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REVIEW ARTICLE

Current concepts of fluid management in enhanced recovery pathways

R. Makaryus[1], T. E. Miller[2] and T. J. Gan[1,*]

[1]Department of Anesthesiology, Stony Brook University, Stony Brook, NY, USA and [2]Division of General, Vascular and Transplant Anesthesia, Duke University Medical Center, Durham, NC, USA

*Corresponding author. Department of Anesthesiology, Stony Brook University, HSC Level 4, Rm 060, Stony Brook, NY 11794-8480, USA. E-mail: tong.gan@stonybrookmedicine.edu.

Abstract

Perioperative fluid management impacts outcomes and plays a pivotal role in enhanced recovery pathways (ERPs). There have been major advances in understanding the effects of fluid therapy and administration during the perioperative period. Improving fluid management during this period leads to a decrease in complications, decrease in length of stay (LOS), and enhanced patient outcomes. It is important to consider preoperative and postoperative fluid management to be just as critical as intraoperative management given multiple associated benefits to the patients. Preoperative hydration with (complex) carbohydrate drinks up until 2 h before surgery is safe and should be encouraged, as this helps improve metabolism, decrease insulin resistance, reduce anxiety, and reduce nausea and vomiting. During the intraoperative period, the goals of fluid management are to maintain euvolemia using an individualized plan for fluid and haemodynamic management, matching the needs for monitoring with patient and surgical risk through goal-directed therapy (GDT). By combining the use of fluids and inotropes, GDT uses measurements and indicators of cardiac output and stroke volume to improve blood flow intraoperatively, and ultimately reduce LOS and complications. In the postoperative period, an early transition to oral hydration helps to enhance the conditions for healing and recovery from surgery. I.V. fluid therapy should be kept at a minimum, and urine output should not be the driving force for fluid administration. The optimization of perioperative fluid management is critical to ERPs as it helps improve pulmonary function, tissue oxygenation, gastrointestinal motility, and wound healing.

Keywords: fluid therapy; perioperative care; perioperative period

The practice of medicine seeks to continually improve the care that is provided to patients. Optimizing fluid therapy in the perioperative setting improves patient outcomes and reduces complications and length of stay (LOS).[1–4] The primary goal of any physician is to optimize patient health to prevent future disease and to treat existing diseases to improve outcomes. Surgery is a complex treatment method, where tissue insult is an expected part of patient care, with the idea that controlled short-term injury is an acceptable risk in the face of long-term health benefits. With a focus on improving patient outcomes and recovery, fluid management plays an important role in enhanced recovery pathways (ERPs) now being used in many hospitals.[5]

Perioperative physicians have multiple goals that can be divided into three categories. First, they seek to optimize the preoperative health status of the patient, including pre-existing conditions and comorbid diseases, so as to maximally decrease the risk of perioperative complications.

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Secondly, intraoperative management of patients is planned with the goals of improving patient recovery. Finally, postoperative care is designed to maximize recovery from the tissue injury. Similarly, perioperative fluid therapy can be divided into three components, namely, preoperative, intraoperative, and postoperative management, as represented in Figure 1.

Given the drive to improve patient care, ERPs have become an essential aspect of perioperative patient care, with fluid therapy playing a pivotal role. Fluid management and administration is an integral aspect of perioperative care. Historically, the focus has been on the intraoperative management of fluids; however, recently the focus has shifted to a more complete perioperative management of fluids, including preoperative hydration, intraoperative management, and postoperative outcomes. The goal of this review is to elucidate basic concepts used in perioperative fluid management and the application of these concepts to preoperative, intraoperative, and postoperative management of fluid therapy.

Goal-directed therapy

Management of intraoperative fluids has been the subject of much debate through the years. Early on, some recommended that patients be given very little fluids intraoperatively, as fluids were thought to increase the risk of postoperative complications.[6,7] As more patients were undergoing surgical procedures, it became clear that not providing intraoperative fluids had major adverse effects on the postoperative period, including complications such as prerenal acute tubular necrosis.[8] Given this knowledge, fluid administration during surgery became a standard of care for all operative procedures requiring anaesthesia.[9] Patients were given fluids liberally during surgery based on the concept that inadequate administration of fluids would result in poor outcomes. Even third-space loss, or oedema, was considered a fluid loss that needed to be replenished aggressively.[10] It became clear, however, that fluid overload in postoperative patients also caused rather severe complications, including pulmonary congestion,[11] decreased tissue oxygenation, decreased wound healing,[12,13] increased oedema,[14] and delayed recovery.[4] With this in mind, it is imperative that we define the treatment goals for management of perioperative fluid therapy.

