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REVIEW ARTICLE

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Perioperative fluid and hemodynamic management within an enhanced recovery pathway

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Goal-directed fluid therapy (GDFT) seeks to improve outcomes through individualized optimization of oxygen delivery using IV fluid and vasoactive infusions. Trials of GDFT show clinical benefits over traditional liberal fluid administration, but fail to demonstrate benefits when compared to a restrictive strategy within an optimized enhanced recovery protocol. The ideal monitors, hemodynamic goals, and fluid administration strategy are not well established but may be less important than rational application of thoughtful fluid management strategies.

KEYWORDS
fluid therapy, hemodynamics, monitoring, perioperative, physiologic

1 | INTRODUCTION

Morbidity and mortality after major surgery remains an ongoing concern across specialties. Many of these negative outcomes are rooted in organ dysfunction, which begins in the perioperative period. Despite improvements in surgical technology and perioperative care, morbidity after major surgery is still high, with complication rates of 30% reported after major elective open colorectal surgery.[1] In particular, high-risk surgical patients while representing only 10% of the overall procedures performed each year, account for a high proportion of morbidity and over 80% of perioperative deaths.[1]

Perioperative fluid and hemodynamic management remains a highly debated topic. Recent evidence suggests that perioperative morbidity is linked to the amount of intravenous (IV) fluid administered with both insufficient and, more commonly, excess fluid delivery increasing postoperative complications.[2] Intraoperative under resuscitation can lead to inadequate end-organ perfusion,[3] which may worsen perioperative outcomes. Conversely, excessive intraoperative fluid volumes or over-resuscitation can result in third spacing, or an increased intra- as well as extravascular volumes, which may precipitate peripheral and/or pulmonary edema.[4]

Traditional methods of intraoperative volume management in which IV fluids are given based on a formula (mL/kg/h) and modified by the perceived magnitude of surgical trauma are not supported by known physiological principles. IV fluid therapy should be considered a drug and administered with as much caution as any other medication: it is beneficial when patients are both in need of enhanced blood flow and are fluid responsive, outside of these circumstances it can cause harm.

Goal-directed fluid therapy (GDFT) was introduced to address the need for optimal tissue oxygen delivery. Both hemodynamic parameters and oxygen delivery are monitored closely (typically using flow-based monitors) and optimized with fluids and/or inotropes.[5] Perioperative GDFT is the deliberate and individualized optimization of hemodynamics and oxygen delivery using IV fluid and/or vasoactive infusions. Over the past 10 years, the hemodynamic optimization of patients undergoing high-risk surgery has been shown to decrease the incidence of postoperative complications, as well as both intensive care unit (ICU) and hospital length of stays.[6,7]

Enhanced Recovery Pathways (ERPs) are evidence-based multidisciplinary pathways that integrate a range of preoperative interventions to maintain physiological function and facilitate postoperative recovery after major surgery. This review will explore the evidence for preoperative fluid and hemodynamic management within an ERP, and explore the evolving role of anesthesiologists to minimize operative risk and improve perioperative outcomes through

careful and considerate hemodynamic optimization, which begins well ahead of the surgery.

2 | PREOPERATIVE MANAGEMENT

From a fluid and hemodynamic standpoint, optimum preoperative management aims to avoid hypovolemia or hypotension. Potential preoperative hydration deficits can vary according to individual patients' comorbidities, preoperative fasting, and use of preoperative mechanical bowel preparation. Current recommendations from the American Society of Anesthesiology on fasting and consumption of clear liquids state that it is appropriate to fast from intake of clear liquids at least 2 h before elective procedures requiring general anesthesia, regional anesthesia, or sedation/analgesia (ie, monitored anesthesia care).[8] The Canadian and European guidelines are similar but subtly different in that rather than allowing clear fluids they have recently been changed to "encourage" oral intake up to 2 h preoperatively. Examples of clear liquids include, but are not limited to: water, fruit juices without pulp, carbonated beverages, clear tea, and black coffee. These liquids should not include alcohol, and the volume of liquid ingested is less important than the type of liquid ingested.

