmann's)	Na^+ 131, Cl^- 111, K^+ 5, Ca^{2+} 2, lactate 29
Ringer's lactate	Na^+ 130, Cl^- 109, K^+ 4, Ca^{2+} 1.5, lactate 28
Ringer's acetate	Na^+ 140, Cl^- 127, K^+ 4, Ca^{2+} 2.5, Mg^{2+} 1, acetate 24, malate 5

Table 1

Evidence: Numerous studies and meta-analyses demonstrate conflicting results on the role of perioperative GDHT (Table 3). These include heterogenous, dated, small, single-centre studies, most of which introduce an element of bias. Moreover, variables are not universally defined between studies such as the monitoring devices used, haemodynamic targets, which fluids or vasoactive drugs to administer, types of surgery involved, outcomes measured and timing of interventions. This ultimately poses difficulties when attempting to draw firm conclusions.

A recent Cochrane systematic review involving a total 6595 patients suggested that complications were less frequent amongst those treated according to haemodynamic therapy algorithms (31.5% versus 41.6%), with a reduced incidence of postoperative infection, reduced duration of hospital stay and a non-significant reduction in mortality.[11]

Trials comparing various intravenous fluid therapies

Topic	Acronym	Reference
Crystalloid type	SPLIT	Young P, Bailey M, Beasley R, et al. Effect of a buffered crystalloid solution vs saline on acute kidney injury among patients in the intensive care unit. *The Journal of the American Medical Association* 2015; 314 (16): 1701—1710.
	SMART	Semler M, Self W, Wanderer J, et al. Balanced crystalloids versus saline in critically ill adults. *The New England Journal of Medicine* 2018; 378: 829—839.
	SALT-ED	Self W, Semler M, Wanderer J, et al. Balanced crystalloids versus saline in noncritically ill adults. *The New England Journal of Medicine* 2018; 378: 819—828.
Colloid vs crystalloid	CRISTAL	Annane D, Siami S Jaber S, et al. Effects of fluid resuscitation with colloids vs crystalloids on mortality in critically ill patients presenting with hypovolemic shock, the cristal randomized trial. *The Journal of the American Medical Association* 2013; 310 (17): 1809—1817.
Albumin	SAFE	The SAFE Study Investigators. A comparison of albumin and saline for fluid resuscitation in the intensive care unit. *The New England Journal of Medicine* 2004; 350: 2247—2256.
	FEAST	Maitland K, Kiguli S, Opoka R, et al. Mortality after fluid bolus in african children with severe infection. *The New England Journal of Medicine* 2011; 364: 2483—2495.
	ALBIOS	Caironi P, Tognoni G, Masson S, et al. Albumin replacement in patients with severe sepsis or septic shock. *The New England Journal of Medicine* 2014; 370: 1412—1421.
Hydroxyethyl starch	VISEP	Brunkhorst F, Engel C, Bloos F, et al. Intensive insulin therapy and pentastarch resuscitation in severe sepsis. *The New England Journal of Medicine* 2008; 358: 125—139.
	6s	Perner A, Haase N, Guttormsen A, et al. Hydroxyethyl starch 130/0.42 versus ringer's acetate in severe sepsis. *The New England Journal of Medicine* 2012; 367: 124—134.
	CHEST	Myburgh J, Finfer S, Bellomo R, et al. Hydroxyethyl starch or saline for fluid resuscitation in intensive care. *The New England Journal of Medicine* 2012; 367: 1901—1911.
Goal directed haemodynamic therapy in sepsis	RIVERS	Rivers E, Nguyen B, Havstad S, et al. Early goal-directed therapy in the treatment of severe sepsis and septic shock. *The New England Journal of Medicine* 2001; 345: 1386—1377.
	ARISE	The ARISE Investigators and the ANZICS Clinical Trials Group. Goal-directed resuscitation for patients with early septic

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Table 2 (*continued*)

