Acta Anaesth. Bel., 2022, 73 | Suppl. 1: *125-133*

Master thesis | Original study

Perioperative fluid management in major surgery

T. Baert[1], G. Dewinter[1]

[1]*Department of Anaesthesiology, UZ Leuven, Herestraat 49, B-3000 Leuven, Belgium..*

Corresponding author: Prof. Dr. Geertrui Dewinter, MD, PhD, Head of Clinic, Department of Anaesthesiology, University Hospitals Leuven, Herestraat 49, 3000 Leuven. Tel. +32 16 3 43407; geertrui.dewinter@uzleuven.be

Abstract

Background: **Perioperative fluid management has been a topic of discussion in the past years. Especially the amount of fluid administered and the type of fluid used are subjects of an ongoing debate.**
Objective: **Our objective was to evaluate the optimal fluid therapy for major surgery. We investigated which type and amount of fluid was the best to reach this goal.**
Methods: **A literature search was conducted using PudMed (Medline) and Cochrane databases. Also, guidelines of several organizations were consulted, notably the European Society of Anaesthesiology (ESA), the American Society of Anesthesiologists (ASA) and the Enhanced Recovery After Surgery Society (ERAS Society).**
Results: **The results of this narrative review provide an overview of the findings of the several reviews and trials that were withheld after performing a literature search. Sufficient evidence advocates the wide use of goal- directed therapy. Restrictive fluid therapy can be useful if perioperative risk is low. There is not sufficient evidence favoring one fluid type to another considering volume therapy.**
Conclusions: **The goal- directed approach has demonstrated to be of great importance in major surgery. It has proved to be the most complete and widely applicable form of fluid therapy. In addition, in major surgery, a restrictive approach could be considered if the perioperative risk is low. Avoiding a too restrictive approach can prevent adverse effects. The choice of fluid is of minor importance compared to the choice of fluid policy.**

Keywords: **Fluid therapy, early goal- directed therapy, colloids, crystalloid solutions.**

Introduction

Perioperative fluid management has been a topic of debate in the past years[1]. There is little uniformity and insufficient evidence in the literature regarding the fluid policy or fluid type that should be used perioperatively[2].

Perioperative fluid therapy aims to accomplish a stable tissue fluid environment and electrolyte homeostasis[3].Deleterious effects of fluid administration, notably water and salt excess, should be avoided[4]. Therefore, normovolemia or central euvolemia should be pursued[5].

The administration of fluids can generally be performed in two ways[5]. First, fluid losses can be estimated and consequentially substituted[6]. This substitution can be done in a restrictive or liberal manner. Second, fluids can be administered to attain normovolemia by realizing certain hemodynamic goals. This goal-directed therapy (GDT) attempts to detect incipient hypovolemia by assessing fluid responsiveness, using hemodynamic indices.

Regarding the choice of fluid type, until today there is not enough evidence to prefer unequivocally one type to another[7].
We searched the literature regarding perioperative fluid therapy in major surgery. We tried to give an evidence-based display of the literature summarizing how fluid management should be addressed in major surgery.

Methods

This manuscript adheres to the applicable Standards for Reporting Qualitative Research (SRQR) guidelines. A literature search was conducted using PudMed (Medline) and Cochrane databases. Also, guidelines of several organizations were consulted, notably ESA, ASA and ERAS. Following MeSH Major Topics were used: hemodynamic monitoring, fluid therapy, colloids, crystalloid solutions, glycocalix/glycocalyx. Likewise, the

Cochrane database was searched for crystalloids, colloids and fluid therapy (under health topic pain & anaesthesia). The PRISMA 2009 literature search tool was used to further acquire a literature selection. Most of the articles (719) were identified through database searching. PubMed searching only considered records published in the last 10 years. Fifty-eight articles were identified by manual research, considering articles displayed in the reference list of reviewed articles. Four reviews were found, consulting ESA, ASA and ERAS guidelines. Following the record screening (titles and abstracts), 657 records were excluded due to not being relevant. Since this is not a quantative review, no articles were found to be non-eligible due to methodological, statistical or other reasons. Finally, 94 articles were retained, all of which were written in English. Not all are included in the reference list or referred to. All of the above resulted in following flowchart (Figure 1).