In addition, oral intake of a maltodextrin carbohydrate (CHO) drink up to 2 h before surgery has been shown to improve patient satisfaction, reduce thirst, and improve insulin sensitivity.[9] The function of the CHO load (>45 g) is to allow maximal glycogen storage and a metabolically fed state at the start of surgery, as well as to attenuate insulin resistance, and thus preserve the action of insulin. This reduces the incidence of perioperative hyperglycemia, which is a risk factor for nosocomial infection. A recent randomized clinical trial (RCT) of 880 patients showed that an oral CHO drink is effective in avoiding a blood glucose level >180 mg/dL, with an incidence of 2.4% compared to 16% in the placebo group ($P < 0.001$).[11] Overall, although larger studies are needed to better examine the impact on meaningful clinical outcomes, based on a low risk of harm, as well as better insulin sensitivity and patient satisfaction, most ERPs incorporate a preoperative CHO drink (except in type I diabetics due to their insulin deficiency state).[10]

The use of a mechanical bowel preparation (MBP) is controversial, however recent evidence recommends the routine use of an isosmotic MBP combined with concurrent oral antibiotics before elective colorectal surgery.[11] It is a common misconception that all MBPs cause significant dehydration: isosmotic MBP does not have the same deleterious effect as older hyperosmolar solutions and most patients can take isosmotic MBP in combination with oral intake without adverse effects. The use of hyperosmotic MBP solutions is not recommended.[11]

In summary, preoperative strategies aim to avoid prolonged preoperative fasting.[12,13] The administration of preoperative carbohydrate drinks[14] has increased patient satisfaction, reduced preoperative hypovolemia, and also reduced intraoperative fluid requirements. Within the authors' institution, we require patients to fast from food for >8 h prior to surgery, and drinking clear liquids is encouraged up to 2 h prior to surgery and by providing patients with a carbohydrate drink.

3 | INTRAOPERATIVE MANAGEMENT

Intraoperative fluid therapy can be considered in two broad categories: maintenance fluid therapy, and volume therapy. The overall goal of intraoperative fluid therapy should aim to maintain a near zero balance, and substantial weight gain of more than 2.5 kg should be avoided. Intraoperative maintenance therapy aims to administer balanced crystalloid solutions to cover the needs derived from the salt and water homeostasis. This contrasts with volume therapy where goal-directed boluses of IV solutions (typically 250-500 mL) are administered to treat hypovolemia.

3.1 | Maintenance therapy

Excess salt and fluid in the perioperative period is now generally accepted as harmful. Lowell et al[15] studied postoperative critical care patients and found that perioperative weight gain (fluid excess) was associated with a dramatic increase in mortality. Fluid and salt excess increases the risk of pulmonary complications, prolonged ileus, and delayed recovery.[16,17] Improved outcomes associated with relative fluid restriction (as compared with traditional approaches) have been found in prospective studies of general surgical patients published in the surgery[4] and anesthesiology[18] literature. This is sometimes deemed a restrictive approach.[18,19]

Shorter hospital lengths of stay (LOS), improved wound healing, fewer surgical site infections, and fewer cardiovascular and pulmonary complications have all been associated with relative fluid restriction and are supported by a meta-analysis.[20] While many of these studies are small, the avoidance of fluid and salt overload in major surgery is now a major key component of ERPs. Current evidence suggests that intraoperative maintenance fluid requirements should be met with a basal crystalloid infusion rate of 1 mL-3 mL $\cdot$ kg^{-1} $\cdot$ h^{-1}. Isotonic balanced crystalloid solutions should be preferred and 0.9% saline solution avoided as hyperchloremia caused by the use of 0.9% saline solutions has been associated with kidney dysfunction, prolonged hospital stay and increased 30-day mortality (OR = 1.58, 95%CI 1.25-1.98).[21]

The largest trial so far comparing a restrictive versus liberal fluid regime, the RELIEF study, has just finished enrollment.[22] The study compared 2800 patients undergoing major abdominal surgery, with the primary endpoint disability free survival at 1-year after surgery. Results are expected in 2018 and should further inform clinicians.