Topic	Acronym	Reference
		shock. *The New England Journal of Medicine* 2014; 371: 1496–1506.
	PROCESS	The ProCESS Investigators. A randomized trial of protocol-based care for early septic shock. *The New England Journal of Medicine* 2014; 370: 1683–1693.
	PROMISE	Mouncey P, Osborn T, Power G, et al. Protocolised management in sepsis (ProMISe): a multicentre randomised controlled trial of the clinical effectiveness and cost-effectiveness of early, goal-directed, protocolised resuscitation for emerging septic shock. *Health Technology Assessment* 2015; 19 (97)
Administration technique	FACTT	The National Heart, Lung and Blood Institute Acute Respiratory Distress Syndrome (ARDS) Clinical Trials Network. Comparison of two fluid-management strategies in acute lung injury. *The New England Journal of Medicine* 2006; 354: 2564–2575.
	RELIEF	Myles P, Bellomo R, Corcoran T, et al. Restrictive versus liberal fluid therapy for major abdominal surgery. *The New England Journal of Medicine* 2018; 279: 2263–2274.

Table 2

While evidence on the benefit of GDHT may be inconsistent, much of the evidence concludes that it likely has a role in optimizing the provision of fluid therapy. By allowing a more individualized approach to fluid management, such as when to administer fluid versus a vasopressor, variation in clinical practice may be reduced. Enhanced consistency and the utilization of best practice underpin the ambitions of the 'getting it right first time' (GIRFT) national programme, aimed at enhancing healthcare quality and cost savings.

Enhanced recovery

It has been suggested that the best method for delivering fluid perioperatively is via the enteral route which, while impractical intraoperatively, may be under-utilized pre- and postsurgery. Current preoperative starvation guidelines advise abstaining from drinking clear fluids for 2 hours prior to surgery, with the intention of reducing the aspiration risk by allowing sufficient time for gastric emptying.

Enhanced recovery protocols often actively encourage enteral fluid intake up until the 2-hour starvation time point, with some evidence that this does not increase gastric volume and may in fact lower gastric acidity. Additionally, complex carbohydrate drinks are utilized with the advantage of decreasing insulin resistance, maintaining an anabolic metabolism, reducing postoperative nausea and vomiting (PONV) and reducing perioperative anxiety. Patients are also actively optimized before surgery by, for example, correcting anaemia to improve oxygen delivery. Many of the above recommendations are now being incorporated into the Royal College of Anaesthetists 'fitter, better, sooner' toolkit, aimed at allowing patient's to better prepare for surgery and improve postoperative outcomes.

Intraoperatively, avoidance of liberal volumes of IvF are considered important to reduce complication rates and lengths of stay. Enhanced recovery protocols often include the utilization of goal directed fluid therapy, aiming to better individualize IvF to the patient and procedure in question. Minimally invasive surgical approaches are utilized with local/regional anaesthetic techniques, to limit postoperative discomfort and augment a return to normal function.

Postoperatively, enhanced recovery protocols often attempt to rapidly return to enteral hydration and nutrition to prevent the unwanted complications of fluid overload. This is thought to improve the conditions for wound healing, expedite discharge and improve the overall patient experience. Oral analgesics are frequently used, reducing the gastrointestinal side effects of systemic opiates, with avoidance of uncomfortable nasogastric tubes or abdominal drains. Early mobilization and discharge, with support from therapy services, may also accelerate a return to normal gastrointestinal function and fluid homeostasis.[12]

Specific conditions

Finally, a number of specific conditions warrant additional consideration when deciding on the choice of intravenous fluid therapy.

