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Review Article

Peri-operative fluid management to enhance recovery

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Summary

'Enhanced recovery after surgery' protocols implement a series of peri-operative interventions intended to improve recovery after major operations, one aspect of which is fluid management. The pre-operative goal is to prepare a hydrated, euvolaemic patient by avoiding routine mechanical bowel preparation and by encouraging patients to drink clear liquids up to two hours before induction of anaesthesia. The intra-operative goal is to achieve a 'zero' fluid balance at the end of uncomplicated surgery: goal-directed fluid therapy is recommended for poorly prepared or sick patients or those undergoing more complex surgery. The postoperative goal is eating and drinking without intravenous fluid infusions. Postoperative oliguria should be expected and accepted, as urine output does not indicate overall fluid status.

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Introduction

Postoperative 'fast-track' programs evolved into 'enhanced recovery after surgery' pathways, which implement a series of pre-operative, intra-operative and postoperative interventions to enhance recovery after major operations. The goal is to minimise postoperative side-effects and to encourage patient activity. Peri-operative care is co-ordinated through evidence-based protocols, from the pre-operative clinic to the postoperative care team. The reliable delivery of evidence-based care is the mainstay of enhanced recovery.

An important aspect of peri-operative care is fluid management. Peri-operative fluid overload has been associated with increased morbidity [1], and its avoidance may improve outcomes after major elective gastrointestinal and thoracic surgery [2]. A multicentre Danish study showed that intra-operative fluid restriction, independent of the amount of fluid given before or after surgery, halved the rate of postoperative complications [3]. Litres of crystalloid administered on the first postoperative day have been associated with postoperative ileus and delayed hospital discharge [4]. Hypoproteinaemia caused by crystalloid infusion may delay gastric emptying, small bowel transit and cause postoperative ileus [5–7]. Peri-operative fluid management deserves more scrutiny by anaesthetists, surgeons and other members of the healthcare team.

In this review, we evaluate the evidence for fluid management in patients undergoing surgery within an enhanced recovery pathway.

Pre-operative fluid management

The patient should come to the operating room in a 'fed', euvolaemic state as this reduces the haemodynamic effects caused by the induction of anaesthesia, compared with a 'starved', hypovolaemic state [8]. Guidelines recommend the consumption of clear fluids up to two hours before anaesthesia [9]. A 12.5% maltodextrin carbohydrate drink is an alternative to water, 400 ml of which are emptied from the stomach within 90 min of ingestion [10, 11]. Carbohydrate drinks decrease hunger, thirst, and anxiety [12] and reduce postoperative insulin resistance [13]. Although a single randomised controlled trial reported that hospital stay was unaffected by pre-operative carbohydrate drink [14], a recent multicentre analysis of observational data reported that pre-operative carbohydrate loading was independently associated with a reduced length of stay after colorectal resection [15].

Routine mechanical bowel preparation increases the incidence and severity of pre-operative dehydration, whereas its avoidance does not increase complications [14, 16]. Mechanical bowel preparation is unpleasant for the patient. It does not decrease mortality but might increase the rate of infection and sepsis secondary to spillage of liquefied bowel contents as opposed to solid stool, and might increase the rate of anastomotic leakage [17]. The disadvantages of mechanical bowel preparation may be ameliorated by oral antibiotics. A retrospective analysis of 8415 colorectal resections concluded that the addition of oral antibiotics to bowel preparation significantly reduced rates of surgical site infections from 12.0% to 6.5%, $p < 0.001$, and shortened median hospital stay from 5 to 4 days, $p < 0.001$ [18]. The authors concluded that mechanical bowel preparation without oral antibiotics should be abandoned, but that preparation with antibiotics was better than no bowel preparation at all. There remains a lack of consensus about which patients should have mechanical bowel preparation [19].

Intra-operative fluid management

Intra-operative fluid management should maintain the patient in a euvolaemic state. Excessive fluid (colloid or crystalloid) should be avoided. Maintenance fluid infusion, in conjunction with small (200–250 ml) boluses of fluid, achieves this objective. In contrast to 'restrictive' fluid therapy, which implies deliberate hypovolaemia [20], the aim is 'zero-balance' fluid management, with the goals of avoiding fluid excess and maintaining pre-operative hydration and weight [21].

Maintenance fluid therapy

Maintenance fluid should be administered to maintain a patient's pre-operative weight, by replacing losses from urine, sweat and other routes. Infusions of balanced crystalloid should not exceed 3 $ml.kg^{-1}.h^{-1}$, as evaporative losses are typically only 0.5–1.0 $ml.kg^{-1}.h^{-1}$ during major abdominal surgery, lower than originally thought. Replacement of 'third-space' loss, describing a non-functional compartment that can sequester a significant amount of fluid intra-operatively [22], is not supported by tracer studies [23]: fluid is either intravascular or interstitial [20, 23].