3.2 | Volume therapy

Volume therapy is a term given to the administration of boluses of IV solutions (typically 250-500 mL) to treat objective evidence of hypovolemia, with the goal of improving intravascular volume, blood flow (stroke volume [SV]), and oxygen delivery. The need for

intraoperative volume therapy should be based on individualized objective measures of responsiveness: a technique often referred to as goal-directed therapy (GDT) or goal-directed fluid therapy (GDFT).[23]

3.3 | The beginnings of goal-directed therapy

The notion of a GDT strategy for improved patient outcomes is based largely upon the early work by Schultz et al over 30 years ago.[24] They found that intraoperative optimization, performed in a nonspecific manner guided by a pulmonary artery catheter (PAC), reduced the remarkably high mortality and morbidity in elderly hip fracture patients from 29% to 2.9%.[24]

The application of this concept of goal-directed hemodynamic optimization began in the late 1980s, however, following work published by Shoemaker et al,[25] which showed greater chance of survival in high risk patients was associated with the attainment of supraphysiologic hemodynamic parameters (cardiac index [CI] ≥ 4.5 L/min/m^2, DO_2 ≥ 600 mL/min). This was followed by a prospective cohort study of 300 surgical patients with septic shock in which those patients who survived had a higher cardiac index, as well as higher oxygen consumption and delivery.[26] Building on these findings, others tested early GDT protocols and observed decreased mortality in patients who received hemodynamic optimization via use of PAC.[27]

From these discoveries, came the concept of a "supertherapeutic optimization" strategy which has been associated with mixed outcomes. Studies utilizing super-optimization in septic[28] as well a mixed group of critically ill ICU patients[29] did not demonstrate an effect on mortality. These studies have been criticized for starting resuscitation up to 4-12 h after arrival to the ICU, which is perhaps too late, long after irreversible tissue hypoxia and end organ damage had already begun.

Using inotropes to increase oxygen delivery (DO_2) during surgery decreased perioperative morbidity and mortality in high-risk surgical patients undergoing general surgery[27,30]; as well as patients undergoing cardiothoracic surgery.[31] Patients whose oxygen delivery was normal to high normal upon arrival in the ICU also had decreased hospital length-of-stay (LOS).[1] However, despite these promising results, uptake was limited. Oxygen-targeted approaches required significant resources, were invasive, intensive, and dependent on the use of the PAC.

3.4 | Modern GDT—which goals?

Unfortunately, there is no one best endpoint for perioperative GDT. The ideal endpoint would be representative of end organ perfusion, readily available in the perioperative period, continuous, and reproducible. Traditional pressure-based parameters such as blood pressure (BP), heart rate (HR), central venous pressure (CVP), and pulmonary artery occlusion pressure (PAOP or wedge pressure) are appealing as they are readily available. Unfortunately, these measures all fall short as accurate endpoints for perioperative GDT.

Both HR and BP have been demonstrated to be insensitive indicators of volume status.[23] CVP and PAOP have also been shown to be poor predictors of volume status in both healthy volunteers[32] as well as critically ill patients,[33] and routine use of CVP measurement to identify which patients need more fluid is not recommended.[33]

Markers of tissue well-being (lactate, SvO_2, $SCvO_2$, gastric tonometry) bridge the gap between hemodynamic monitoring and monitoring tissue dysoxia. Although lactate is established as a marker in septic shock,[34,35] lactate has not been well studied as an endpoint for GDT. Similarly, SvO_2 is not well studied in perioperative GDT outside of cardiac surgery, but perioperative GDT with $SCvO_2$, a closely correlated surrogate,[36,37] has been shown to reduce postoperative complications and hospital LOS in patients undergoing abdominal surgery.[38]

3.5 | Minimally invasive cardiac output (CO) monitors

The last 20 years have seen the arrival of a number of minimally invasive CO monitors that enable clinicians to monitor and optimize SV, stroke volume variation (SVV), CO, and other hemodynamic variables routinely in high-risk patients without the need for a PAC. This has led to the concept of "SV optimization" as the most widely used endpoint of perioperative GDT. Fluid therapy using SV optimization is based on "fluid responsiveness," where repeated administration of fluid boluses occurs when patients "respond" to fluids (by objectively increasing SV).