Recent evidence for GDHT (Adapted from Kauffman et al.)[10]

Study	Surgical specialty	GDHT effect
Elgendy M, Esmat I, Kassim D. Outcome of intraoperative goal-directed therapy using Vigileo/FloTrac in high-risk patients scheduled for major abdominal surgeries: A prospective randomized trial. *Egypt J Anaesth* 2017; 33: 263–269.	Abdominal	↓morbidity ↓LOS
Gomez-Izquierdo J, Trainito A, Mirzakandov D, et al. Goal-directed Fluid therapy does not reduce primary postoperative Ileus after elective laparoscopic colorectal surgery: a randomized controlled trial. *Anesthesiology* 2017; 127: 36–49.	Abdominal	↔
Kapoor P, Magoon R, Rawat R, et al. Goal-directed therapy improves the outcome of high-risk cardiac patients undergoing off-pump coronary artery bypass. *Ann Card Anaesth* 2017; 20: 83–89.	Cardiothoracic	↓LOS ↓inotrope duration
Kaufmann K, Stein L, Bogatyreva L, et al. Oesophageal Doppler guided goal-directed haemodynamic therapy in thoracic surgery - a single centre randomized parallel-arm trial. *Br J Anaesth* 2017; 118: 852–861.	Thoracic	↓complications ↓LOS
Li B, Zhang L, Zhang S, et al. Application of ultrasound in goal-directed fluid management of anesthesia in elderly patients. *Biomed Res* 2017; S482–S486.	N/A	↓complications ↑haemodynamic values
Liang M, Li Y, Lin L, et al. Effect of goal-directed fluid therapy on the prognosis of elderly patients with hypertension receiving plasmakinetic energy transurethral resection of prostate. *Int J Clin Exp Med* 2017; 10: 1290–1296.	Urology	↓complications ↑haemodynamic values
Luo J, Xue J, Liu J, et al. Goal-directed fluid restriction during brain surgery: a prospective randomized controlled trial. *Ann Intensive Care* 2017; 7: 16.	Neuro	↓complications ↓LOS
Reisinger K, Willigers H, Jansen J, et al. Doppler-guided goal-directed fluid therapy does not affect intestinal cell damage but increases global gastrointestinal perfusion in colorectal surgery: a randomized controlled trial. *Colorectal Dis* 2017; 19: 1081–1091.	Abdominal	↑GI perfusion
Stens J, Hering J, Van der Hoeven C, et al. The added value of cardiac index and pulse pressure variation monitoring to mean arterial pressure-guided volume therapy in moderate-risk abdominal surgery (COGUIDE): a pragmatic multicentre randomised controlled trial. *Anaesthesia* 2017; 72: 1078–1087.	Abdominal	↔
Wu J, Ma Y, Wang T, et al. Goal-directed fluid management based on the auto-calibrated arterial pressure-derived stroke volume variation in patients undergoing supratentorial	Neuro	↓complications

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Table 3 (*continued*)

Study	Surgical specialty	GDHT effect
neoplasms surgery. *Int J Clin Exp Med* 2017; 10: 3106—3114.		
Xu H, Shu S, Wang D, et al. Goal-directed fluid restriction using stroke volume variation and cardiac index during one-lung ventilation: a randomized controlled trial. *J Thorac Dis* 2017; 9: 2992—3004.	Thoracic	↑P/F ↓complications ↓LOS
Sethi A, Bebbarma M, Narang N, et al. Impact of targeted preoperative optimization on clinical outcome in emergency abdominal surgeries: a prospective randomized trial. *Anesth Essays Res* 2018; 12: 149—154.	Abdominal	↓LOS ↓mortality
Calvo-Vecino J, Ripollés-Melchor J, Mythen M, et al. Effect of goal-directed haemodynamic therapy on postoperative complications in low-moderate risk surgical patients: a multicentre randomised controlled trial (FEDORA trial). Br J Anaesth 2018; 120: 734—744.	Abdominal	↓complications ↓LOS
Demirel İ, Bolat E, Altun A, et al. Efficacy of goal-directed fluid therapy via pleth variability index during laparoscopic roux-en-y gastric bypass surgery in morbidly obese patients. Obes Surg 2018; 28: 358—363.	Abdominal	↔lactate/Cr ↓IvF
Kim H, Kim E, Lee H, et al. Effect of goal-directed haemodynamic therapy in free flap reconstruction for head and neck cancer. *Acta Anaesthesiol Scand* 2018; 62: 903—914.	Plastics	↓LOS ↓complications
Liu T, Zhang J, Gao X, et al. Clinical research of goal-directed fluid therapy in elderly patients with radical resection of bladder cancer. *J Cancer Res Ther* 2018; 14: S173—S179.	Urology	↑haemodynamic values ↓LOS ↓complications