Anaesthesiologists often consider fluids as a carrying device or a vehicle through which other medications can be given. However, it is important that we consider fluids as medications in and of themselves. Thus, fluids should be accurately calculated and dosed in a more specific way. Intraoperative management of fluids during surgery should be guided by goal-directed therapy (GDT) rather than predetermined calculations. Just as with any perioperative medication given, fluids should be titrated to the desired effect.

Routes of fluid administration

Fluid administration has only been considered via one method, which is directly into the intravascular space, specifically by the i.v. route. As we start to learn more about fluid management, intravascular volume, intracellular volume, and fluid volume in the interstitial space, it is becoming more and more clear that i.v. fluid administration does not necessarily lead to a direct increase in intravascular volume.[15] Particularly after surgery and as a result of tissue injury, much of the fluids administered i.v. accumulate in the interstitial space causing unwanted oedema. The best method to improve hydration is by increasing *per os* (PO) fluid intake. Although this is not practical in the anaesthetized patient, it should still be an important consideration in perioperative patient care. While following nil *per os* (NPO) guidelines, preoperative as well as early postoperative PO hydration is very important and can have significant benefits in the recovery period.

Most often, fluid management is about which fluid is given and how the provider administers or withholds it. There is, however, a rather important role that the patients themselves can play in optimizing their own fluid status. It is becoming more apparent that PO hydration is superior to i.v. fluid therapy. For example, children who are being treated for gastroenteritis historically received i.v. fluids as a first line therapy. This has been challenged with new data demonstrating that those being treated with PO hydration or hydration through nasogastric tubes tend to fare better than those who receive i.v. fluids.[16] This is postulated to be due to much of what is given i.v. not remaining intravascular, possibly resulting in unwanted oedema. Similarly, in perioperative patient care, it is becoming more apparent that PO hydration, both preoperatively and postoperatively, can improve patient experience and outcomes. Thus, it is crucial for the provider to empower patients to take control over aspects of their preoperative management that they can improve, such as PO hydration prior to surgery.

Preoperative fluid management

NPO guidelines

The ASA provides well-defined guidelines about how long a patient should be NPO prior to procedures requiring anaesthesia. While patients are required to refrain from eating solid foods, particularly fatty meals, for at least 8 h prior to surgery, the requirement for refraining from clear liquids is only 2 h prior to surgery.[17] Given these guidelines, patients should be encouraged to continue PO hydration up until 2 h before surgery.

The goal of NPO guidelines is to reduce the risk for pulmonary aspiration by giving the appropriate time needed for gastric emptying. There is now increasing evidence that increasing PO hydration with clear liquids ending 2 h prior to surgery does not increase gastric volumes, and may even reduce the acidity of stomach fluids.[17] The recommended preoperative use of clear carbohydrate beverages prior to surgery has not been associated with any increase in the risk of aspiration or other pulmonary complications.[18] Recent magnetic resonance imaging studies have shown that the time needed for sufficient gastric emptying in healthy adult volunteers after the ingestion of clear carbohydrate beverages is 120 min.[19] This has also been corroborated in a more recent study that sought to compare morbidly obese to average weight patients.[20] Residual gastric volumes after oral rehydration in the morbidly obese were not greater than those who had fasted overnight, as determined by magnetic resonance imaging.[20] These findings support the rationale for the recommended 2 h of NPO time for clear liquids prior to surgical procedures. The European and Canadian guidelines not only allow fluids up until 2 h prior to surgery, but they encourage it.[21]

Advantages of carbohydrate drinks

The advantages of preoperative hydration go beyond simply optimizing the volume status of patients prior to surgery, it