At present, nearly all minimally invasive CO monitors have been validated using the PAC as the "gold standard" monitor of SV despite its accepted flaws. These validation studies are reviewed elsewhere,[39–44] unfortunately there remains some discrepancies in accuracy between the minimally invasive monitors. This may have to do with imprecision of the reference technique, though, as many studies show acceptable accuracy but unacceptable limits of agreement (precision).

Dynamic parameters such as SVV, pulse pressure variation (PPV), and pleth variability index (PVI) are gaining popularity as endpoints for perioperative GDT. Intraoperative SVV-guided GDT decreased GI complications in patients undergoing major abdominal surgery,[45] decreased wound infection in high-risk surgical patients and reduced fluid volumes and nausea/vomiting in thoracic surgery patients.

The use of PPV for intraoperative GDT has been shown to decrease length of mechanical ventilation, postoperative complications, and ICU and hospital LOS in patients undergoing high-risk surgery.[46,47] Both SVV and PPV take advantage of cardiorespiratory interaction over a mechanically ventilated respiratory cycle and are limited by their requirement for somewhat high (≥8 mL/kg ideal body weight) tidal volumes, normal sinus rhythm, and a normal interaction between the right heart and the lungs. These limitations are more common in ICU, but can occur in the perioperative period.[48] PVI and pulse oximetry plethysmographic waveform amplitude (ΔPOP) are completely noninvasive measures that use changes in the pulse oximetry waveform to predict fluid responsiveness.[49] Perioperative PVI-based GDT has been associated with lower intra- and postoperative lactate levels in patients undergoing major abdominal surgery.[50]

Arguably more important than absolute agreement is the ability of various monitors to net similar clinical outcomes.

3.6 | Trials of GDFT

Many trials of GDFT have shown clinical benefits over traditional liberal fluid administration.[51–55] A meta-analysis of more than 2000 patients suggested that perioperative GDT reduced morbidity regardless of the monitoring technique used,[6] which has led some investigators to postulate that the benefit of GDT arises from a systematic approach to hemodynamic optimization.[56]

The benefits of GDT include reductions in length of stay, surgical complications, acute kidney injury, and hospital costs. However, most of these studies were not conducted within an ERP, and perioperative fluid overload (probably common in the liberal fluid control group in many of these studies) has been associated with adverse outcomes.[57,58] This has led investigators to compare GDT with restrictive volume regimens within an ERP.

Srinivasa et al[59] conducted a prospective double-blind single-center randomized clinical trial with a 1:1 patient allocation ratio and were randomized to a fluid restriction group or a GDFT group within a well-functioning ERP. The primary outcome of the study was the surgical recovery score, which assesses fatigue, vigor, mental function, impact on patient activity, and activities of daily living. Secondary outcomes included intraoperative cardiac indices obtained from esophageal Doppler measurements, as well as vasopressor use, serum concentrations of brain natriuretic peptide, renin and aldosterone levels pre- and post-surgery, as well as markers of renal function. Those patients randomized to the GDFT arm received significantly more colloid during surgery than the fluid restriction group (591 ± 471 vs 297 ± 275 mL; $P = 0.012$; mean ± SD) and an overall much greater volume of IV fluid 1994 ± 590 vs 1614 ± 420 mL; $P = 0.01$). Both groups had similar transfusion needs and there were no differences observed in bodyweight, urine output, serum electrolytes, and vasoactive hormones. Similarly, there were no differences between the fluid restricted group and the GDFT groups throughout the recovery period as measured by the surgical recovery score.