Results

Fluid management can be approached in several ways. In the literature, mainly two methods of fluid administration are considered[5]. On the one hand, several studies compare a restrictive to a conventional or liberal approach in order to verify how much fluid should be administered[8]., on the other hand a goal-directed fluid therapy is evaluated[9].

Fluid therapy

Restrictive vs liberal approach

The restrictive approach replaces only fluids that are lost perioperatively[6]. Considering that surgery used to be generally more invasive, thus evoking more tissue trauma, fluid shift and blood loss, fluid management tended to be rather liberal until two decades ago[2]. This liberal approach aimed to compensate for fluid losses that are due to preoperative fasting, insensible losses, diuresis, blood loss and losses to the third space.

Correction for blood loss varies depending on the trials considered[10,11]. Not infrequently, a 3:1 ratio of crystalloid to blood and 2:1 ratio of colloid to blood was applied[12]. However, these ratios do not reflect current insights, notably the glycocalyx and as consequence the context-sensitivity of fluid boluses, meaning that the same amount of a fluid bolus will have a markedly different effect according to the fluid status of a patient[13,14]. Likewise, loss of fluid to the third space is rendered obsolete and can mostly be explained by the formation of tissue edema[15].

Opposed to a liberal fluid policy is a restrictive fluid policy. The terms restrictive fluid policy and zero balance strategy are used interchangeably. This approach no longer compensates for the presumed fluid loss to the non-existing third space and aims to reduce postoperative weight gain as much as possible. Also, blood loss is substituted by a physiologically more acceptable and lower amount of crystalloids and colloids. Generally -but differing according to the many trials- a 1.5:1 ratio crystalloids to blood and a 1:1 ratio colloids

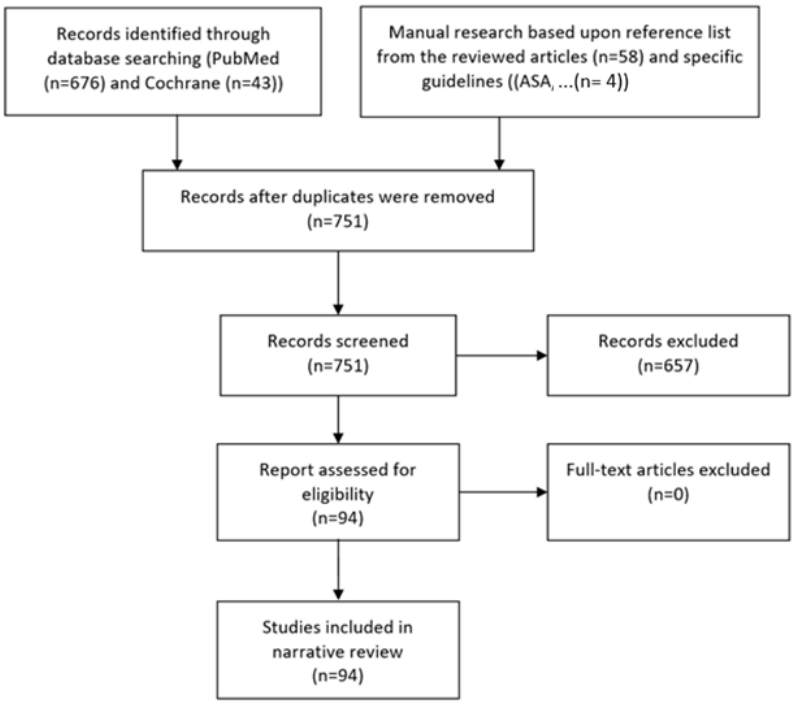

Fig. 1 — Flow chart.

to blood, is upheld[16]. As in a liberal approach, crystalloids are used for maintenance fluid therapy, as to compensate for the other losses.