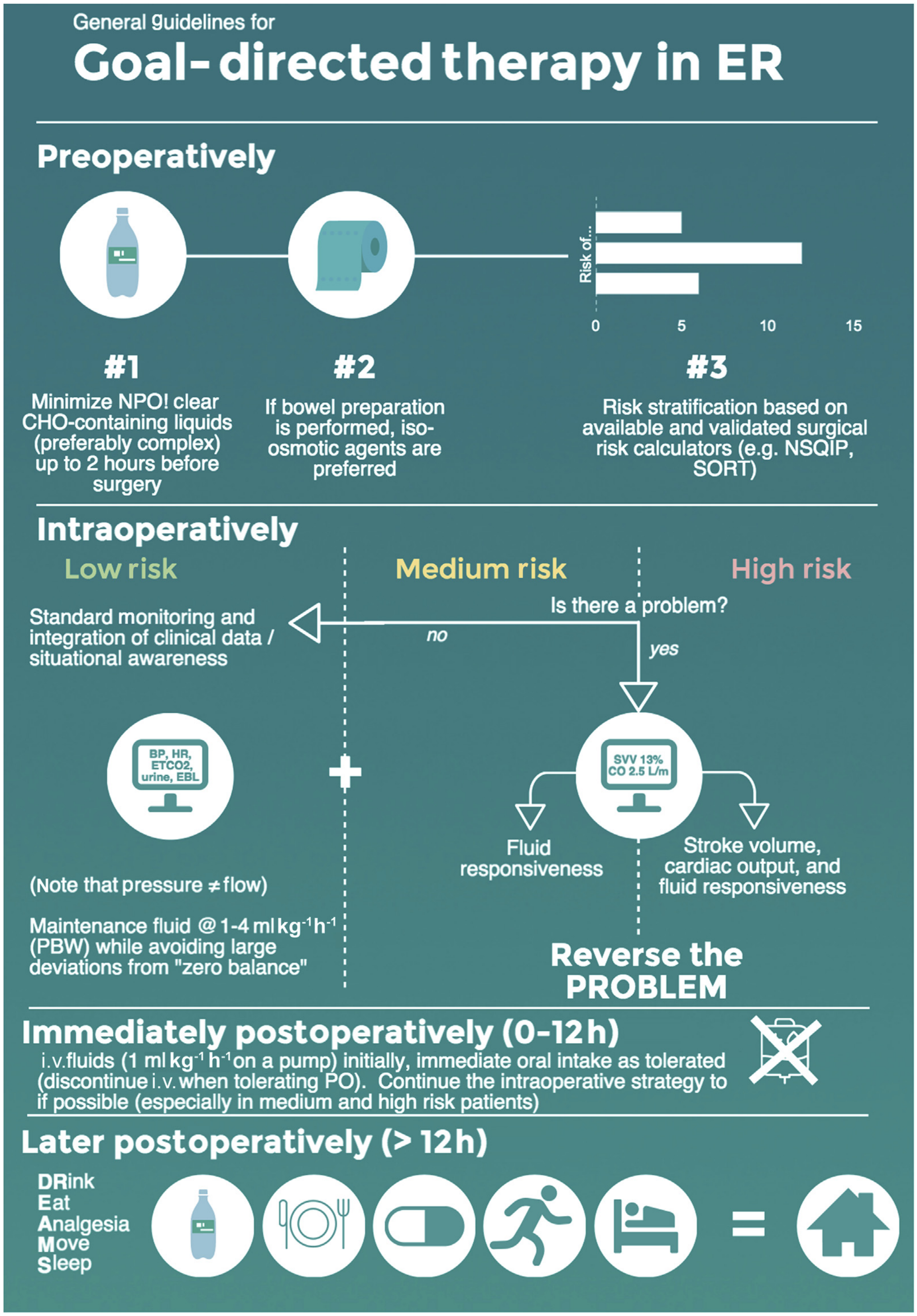

Fig 1. Guidelines from the American Society for Enhanced Recovery (ASER) and Perioperative Quality Initiative (POQI) for the perioperative management of fluids using goal-directed therapy (GDT) in enhanced recovery pathways (ERPs). BP, blood pressure; CHO, carbohydrate; CO, cardiac output; EBL, estimated blood loss; $ETCO_2$, end tidal carbon dioxide; HR, heart rate; IV, intravenous; NPO, *nil per os*; NSQIP, National Surgery Quality Improvement Program; PBW, predicted body weight; PO, *per os*; SORT, Surgical Outcome Risk Tool; SVV, stroke volume variation.