This RCT of GDFT did not demonstrate a measurable benefit to patients undergoing elective colectomy within an ERP incorporating fluid restriction. Although those patients randomized to GDFT received more intraoperative colloid resulting in a larger volume of IV fluid overall and having a greater aortic flow—there were no differences between groups in either clinical or surgical recovery outcomes; physiological variables; serum markers; or vasoactive hormones.

Their study is dissimilar to previous trials as it explored the efficacy of GDFT alongside intraoperative fluid restriction. Moreover, this is one of the few trials to have been conducted in an otherwise optimized perioperative environment. It is notable that the most recent trials exploring GDFT within an ERP, but without fluid restriction, showed equivalent outcomes for patients randomized to GDFT. It appears that the benefits of GDFT may be offset by the other advances in perioperative care (such as ERPs), and, therefore, small single center trials may no longer be able to demonstrate significant outcome benefits. In other words, as perioperative care changes, so does the measurable impact of any single intervention.

The first multicenter study of GDFT, the OPTIMISE study, was conducted in the UK and focused on 734 high-risk patients managed within an ERP. The incidence of the primary outcome, a composite of postoperative complications and mortality, was lower in the GDT group (36.6% vs 43.4%). However this reduction, while consistent with the benefit observed in many previous trials, was not statistically significant ($P = 0.07$). The study was underpowered as the incidence of the primary outcome was less compared with the higher value (68%) from preliminary data, which was used to calculate the sample size for the trial. Hence the study did not provide a definitive answer, and OPTIMISE II, sample size 2800, is just starting recruitment.

It is important to note that whatever fluid management strategy is employed, all patients should have a fluid management plan based on local departmental guidelines. Institutions without local guidelines have consistently been shown to have wide variations in fluid management both within and between anesthesia providers.[60]

So where are we now? First, in the many studies that have been conducted using GDFT there is no evidence that GDFT causes harm. Second, as perioperative care has improved the most benefit from GDFT over a restrictive fluid management strategy, if present, appears likely to be in certain subsets of high-risk patients rather than all patients undergoing surgery within ERPs. Current recommendations are that all patients should have an individualized plan for fluid management that matches the monitoring needs with patient and surgical risk (Figure 1).[10]

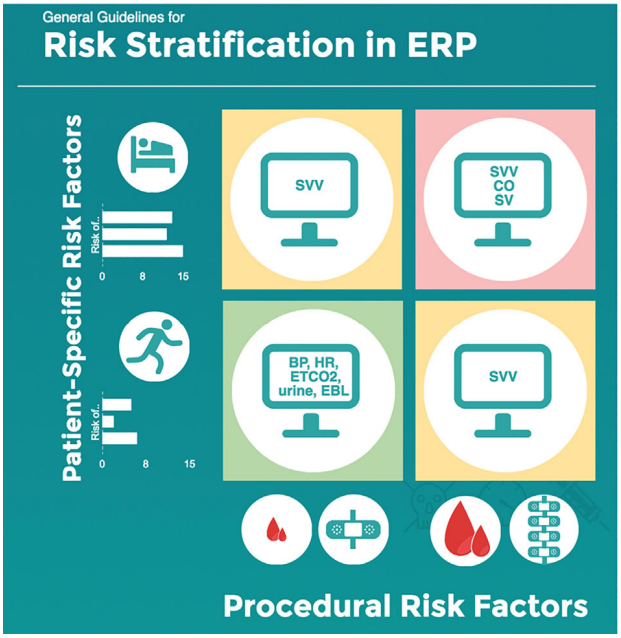

FIGURE 1 Risk-stratified approach to hemodynamic monitoring. As patient-specific risk factors increase along with the increasing risk factors from the procedures themselves, hemodynamic monitoring choices should follow based on clinical need and clinician judgment/experience (reproduced with permission from POQI.org)

4 | POSTOPERATIVE MANAGEMENT

The principles of intraoperative fluid management (avoiding insufficient and excess fluid delivery) also apply postoperatively, although there are significant differences in the environment that effect management and treatment options.

Within ERPs early postoperative oral intake is encouraged, with many patients allowed oral intake immediately after surgery. "Once oral fluid intake is established, IV fluid administration can be discontinued", often before the patient leaves PACU. This gives patients the ability to regulate their own oral intake.