Excessive fluid administration can harm the patient significantly [3, 4]. Hypervolaemia increases intravascular hydrostatic pressure, damaging the endothelial glycocalyx that mediates vascular permeability, contributing to fluid retention in the interstitial space [24]. Oedema of the gut wall with resultant ileus is the most common manifestation of excessive fluid therapy after major bowel surgery. Excessive fluid administration in rats causes significant intestinal oedema after bowel resection, with a substantial decrease in the structural stability of the intestinal anastomosis [25]. In humans, a modest 3 kg fluid weight gain after elective colonic resection is associated with delayed recovery of gastrointestinal function, an increased rate of complications and a prolonged hospital stay [4].

Bolus fluid therapy

Blood loss and fluid shifts must be accounted for and replaced as necessary. Signs or symptoms of intravascular hypovolaemia should be treated with a rapid infusion of fluid over 5–10 min [26]. Patients with haemodynamic instability are not necessarily volume-depleted and rapid infusion should only be administered when hypovolaemia is evident or likely. Even so, rapid infusion only improves haemodynamic stability in fewer than half of patients, and responders should not be assumed to be hypovolaemic [27]. Additional administration of vasopressors may help to determine the effect of reduced vascular tone in causing relative hypovolaemia.

Heart rate, blood pressure, urine output and central venous pressure are not reliable measures of volume status. Acute blood loss of up to 25% of the circulating volume, for example, is not associated with rapid or significant changes in heart rate and/or blood pressure, because splanchnic vasoconstriction maintains core perfusion [28]. Systematic review has concluded that central venous pressure does not accurately identify which patients required fluid therapy, how much they require or whether routine monitoring of central venous pressure is of value in the operating room, emergency department or the intensive care unit [29]. Neurohormonal responses to surgical stress reduce urine output below 0.5 $ml.kg^{-1}.h^{-1}$, without indicating a need for fluid administration [30].

Goal-directed fluid therapy

Goal-directed fluid therapy extrapolates fluid responsiveness from measurable haemodynamic changes, according to the Frank–Starling law in patients without myocardial disease [31]. Several meta-analyses of multiple studies have concluded that goal-directed fluid therapy reduces complications, such as nausea, postoperative hemodynamic instability and shortens hospital stays after major surgery by 25–50% [32, 33].

Fluid responsiveness can also be predicted without administration of a fluid bolus. A number of cardiovascular measurements vary during the ventilatory cycle, such as stroke volume, pulse pressure and systolic pressure, the amplitude of their variation indicating the degree of hypovolaemia. These are more sensitive for hypovolaemia than changes in heart rate and blood pressure, allowing for earlier therapeutic intervention [34, 35]. Variation in the stroke volume or pulse pressure of at least 13% predicts fluid responsiveness [31], although fairly constant R-R intervals [36], with constant intrathoracic pressure and tidal volumes above 7 $ml.kg^{-1}$ [36] are needed for accurate interpretation. When lower tidal volumes are used, as is often the case in clinical practice, the predictive value of these dynamic indices substantially decreases [37]. These indices should not be used in isolation, but should be combined with other clinical measurements to determine the presence of hypovolaemia.

Goal-directed fluid therapy for enhanced recovery

Goal-directed fluid therapy appears to be less effective in the context of an enhanced recovery protocol, probably because the patient is unlikely to be hypovolaemic at induction of anaesthesia. Goal-directed fluid therapy reduced the rate of gastrointestinal complications and the length of hospital stay (by two days) after major elective surgery among patients who did not follow an enhanced recovery protocol [38]. In a similar study of fasted patients who were hypovolaemic on induction of anaesthesia, goal-directed fluid therapy also reduced hospital stay by two days, even though the amount of fluid infused intra-operatively was the same (approximately 3.7 l) as for patients who did not have fluid guided by oesophageal Doppler readings [39]. In this study, goal-directed therapy patients had a higher mean (SD) cardiac index at the end of surgery than controls: 3.8 (1.3) $l.min^{-1}$ vs. 3.2 (1.2) $l.min^{-1}$, $p = 0.01$. There were also fewer postoperative complications, 1/50 vs. 8/51, $p = 0.043$. Other studies of goal-directed fluid therapy as part of an enhanced recovery protocol after colorectal surgery, have involved less fluid administration (approximately 1.5 l) and have not found improvements in outcome [9, 28].

Postoperative fluid management

Postoperative fluid management aims to maintain a euvolaemic state and continues to assess fluid responsiveness, particularly in high-risk patients [40]. Most patients are less able to excrete fluid and sodium postoperatively, which they retain [4].

Eating and drinking soon after gastrointestinal resection should be encouraged, as feeding is associated with a reduced risk of infection and a decreased length of stay, without an increase in the risk of anastomotic dehiscence [20]. Intravenous fluids should be discontinued and not restarted unless there is a clinical indication. Patients without ongoing fluid deficit or losses should drink at least 1.75 l water each day [41]. Normovolaemic patients made hypotensive by neuraxial anaesthesia should not be infused with fluid [14]. Instead, the dose of epidural local anaesthetic should be reduced, accompanied by vasopressor infusion. Postoperative oliguria should not trigger intravenous fluid infusion, as fluid retention is a normal neurohormonal response to stress.