also improves their overall metabolic status. The use of carbohydrate drinks up until 2 h prior to surgery has multiple benefits without increasing the risk of aspiration. These key advantages include improving metabolism to an anabolic state,[22] decreasing insulin resistance,[23] reducing anxiety,[24] and reducing nausea and vomiting.[25]

The metabolic state of the preoperative patient should be optimized in preparation for surgery. They should be in a well-fed, anabolic state rather than in a starved, catabolic state.[22] The typical fasting period of 8 h prior to surgery forces metabolism into a catabolic state, wherein complex lipids, proteins, and carbohydrate stores are broken down to allow for continued energy sources needed for normal metabolic activity. The ingestion of complex carbohydrates prior to surgery helps to keep the body in the desired anabolic state.

Not only does oral carbohydrate ingestion help improve metabolic status, it decreases overall discomfort in the preoperative and postoperative period. Preoperative carbohydrate drinks reduce postoperative nausea and vomiting (PONV). A randomized single-blinded study demonstrated a significant reduction in PONV and use of antiemetic medications after laparoscopic cholecystectomy in patients who received a complex carbohydrate drink containing maltodextrin.[25] Another study reported a decrease in malaise, anxiety, hunger, and thirst with use of a complex carbohydrate drink.[24]

Another advantage of preoperative carbohydrate ingestion is a reduction in insulin resistance. Preoperative administration of oral carbohydrates reduced insulin resistance in patients in the postoperative recovery period.[23] In a recent meta-analysis, preoperative carbohydrate drinks reduced insulin resistance, and was associated with a reduction in postoperative LOS in patients having major abdominal surgeries.[18] Patients who had at least 45 g of carbohydrates prior to surgery had a trend towards improved insulin resistance postoperatively.[26] As a result, the recent American Society for Enhanced Recovery released a consensus statement recommending that patients take at least 45 g of carbohydrate solution prior to surgery, while following established NPO guidelines.[5]

With the advantages demonstrated by preoperative hydration, it is important to identify which drinks are the most beneficial. There are several types that can be utilized ranging from proprietary to non-proprietary, and from simple carbohydrate drinks to complex carbohydrate drinks. In preclinical studies, complex carbohydrate solutions decrease protein catabolism postoperatively, however these studies do not compare complex carbohydrates to simple carbohydrates.[27,28] While most preoperative carbohydrate solutions contain complex carbohydrates, such as maltodextrin, it is not known if these solutions are superior to ones containing simple carbohydrates. However, given the evidence that complex carbohydrates reduce insulin resistance, it is possible that complex carbohydrates will be superior to simple carbohydrates. The cost for these solutions is not much greater than the cost for simple carbohydrate containing solutions. Therefore, it is recommended that complex carbohydrate solutions be used when possible.[5]

Intraoperative fluid management

The goals of intraoperative fluid management are to maintain central euvolemia whilst avoiding salt and water excess. This is frequently described as a U-shaped curve where episodes of hypovolaemia and fluid overload are theoretically associated with harm.[29]

There have been many small trials of 'restrictive' *vs* 'liberal' fluid management that have been limited by varying definitions of restrictive and fluid strategies, as well as different surgical populations, and that therefore yielded conflicting results.[30] For major abdominal surgery, current evidence favours liberal fluid management being associated with the most harm, both in randomized clinical trials (RCTs)[31] and observational studies. Two recent large observational studies replicated the theoretical U-shaped curve proposed by Bellamy[29] in 2006 and showed that liberal fluid management is associated with more complications.[32,33] For ERPs, fluid excess has also been associated with increased complications and LOS.[34] Since there is no established definition of normovolaemia and fluid requirements vary significantly according to patient and surgical needs, there is also a large body of evidence aimed at individualizing fluid management with GDT.[35]