Despite adequate oral intake, postoperative urine output (UOP) may be low. With traditional management principles, this would be treated with a bolus of IV fluid. However there is increasing evidence that oliguria (defined as <0.5 mL/Kg/h) may be a normal physiologic response to stress and surgery, and does not predict either volume status or progression to renal failure.[61] This contrasts with anuria which is abnormal and should always warrant further investigation.

A recent meta-analysis (1594 patients, 15 studies) investigating the effect of fluid restriction on postoperative oliguria and AKI found there was a trend toward oliguria in the fluid restriction group (OR 2.07, 95%CI 0.97-4.44) but there was no difference in the incidence of AKI (OR 1.07, 95%CI 0.60-1.92). In addition, targeting oliguria as a trigger for fluid boluses within GDFT protocols does not reduce postoperative AKI,[62] and may cause harm.[63]

Therefore, current evidence suggests that low UOP alone should not trigger fluid therapy. The recently completed RELIEF study will be the largest study yet to study the relationship between restrictive versus liberal fluid therapy, perioperative UOP, and postoperative AKI and should provide more evidence: results are expected in 2018.[22]

In contrast, there is increasing evidence that perioperative hypotension is associated with harm. Recent observational data from over 50 000 patients suggested that mean blood pressure (MBP) <65 mmHg for greater than equal to 15 min was associated with significantly higher rates of myocardial and kidney injury. The association was stronger at lower MBP's, and when hypotension was prolonged. Interestingly, there was no clinically important correlation with preoperative pressure. Although this data is observational and cannot assess causality, it seems prudent to avoid MBP <65 mmHg whenever possible.[64]

The treatment of postoperative hypotension is controversial, but may involve a combination of IV fluid challenges, vasopressors, and other interventions (reducing the rate of any epidural infusion). If IV fluid is required postoperatively for hypotension or any other reason (nausea and vomiting, ileus, etc), excess salt should be avoided, as most patients will be in a positive sodium balance,[65] which can delay GI recovery. Clinicians should also avoid high-volume fluids and aim to maintain preoperative body weight wherever possible. In high-risk patients there is some evidence that maintaining GDFT into the early postoperative period may be beneficial.[30]

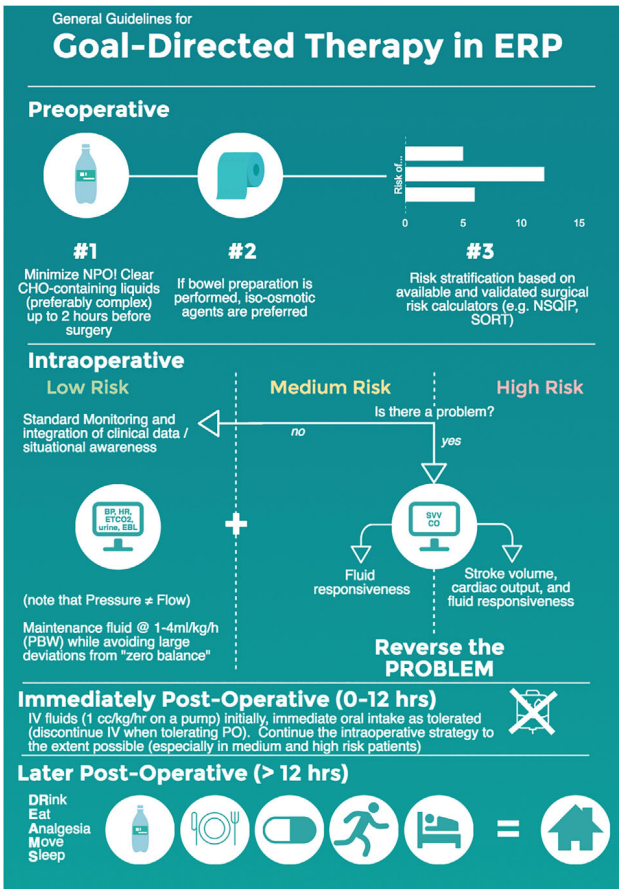

FIGURE 2 A summary of fluid and hemodynamic management within an ERP (Reproduced with permission from POQI.org)

5 | CRYSTALLOID OR COLLOID—WHICH FLUID TO USE?