A 2003 landmark trial by Brandstrup et al.[17] concerning 172 patients undergoing a colectomy, showed a significant decrease in morbidity in the restrictive group compared to the traditional, liberal control group. The restrictive fluid regimen resulted in less postoperative complications as compared to the standard fluid regimen (33% vs 51%, P=0.013). Both cardiopulmonary complications (7% vs 24%, P=0.007) -among others ventricular arrhythmias, bleeding, pulmonary edema, pneumonia, stroke- but also tissue healing complications (16% vs 31%, P=0.04) -anastomotic leakage, wound dehiscence, peritonitis, sepsis, …- were significantly reduced. Also, there was a reduced mortality in the restrictive group (0 deaths vs 4 deaths), but this did not reach statistical significance (P=0.12). Patients in the restrictive group were administered on average 4 liters of fluid during the day of surgery leading to a weight gain of 1kg. The control group which received a conventional liberal fluid therapy received on average 6 liters of fluids which resulted in a weight gain of 4kg. These extra 2 liters of fluid administered were apparently not excreted renally, but resulted into a further weight gain and the buildup of edema instead, leading to increased morbidity and mortality. Although lower urinary output was noted on the day of surgery in the restrictive group, this did not lead to a further significant difference in urinary output or an increased incidence of kidney failure at later time points.

Further trials showed similar results. For example, data from 12 restrictive versus liberal fluid therapy RCT's, concerning more than 1100 patients undergoing vascular, thoracic, abdominal and orthopedic surgery, were combined in a meta-analysis[18]. Patients in the liberal group developed more respiratory complications. They showed a higher risk ratio (RR) for developing pneumonia (2.2; P= 0.04)), pulmonary edema (3.8; P= 0.03) and a longer length of hospital stay (mean difference of 1.96 days; P= 0.009). A difference in mortality, renal function or wound healing could not be established.

A larger meta-analysis[19] divided more than 90000 patients undergoing major non-cardiac surgery, in 5 quintiles according to amounts of fluid given. Mortality was significantly increased in the lowest quintile (less than 900mL given) and highest quintile (more than 2700mL given), resulting in a hazard ratio (HR) of 1.41 (P= 0,034) and 1.65 (P= 0.032), respectively. Respiratory complications -pulmonary edema, pneumonia, respiratory failure, reintubation- were significantly increased in the most liberal quintile, showing an odds ratio (OR) of 1.27 (P=0.003). Also, there was a significant higher incidence of acute kidney injury in both the most restrictive and most liberal quintiles, resulting in an odds ratio of 1.66 (P= 0.001) and 1.29 (P < 0.001), respectively. Patients in the most liberal group had a 1.15 times longer length of hospital stay than the second quintile (P < 0.001) which resulted in a significantly higher hospitalization cost. In this study, the moderately restrictive group -the second quintile- was consistently associated with optimal postoperative outcomes regarding morbidity and mortality. In average the total amount of administered fluids in this group was 900mL to 1100mL.

The concerns regarding kidney failure as postulated by Shin et al.[19] seemed substantiated. Another more recent landmark trial[20]-the RELIEF trial - was able to demonstrate that in patients undergoing major abdominal surgery, there was a significantly higher incidence of acute kidney failure in the restrictive group as compared to the more liberal arm, at one month after surgery (8.6% vs 5%, P= 0.001). The amounts of fluid administered were similar to the Brandstrup study (approximately 4L and 6L) but the average duration of surgery was almost double. Likewise, a recent retrospective trial showed a higher incidence of renal failure in the more restrictive group, following a cystectomy with Bricker derivation[21]. The amount of crystalloids administered seemed to be an independent predictor of acute kidney injury. Higher amounts of crystalloids administered were correlated with less kidney injury (odds ratio (OR): 0.79; P= 0.002).

These recent findings have led to the growing concern that fluid therapy has in turn become too restrictive, entailing a renewed plea for an approach that abandons the zero balance principle while striving for a slightly positive fluid balance. This view is endorsed by several authors -including Brandstrup- and is referred to as a proposed "moderately liberal" approach in which a positive fluid balance of 1 to 2 liters should be pursued at the end of major surgery[5]. All these conclusions confirm Bellamy's well-known parabola[22], illustrating that least complications occur in those patients who receive neither too little nor too much perioperative fluid, thus displaying that pronounced hypo- and hypervolemia lead to more complications. Of course, one size does not fit all and a physician should always establish an individual fluid policy for each specific patient.