Fluid choice

Balanced crystalloid solutions, such as lactated Ringer's solution, are recommended for intra-operative infusion [42], whereas reduced salt solutions, such as dextrose saline, are preferred postoperatively [20]. Normal saline, as a crystalloid or as part of a colloid should be avoided, because hyperchloraemic acidosis has been associated with reduced gastric blood flow, a decrease in gastric intramucosal pH, a reduction in renal blood flow velocity and reduced renal cortical tissue perfusion [43–47], although it may be beneficial in upper gastrointestinal surgery to correct hypochloraemic metabolic alkalosis [20].

There is no consensus on whether to use crystalloid or colloid for goal-directed fluid boluses. In principle, colloids are believed to restore blood pressure, and therefore organ perfusion, faster than crystalloids [20]. Patients given crystalloid boluses usually receive higher cumulative volumes than patients given colloid boluses, but without affecting outcome [47]. Colloids may be preferable to crystalloid [20], but increase the risk of bleeding, especially when larger volumes of older types of hydroxyethyl starch are used [39, 48], compared with newer starches [49, 50].

Starches increase renal injury rates in the critically ill, although this problem has not been shown for scheduled surgery [51, 52]. In June 2013, the United States Food and Drug Administration recommended that hydroxyethyl starch should not be used in patients with pre-existing renal dysfunction. It also recommended monitoring renal function for at least 90 days after hydroxyethyl starch had been given and to discontinue it at the first sign of renal injury or coagulopathy [53]. These recommendations were based on the Crystalloid versus Hydroxyethyl Starch 'CHEST' trial and the Scandinavian Starch for Severe Sepsis '6S' trial, which reported relative risks (95% CI) of 1.21 (1.00–1.45) and 1.35 (1.01–1.80), respectively, for renal replacement therapy after starch infusion [49, 50].

It is unclear whether results on starch use from critically ill populations apply to scheduled peri-operative care. Hydroxyethyl starch 6% has been found to be nephrotoxic after orthotopic liver transplantation [54], but not after prostatectomy [55], although this may be explained by transplant patients being more susceptible to renal damage caused by starch.

Common clinical challenges

Fluid management in laparoscopic surgery

The limited fluid shifts that accompany simple laparoscopic procedures can be readily tolerated by healthy prepared patients without the need for goal-directed therapy. Fluid administration during more complex laparoscopic procedures in sicker patients may benefit from goal-directed therapy. However, pneumoperitoneum and head-down positions make goal-directed fluid therapy indices difficult to interpret. Increased intra-abdominal pressure decreases ventilatory compliance, which increases the ventilatory pressure required to deliver a given tidal volume [56], in turn increasing the variation in haemodynamic indices during volume-controlled ventilation without the blood volume changing [57, 58]. For instance, Høiseth et al. reported the variation in pulse pressure that determined fluid responsiveness was 20.5% with an intra-abdominal pressure of 26 mmHg, but was 11.5% with an intra-abdominal pressure of 7 mmHg [58], and found that the correlation between stroke volume variation and fluid responsiveness only existed below an intra-abdominal pressure of 25 mmHg, in contrast to a study by Kambhampati et al. which did not find a pressure threshold for correlation [59].

Peri-operative urine output

Traditionally, intra-operative urine output has been assumed to correlate with intravascular volume, with oliguria predicting postoperative renal failure. Postoperative acute renal failure is commonly attributed to pre-renal acute tubular necrosis, treated by maintaining renal blood flow with intravenous infusions of fluid and vasoconstrictors. However, an observational study of over 65 000 patients undergoing non-cardiac surgery suggest these assumptions are wrong, finding no significant correlation between the prevalence of postoperative acute renal failure and intra-operative urine output less than 0.5 $ml.kg^{-1}.h^{-1}$, regardless of the pre-operative risk of developing acute renal failure. In addition, a positive postoperative fluid balance is associated with increased risks of acute kidney injury and gastrointestinal dysfunction [59]. These suggest that within an enhanced recovery protocol, oliguria should be anticipated and permitted, without detrimentally affecting outcome.

Conclusion

Enhanced recovery protocols are associated with improved outcomes and reduced volumes of intravenous peri-operative fluid. Emphasis on the detrimental effects of hypovolaemia, which accompanied traditional patient preparation, has been replaced by concern about the harmful effects of hypervolaemia and hyperchloraemia. Excess fluid administration causes oedema and postoperative ileus. Patients should be anaesthetised in the euvolaemic 'fed' state and should be given intra-operative fluids according to protocol to decrease the risk of complications and to hasten recovery. Intra-operative goal-directed fluid protocols have decreased postoperative complications and hospital length of stay, particularly following induction of anaesthesia in hypovolaemic, starved patients, but have yet to demonstrate similar benefits in enhanced recovery studies, sicker patients having complex surgery excepted. Patients should receive individualised fluid management plans that take into account their co-morbidities and operative complexity. A zero-balance fluid approach should be employed, using balanced salt crystalloid solutions rather than 0.9% saline for fluid maintenance. Eating and drinking should be encouraged postoperatively and oliguria should be accepted.

Competing interest

No external funding or competing interests declared.

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