Blood pressure monitoring has significant limitations as a monitor as the physiological response to haemorrhage is to maintain pressure at the expense of flow.[36] However, most organs require flow as well as pressure. GDT uses a combination of fluids and inotropes to optimize flow through measurement of cardiac output and stroke volume.[37] There have been many small studies over the past 20 yr that have shown benefits from GDT with reductions in LOS and complications.[35]

However, established ERPs used in a number of GDT studies have not shown the same benefit on patient outcomes.[38] This in many ways is not surprising: as perioperative care pathways have improved, the value of a single practice change on outcomes is diminished and therefore small, single centre trials are unlikely to show benefit.[39]

The first multicentre trial of GDT in moderate to high risk patients, the Optimisation of Cardiovascular Management to Improve Surgical Outcome (OPTIMISE) study, failed to find a definitive answer: although there was a trend towards a reduction in the primary outcome (a composite of postoperative complications and mortality) in the GDT group, this did not reach clinical significance (P=0.07).[40] The study was underpowered as the incidence of the primary outcome was less compared with the higher value (68%) from preliminary data used to calculate the sample size.

So where do we go from here? Should we just use a restrictive approach during major surgery, or is there any additional benefit from GDT? As previously described, observational data show that there is a U-shaped distribution of risk with excessive fluid restriction also causing harm, particularly with a significant increase in acute kidney injury.[33] So, during high-risk surgery there is a possibility that a restrictive approach could cause harm. There is also evidence to suggest that in the 'real world' fluid management is significantly more chaotic than in the artificially controlled environment of an RCT.[41,42] For example, a 75 kg patient undergoing a 4 h procedure with minimal blood loss could receive 700 ml or 5400 ml of crystalloid during surgery, depending on the specific anaesthesia provider.

What is needed now are large multicentre trials evaluating the effectiveness of different fluid regimens. The central question is whether there is any benefit of GDT over a restrictive fluid regimen within a best practice perioperative care pathway such as ERP.[43] OPTIMISE II, which has a planned sample size of 2500 and is designed to address that question, has just started recruitment. The largest trial to date comparing a liberal *vs* restrictive fluid regimen, the Restrictive versus Liberal Fluid Therapy in Major Abdominal Surgery

(RELIEF) study, has just finished enrolment. This study compared 2800 patients undergoing major abdominal surgery, with the primary endpoint of disability free survival at 1 yr after surgery,[44] with results expected in 2018. In the meantime, it is important to note that there is no evidence from well performed studies that GDT causes harm. Complications, however, are expensive[45] and can cause long-term patient harm.[46] The largest benefit of GDT over a restrictive fluid management strategy within an ERP, if present, is likely to be in particular subsets of high-risk patients.[5]

Another factor that may be relevant is the avoidance of hypotension. There is increasing evidence from large