However, despite showing favorable outcomes in major surgery in which expected blood losses

and fluid shifts tend to be low to moderate, evidence suggests that a restrictive policy will not prove to be preferable when marked fluid losses are to be expected[23]. The threshold regarding blood loss, below which a more restrictive approach will prove to be sufficient, has not yet been clearly defined. Nevertheless, most of the RCTs listed in an influential review[2] in which restrictive approaches were compared to the control group, mainly showed improved outcomes when blood loss was generally less than 500ml. A 2019 Cochrane review was able to state -based on very low-certainty evidence- that restrictive fluid management might be inferior to goal-directed therapy in a low- to moderate risk population of major surgery but results could not be extrapolated to higher risk surgery[3]. Nevertheless and despite a lack of evidence, a risk-adapted approach of fluid management has been proposed, suggesting use of a restrictive approach is not recommended in high-risk surgery[5,24,25].

Goal-directed fluid therapy

In goal-directed fluid therapy (GDT), fluid boluses are administered on top of maintenance fluids in order to optimize stroke volume (SV) and cardiac output (CO) and thus systemic blood flow[19]. The rationale behind this is that sufficient perfusion and oxygenation of the various tissues and organs rely on perfusion pressures yet predominantly on blood flow[26].

GDT distinguishes more explicitly between maintenance therapy and volume therapy. As for volume therapy, usually a fluid bolus of 200ml to 250ml is given. However, smaller boluses -for instance 100ml[27] - can be used reliably. Most GDT-trials make use of colloids for volume therapy, given their physiological profile[2]. In a particular Cochrane meta-analysis, all 6 included RCT's used colloids as volume bolus[3]. In another meta-analysis[18], 10 out of 12 RCT's made use of colloids for volume therapy. The other 2 RCT's made use of crystalloids. As in restrictive and liberal approaches, maintenance therapy consists of crystalloids.

In the current Enhanced Recovery After Surgery (ERAS)-era, patient outcome has already much improved. Hence, small RCTs could be underpowered to significantly demonstrate an improved outcome[2,25]. After all, implementation of ERAS-protocols led to less fluid imbalances and to fewer complications as assessed by counting the total number of patients with complications in ERAS- and non-ERAS- groups (RR: 0.53, P < 0.000001)[28]. Also, length of hospital stay is reduced with more than 2 days (weighted mean difference: 2.55 days; P < 0.000001) according to the same study. However, fluid therapy was only one of 23 constituents of the ERAS-protocol and the impact of fluid therapy on the results could not be determined as the RCT's included in the meta-analysis, were not designed for this purpose.

Maybe, the impact of ERAS-protocols is best displayed by following example. Noblett et al. included 108 patients undergoing colorectal surgery in 2006[29]. They were randomized in a GDT-arm and a control-arm in which patients received a fluid therapy at the discretion of the anesthetist. Eventually the GDT-group received 3.6L perioperatively, whereas the control group received 3.8L. Fewer major complications such as death, ICU-transfer, redo surgery,… occurred in the GDT-group, as compared to the control group (2% vs 15%, P= 0.043). The same study was repeated in 2013 by Srinivasa et al. in 85 patients, however, both groups were submitted to the ERAS-protocol[30]. As a result, prolonged fasting was avoided as well as routine bowel preparation. Now, the GDT-group received 1.9L, which was more than the control group (1.6L). Even though different outcome parameters were used to reflect the incidence of complications, displayed by the number of patients with complications, no difference in complications could now be demonstrated (26 patients vs 27 patients, P= 1.000).

Nevertheless, many studies have shown that GDT provides better outcomes compared to the fluid therapy in control groups. The first large RCT in this regard, the OPTIMISE-trial[31], wanted to demonstrate a difference in relative risk of a combination of mortality and morbidity (pulmonary embolism, myocardial ischemia, gastrointestinal bleeding, bowel infarction, anastomotic breakdown, paralytic ileus, stroke, acute kidney injury, infection et cetera), 30 days after surgery. More than 700 patients that underwent major abdominal surgery were included. A reduced relative risk could be shown (RR: 0.84), however it failed to reach statistical significance (P= 0.07).