Fluid homeostasis in the body is the result of complex interactions between compartments and barriers and the prerequisite of stable hemodynamics.[66] The questions of which type of IV fluid to use and how much to use during surgery has been reviewed elsewhere.[67] Nevertheless, the ideal fluid type has yet to be determined.

GDT algorithms typically include a baseline infusion of a balanced crystalloid as well as intermittent boluses of a colloid, to optimize CO, along with the addition of vasoactive medications. While replacement of extracellular losses, such as urine output and insensible water losses through evaporation, using isotonic crystalloids seems rational,[68] there are multiple divergent opinions for maintaining and/or restoring intravascular volume.[69] The use of non-buffered crystalloids (such as, normal saline) has been associated with more metabolic derangements (hyperchloremia, metabolic acidosis) than buffered fluids,[70] perhaps explaining the dominance of buffered versus non-buffered fluids in anesthesiology.

Initially, colloids were thought to optimize the microcirculation better than crystalloids[71] through their superior volume-expansion properties, thereby allowing smaller volumes of fluid to be used which remained within the vasculature and was associated with improved perioperative outcomes.[72]

TABLE 1 Summary of key points

• Goal-directed fluid therapy is the individualized optimization of hemodynamics and oxygen delivery using IV fluids and/or vasoactive infusions guided by objective monitoring.
• Careful attention to perioperative fluid and hemodynamic management within an enhanced recovery pathway improves outcomes, including shorter hospital length of stay, improved wound healing, fewer surgical site infections, and fewer cardiovascular and pulmonary complications.
• Perioperative management aims to avoid baseline hypovolemia by avoiding prolonged preoperative fasting and including preoperative carbohydrate drinks.
• Intraoperative management includes thoughtful maintenance fluid therapy and volume therapy in the form of goal-directed fluid therapy.
• Postoperative management encourages early PO intake and thoughtful restrictive IV fluid therapy.

This theoretical advantage to using colloids extends into the postoperative period, as lower volumes are needed to achieve similar hemodynamic endpoints, which results in decreased tissue edema and greater anastomotic integrity.[71] These physiological vascular barrier properties may explain a possible advantage of artificial colloids or natural protein solutions. These iso-oncotic preparations are believed to remain within the intravascular space longer, while crystalloids quickly distribute evenly across the whole extracellular compartment, that is, 80% move into the interstitial space.[68] Several studies have demonstrated that excess volumes of crystalloid solution in the perioperative period, and the associated positive fluid balance, are detrimental to recovery.[4,18]

Yates et al performed a double-blind, randomized controlled trial to assess whether a balanced hydroxyethyl starch (HES) solution reduced morbidity after colorectal surgery compared with a balanced crystalloid solution—when both were used in the same GDFT protocol.[73] A total of 206 patients were randomized to either the colloid group or crystalloid group, with primary outcome being the presence of gastrointestinal (GI) morbidity at postoperative day 5, the secondary outcome measures were complications during the hospital admission; hospital length of stay; perioperative hemodynamic variables; use of vasopressor or inotropic support; changes in inflammatory markers; and changes in coagulation.

These authors found small increases in both minor and major complications in patients in the HES group, however, after correcting odds ratios for baseline differences in oxygen delivery there were no significant differences between those patients in the HES group versus the crystalloid group.[73] Patients in the crystalloid group required significantly more fluid during the intraoperative phase, yet patients in the HES group required more fluids in the postoperative period. When considering the overall fluid requirements, the crystalloid group required 4226 mL (3251-5779 mL) to the HES's 3610 mL (2443-4519 mL) ($P < 0.001$).[73]

Interestingly, Yates et al reported a 1:1.6 colloid to crystalloid ratio in their study, suggesting that less crystalloid is needed to maintain equivalent hemodynamics than previously reported.[73] However, these findings are in the setting of patients who were previously optimized for surgery and therefore the differences between their study and others may be due to the other components of optimization rather than the fluids themselves.