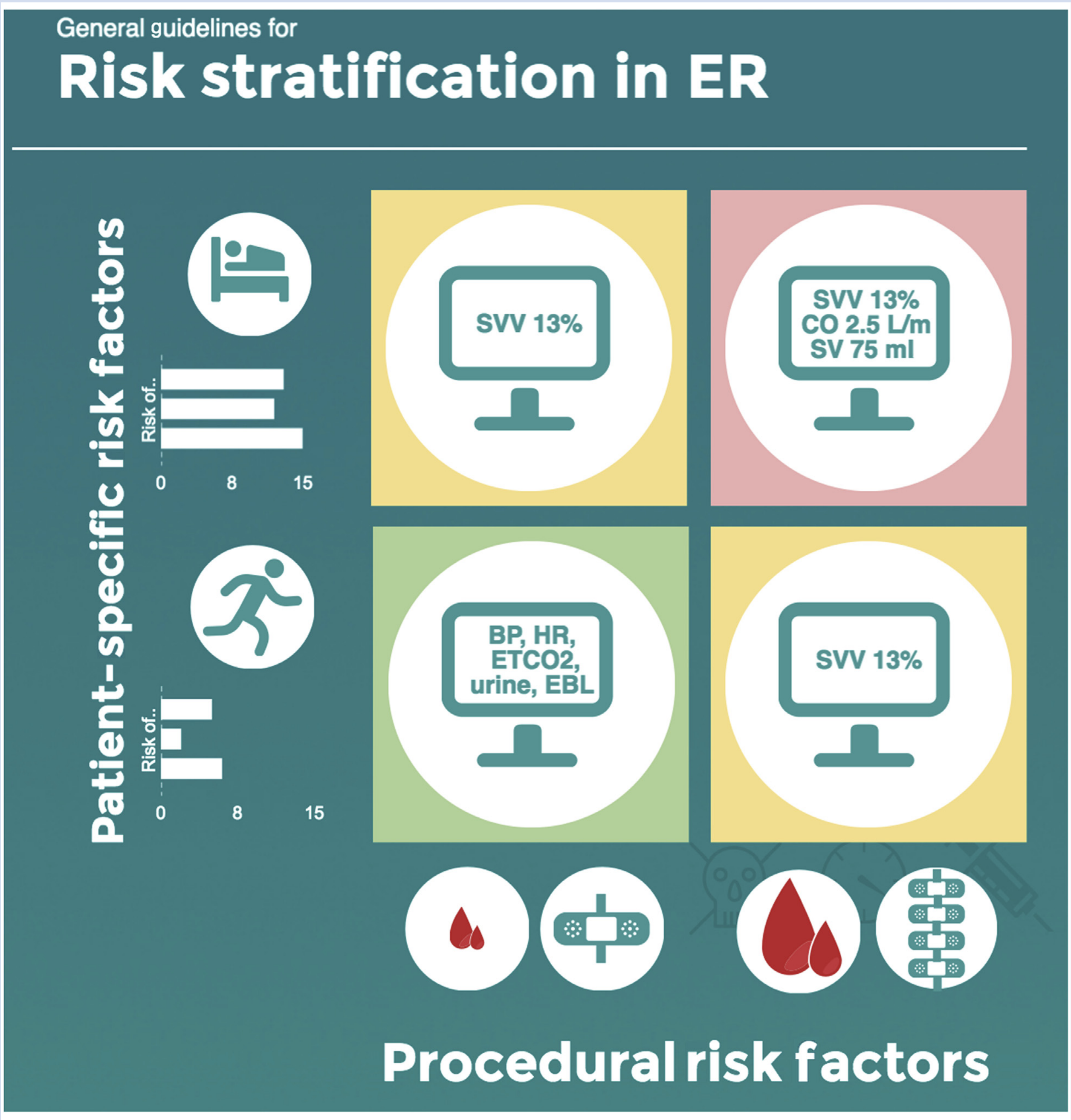

Fig 2. Guidelines for risk stratification of patients by cross matching procedural risks and patient-specific risk factors, as presented by the American Society for Enhanced Recovery (ASER) and Perioperative Quality Initiative (POQI). As patient risk factors increase, procedural risk factors increase, or both, more advanced monitoring should be used to help guide fluid management using goal-directed therapy (GDT). BP, blood pressure; CO, cardiac output; EBL, estimated blood loss; $ETCO_2$, end tidal carbon dioxide; HR, heart rate; PBW,; SV, stroke volume; SVV, stroke volume variation.

databases that even short durations of hypotension with mean arterial pressure <65 mm Hg are associated with myocardial and kidney injury.[47,48] As GDT has been shown to improve intraoperative haemodynamic stability, it is therefore possible that some of the benefit of GDT might result from avoidance of episodes of hypotension.[49]

Current recommendations are that all patients have an individualized plan for fluid and haemodynamic management that matches monitoring needs with patient and surgical risk (Fig. 2). Institutions without local guidelines have consistently been shown to have wide variations in fluid management both within and between anaesthesia providers.[42] Fluid excess should be avoided, as should hypotension wherever possible. In many institutions, as we await adequately powered trials, perioperative fluid management protocols currently include use of GDT.