The FEDORA trial confirmed a lesser incidence of complications using a goal-directed approach as opposed to a standard fluid therapy[32]. 450 patients undergoing major abdominal, urological, gynecological, or orthopedic surgery, were included. In the goal-directed arm, cardiac output was optimized first until stroke volume variation (SVV) did not show any more fluid responsiveness. Fluid boluses were given when SVV was more than 10%. If the cardiac output was normal and the SVV was lower than 10%, a mean arterial pressure lower than 65mmHg was treated with vasopressors according to the discretion of the anesthesiologist.

In the control group a continuous infusion of Ringer's lactate was given. If needed, colloids and vasopressors or inotropes could be associated. Eventually, fewer complications (acute kidney injury, pulmonary oedema, respiratory distress syndrome, wound infections, etc.) were noticed in the GDT-group than in the control group (8.6% vs 16.6%, P= 0.018).

This reduction in complications through the use of GDT as compared to using standard fluid therapy is even more extensive in procedures where the expected blood loss and perioperative fluid shifts are more pronounced and the estimated perioperative risk is higher[33].

A large meta-analysis from 2018[34], including more than 11000 patients, concerning different types of major surgery (cardiac, vascular, thoracic surgery,...) was able to demonstrate lower mortality and morbidity compared to a traditional fluid regimen. A decrease in mortality was shown (OR: 0.66; P= 0.004) as well as a reduced postoperative incidence of acute renal failure (OR: 0.73; P= 0.007) pneumonia (OR: 0.69; P= 0.01) and sepsis (OR: 0.55; P= 0.02), among others, in patients administered goal directed fluid therapy, compared to the control group. Other meta-analyses[23] too, have shown reduced mortality (OR: 0.48; P= 0.0002) and fewer surgical complications (OR: 0.43; P< 0.0001). In this meta-analysis, surgical complications were determined by the number of patients with complications, as reported in the several included RCT's. In general, more than 4800 patients were included, undergoing several types of major surgery.

Restrictive and goal-directed fluid strategies, according to several studies, provide a better outcome and fewer complications when compared to the control group, despite using different methods, as described above. In contrast, RCT's comparing restrictive and goal-directed strategies are sparse and show little difference in outcom[35].

A 2019 Cochrane review[3] on non-cardiac major surgery, comprising predominantly RCT's in abdominal and orthopedic procedures, compared both approaches and stated that there was a small yet significant difference in mortality (Risk difference: 0.03; P= 0.04) to the detriment of the restrictive group. Otherwise no difference in complications could be demonstrated.

Fluid type

Maintenance therapy

It is generally accepted that maintenance therapy during major surgery should consist of balanced crystalloids[25]. This is only a theoretical consideration since maintenance therapy is considered to predominantly replace the extracellular losses such as urine production and insensible losses. Also, the volume distribution of balanced crystalloids happens to be the extravascular space, hence the theoretical preference[36]. Specifically, in both restrictive and goal-directed approaches, maintenance therapy should consist of 1 to 3ml/kg/hr of balanced crystalloids[25]. However, not all crystalloids should be used. The SALT-ED[37] trial randomly assigned more than 13000 patients in the emergency department to either a group in which patients received balanced crystalloids (Ringer's Lactate or Plasmalyte) or to a group that received normal saline. A median crystalloid volume of 1080ml was administered. After 30 days there was a lower incidence of major adverse kidney events (death, renal replacement therapy, persistent renal dysfunction) in the balanced crystalloids groups (4.7%) compared to the normal saline group (5.6%) (adjusted OR: 0.82%; P= 0.01). Balanced crystalloids are preferred.