(LOS — Length of stay, GI — Gastrointestinal, P/F — PaO_2/FiO_2 ratio, Cr — Creatinine, ↑ - increased, ↓ - decreased, ↔ - Unchanged.).

Table 3

Traumatic brain injury

Hypotonic IvF should be avoided due to the theoretical risk of worsening intracerebral oedema and raising intracranial pressure. Albumin has also been associated with a greater mortality, possibly due to the hypotonic carrier solution.[13]

Organ dysfunction

Liver failure may hinder the abilities of a patient to metabolize and clear lactate, suggesting the avoidance of lactate containing fluids.[2] Caution must also be used when administering potassium to those with renal impairment.

Trauma

Damage-control resuscitation is currently recommended in the management of the trauma patient, replacing haemorrhagic losses with blood products, restricting crystalloid replacement and allowing for a degree of permissive hypotension.

Malnourishment

This may lead to sodium and water excess, with depletion of potassium, calcium, phosphate and magnesium levels. Refeeding syndrome is a significant risk, with the potential for fluid overload and cardiac arrhythmias if treated inappropriately with IV glucose.[5]

Sepsis

Early goal-directed fluid therapy was a notable component of recent surviving sepsis guidelines, targeting central venous pressure, MAP or central venous oxygen saturations. More recently, however, three key randomized controlled trials have questioned the validity

of this approach (the three papers in question are in Table 2). Rapid fluid resuscitation with frequent reassessment appears to be a key underlying principle.

Burns

Burns present a significant mechanism for insensible fluid loss. They may also lead to more problematic intravenous access and, where circumferential, can inhibit tissue perfusion. Rapid fluid correction, with repeated reassessment, can substantially impact upon morbidity and mortality. The modified Parkland formula (IvF requirement over the first 24 hours = 4 ml/kg x %BSA burn) has been developed to assist in resuscitation of the burn victim. This dictates the volume of IvF required in the first 24 hours from the time of injury, providing the first half over 8 hours and the second half over the subsequent 16 hours.

Conclusion

IvF therapy influences every aspect of patient outcome, with inappropriate fluid management undoubtably contributing to worsening complications, length of stay, healthcare cost, morbidity and mortality. It is difficult to draw definitive conclusions from the array of conflicting evidence in existence on IvF therapy. Indeed, there is likely no right or wrong approach suitable for every patient. Growing evidence suggests that crystalloids seem to be of largely similar benefit to colloids, with balanced solutions containing reduced chloride now equally cheap and accessible. Moreover, increasing safety concerns suggest that some colloids should be avoided (HES and gelatins). An individualized approach to fluid management will still be necessary, tailoring IvF to both the patient and clinical circumstances encountered. GDHT may also be of benefit and, additionally, may facilitate individualization of care by optimising when fluids or vasoactive agents should be administered. Identification and selection of appropriate patients and procedures may therefore be a key metric to address.

Significant improvements have developed in modern practice and approaches to the high-risk surgical patient using less invasive techniques, preoperative optimization, novel surgical approaches, avoiding harmful drugs and improving critical care techniques. Further education of healthcare team members and development of local guidelines will help to improve fluid choices, maintain consistency and progress patient outcomes. Ultimately, universally agreed standards for GDHT and outcome data from upcoming trials (iPEGASUS, OPTIMISE II, FLO-ELA, RELIEF, BaSICS and PLUS) should help us to differentiate the best approach to use when managing IvF therapy for our perioperative patient. ◆

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