Postoperative benefits of improved fluid management

Maintaining proper hydration without fluid overload in the intraoperative period is important, however, just as important is maintaining proper fluid management in the postoperative period. There are several benefits conferred to patients from improved perioperative management of fluids. Most important is prevention of unwanted complications related to fluid overload and excessive i.v. hydration. These benefits range from improved pulmonary function,[11] tissue oxygenation, gastrointestinal (GI) motility,[2,50] and wound healing.[12,13] Just as in the preoperative setting, PO hydration provides an improved method of fluid delivery postoperatively. It is recommended that patients receive 25–35 ml kg^{-1} of water per day in the recovery period.[3] Early transition to oral hydration postoperatively improves conditions for healing and recovery from surgery, allowing for an improved patient experience and earlier discharge without an increase in morbidity.[2,39,51]

Excessive i.v. fluid administration generally leads to increased fluid in the intravascular space that eventually cannot be contained. This leads to unwanted interstitial fluid accumulation, leading to organ dysfunction.[52–54] For example, pulmonary oedema can result in poor oxygenation due to an increase in the alveolar–arterial oxygen gradient. In healthy volunteers receiving 40 ml kg^{-1} of lactated Ringers solution, even subclinical pulmonary oedema resulted in significant pulmonary dysfunction.[55] With lower volumes of 22 ml kg^{-1}, functional residual capacity was reduced by 10% and diffusion capacity was decreased by 6%.[56] Pulmonary oedema can also have systemic effects due to poor tissue oxygenation. Another example of organ dysfunction as a result of oedema can be seen in the GI system. Oedema of the gut can lead to bacterial translocation, prolonged ileus, and impaired GI function and tolerance for enteral nutrition.[1,14,57] Impaired GI function reduces fluid absorption from the GI tract, and a prolonged ileus delays the transition to PO hydration, both of which are important for improved postoperative fluid status.

Excessive fluid administration and the resultant oedema can impact wound healing as well. Wound healing is suboptimal in conditions of tissue hypoxia resulting from decreased oxygen tension from surgery induced oedema.[13] Increased tissue perfusion and oxygenation improves wound healing in abdominal surgery patients.[12] Taken together, reduction in tissue oedema and subsequent improvement in oxygenation and perfusion can lead to improved wound healing in the postoperative period.

Oliguria in the postoperative period

Some degree of oliguria in response to the stress of surgery appears to be a normal and predictable physiological response. This may be due to the release of vasopressin in response to the stress of surgery.[5,58] Although traditionally oliguria is taken as a sign of hypovolaemia and subsequent reduction in kidney perfusion, perioperative oliguria now is not always abnormal, especially when no other signs of hypoperfusion are present.[5,59] In a recent study, there was no significant correlation between oliguria and postoperative renal failure, but there was an increase in acute kidney injury associated with increased postoperative fluid balance.[60] Although anuria is abnormal and should be taken seriously, oliguria, however, can be a normal and expected occurrence as a result of judicious fluid management in the perioperative period.[5] Recent studies suggest 0.3 ml kg^{-1} h^{-1} as a threshold for increased risk of acute kidney injury in major abdominal surgery.[61]

Conclusions

Improvements in the management of perioperative fluid therapy enhance patient outcomes, decrease complications, and decrease total LOS. With the goals of maintaining euvolaemia and avoiding salt and water excess, intraoperative GDT utilizes a combination of fluids and inotropes to optimize perfusion during surgery. It is important to identify that urine output does not play an important role in GDT. Although anuria should be taken seriously and treated appropriately, oliguria should not be treated with aggressive i.v. fluids unless there are other signs and symptoms of hypovolaemia, since oliguria can be an expected outcome of the stress response associated with surgery.

The proper administration of fluids though GDT during the intraoperative period is a very important aspect of individualized plans for fluid and hemodynamic management. Perioperative fluid management, however, should also include the preoperative and postoperative periods, given the added benefit of being able to provide PO hydration at those times. When the option is available, PO hydration is preferable to i.v. hydration. Preoperative hydration with complex carbohydrate drinks has been linked to multiple benefits, including a reduction in postoperative insulin resistance, improved metabolic state, decreased hospital LOS, and reduced nausea and vomiting. Perioperative physicians should be encouraging patients to increase PO hydration up until 2 h prior to surgery, which has been proven to be safe and adheres to strict NPO guidelines. Similarly, in the postoperative period, patients should be encouraged to start PO hydration early, and excessive i.v. fluid administration should be avoided.

Authors' contributions

Contributed to writing and reviewing of the manuscript: all authors.

Declaration of interest

None declared.

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