Although in a different patient population, this has prompted further investigation of the issue of crystalloid versus colloid in perioperative GDT. Studies comparing crystalloid- versus colloid-based GDT in both colorectal[73] and neurosurgical[74] procedures have demonstrated lower IV fluid volumes in colloid-based GDT patients without any meaningful clinical differences between the two groups.

A study comparing balanced crystalloid- versus colloid-based GDT algorithms in patients undergoing cytoreductive surgery for primary ovarian cancer demonstrated lower volumes of IV fluids, higher CO, and higher SV in colloid patients, though they found no differences in postoperative complications or LOS.[75] It appears that colloids do allow for better volume expansion, but that this is associated with little to no clinical benefit in perioperative GDT, especially when the administered volumes are modest. It may be that perioperative patients are less prone to diffuse capillary leak than septic patients, and, thus, at less risk of harm from synthetic colloids. However, this idea deserves further consideration and study before conclusions are reached.

In summary, the crystalloid versus colloid debate continues. There is a strong theoretical advantage to colloid for volume therapy as part of perioperative fluid management when there are objective measures of intravascular hypovolemia. There is also good evidence clinically that more crystalloid is needed than colloid for the same volume effect (ratio probably around 1.6:1), and that excess fluid and its associated weight gain is associated with harm. However, there are limited outcome studies, most of which are small, and do not demonstrate any benefit to colloid therapy. Therefore, the question remains: is the difference in volume required perioperatively between crystalloid and colloid meaningless, or has a large enough study not been performed to demonstrate an outcome benefit?

The European Society of Anesthesiology Clinical Trials Network is planning the PHOENICS study, a 2280 patient multicenter study of HES versus a balanced crystalloid solution in major abdominal surgery to help address this question. Meanwhile, although many centers use colloid boluses for fluid management, current guidelines are mixed in their recommendations.[76]

6 | CONCLUSION

Perioperative fluid and hemodynamic management within ERPs is a continuum that occurs before, during, and after surgery: from preparation for surgery, through the procedure itself until the patient is hemodynamically stable and can regulate their own fluid intake (Figure 2). While the exact approach will depend on patient risk and the

extent of the surgical insult, the principles of avoiding preoperative hypovolemia, maintaining perioperative intravascular volume while avoiding fluid overload, and drinking as soon as possible postoperatively apply to all patients.

Tissue hypoxia, which develops within the perioperative period, contributes to morbidity and mortality and may be mitigated using perioperative GDT in high-risk patients. However, there continues to be significant debate on the optimal conduct of GDT. At its core, perioperative GDT requires both a hemodynamic goal and some form of hemodynamic monitor. Further study is needed to which patients will benefit from GDT for different procedures within a well-established ERP. Moreover, it would help to better delineate which patients would benefit from fluids alone versus fluids and vasoactive medications, and whether colloid or crystalloid should be used for volume therapy.

In summary, fluid and hemodynamic management within an ERP is important as hypovolemia, hypotension, and fluid overload are all associated with harm. This is reflected in the number of large RCTs currently ongoing to help inform practice. Current evidence, which is summarized in Table 1, supports the recommendation are that all patients should have an individualized plan for fluid and hemodynamic management that matches the monitoring needs with patient and surgical risk. The exact pathway will vary according to local factors, and should be specific to the patient, surgeon, procedure, and institution.

CONFLICTS OF INTEREST

MWM and WJD have nothing to disclose, TEM receives research funding from Edward Lifesciences, and is a consultant for Edwards Lifesciences and Cheetah Medical.

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SYNOPSIS

Careful attention to perioperative fluid and hemodynamic management as part of an Enhanced Recovery Pathway improves outcomes. All patients should have an individualized plan for fluid and hemodynamic management that matches the monitoring needs with patient and surgical risk.