Volume therapy

Crystalloids vs colloids

As for volume therapy, the choice for a particular fluid seems less obvious. Colloids seem to be the fluid of choice since they improve the circulatory flow to a greater extent than crystalloids and cause a bigger blood volume expansion[38]. The often-cited CRISTAL trial[39], which compared resuscitation with colloids and crystalloids, was one of the few studies to show a significant difference in mortality between colloids and crystalloids. It randomized more than 2800 patients in two groups, one group receiving colloids for fluid interventions other than maintenance therapy, throughout the stay on intensive care. The other group received crystalloids on top of a maintenance therapy. After 90 days a significant difference in mortality could be demonstrated. There was a mortality of 30.7% in the colloids group and a mortality of 34.2% in the crystalloids group, resulting in an OR of 0.92 (P= 0.03). However, the study displayed some gaps. For example, 70% of the patients in the colloid group received HES and other patients in the colloid group received gelatins or albumin. Thus, no statement could be made about the individual colloids. In addition, the study was not blinded and some patients in the colloid group received colloids prior to inclusion in the colloid group.

Conversely, a recent Cochrane meta-analysis[40], including more than 30000 ICU-patients, was unable to demonstrate a difference in mortality when using Hydroxy Ethyl Starches (HES) compared to crystalloids as a resuscitation fluid. The relative risk of mortality after 30 days (RR:

0.99, P= 0.83) and after 90 days (RR: 1.01; P= 0.91) never reached any statistical significance. Using starches, a slight increase in blood transfusion (RR: 1.19; P= 0.03) and a higher eventual need for renal replacement therapy (RR: 1.3; P< 0.0001) were noticed. As for the other synthetic colloids, according to this meta-analysis, no differences could be withheld regarding blood transfusion, renal replacement therapy and mortality, neither between dextrans and crystalloids, nor between gelatins and crystalloids.

Albumin

Albumin does not lead to an increased incidence of acute renal failure, coagulation problems or anaphylaxis[41]. However, clinical studies have not yet been able to demonstrate a significant benefit using albumin in comparison with other fluids, including crystalloids. For example, the ALBIOS trial[42] randomized 1818 patients with severe sepsis into a group that received fluid resuscitation with crystalloids and albumin 20% and a group that received fluid resuscitation through crystalloids only. After fluid resuscitation, the albumin group received on a daily base albumin 20% to achieve a serum albumin level of 30g/L. Despite a significant difference in mean arterial pressure during the first week (P= 0.03), no difference in mortality was seen at 28 days (incidence in albumin group: 31.8%; incidence in the crystalloid group 32%, RR: 1; P= 0.94) nor at 90 days (41.4% mortality in the albumin group, 43.6% in the crystalloid group, RR: 0.94; P= 0.29%).

There are not many comparative studies comparing the different colloids. In any case, starches do seem to result in increased bleeding risk and increased transfusion when compared to albumin[43].

Plasma

A recent investigation suggested a possible benefit of fluid resuscitation by means of plasma compared to crystalloids, whereby the difference in mortality could not solely be explained ROTEM-wise[44]. This led to the conceptualization of a glycocalyx preserving fluid policy. Indeed, recent observational and preclinical studies suggest that early restoration of the glycocalyx leads to less inflammatory response, less coagulopathy and better fluid responsiveness in systemic inflammation[4].

Also clinically, there seems to be more evidence that resuscitation therapy with plasma or plasma constituents can be beneficiary in regard to mortality and morbidity. For example, the PAMPer-trial[45] examined whether or not prehospital fluid resuscitation using plasma proved to be beneficiary to the standard resuscitation with crystalloids, in hemorrhagic shock. Two hundred thirty patients were randomized into the plasma resuscitation group, 271 patients received standard-care resuscitation through crystalloids. The trial was able to significantly show a reduced mortality after 30 days in patients in hemorrhagic shock who were treated with plasma(23.3%) compared to crystalloids only (33.0%) (adjusted OR: 0.63%; P= 0.02%). This could be explained at least in part by coagulation factor supplementation. Nonetheless, the INR did not appear to differ significantly between the two groups. Of course, it should be noted that the INR is by no means an ideal laboratory representation of in vivo coagulation, especially in a setting of major trauma. Yet, this could be in part due to the sealing effect of albumin on capillary leakage[46].

Preoperative fluid therapy

Preoperative fluid therapy means to avoid preoperative fluid imbalances[25]. According to a study[47], in 40% of the study population, stroke volume increased by 10% or more after a bolus of colloids. Although being assessed immediately following induction, it is to be regarded as a positive response following a fluid bolus. This does not necessarily demonstrates hypovolemia pre-induction, it does however show a functional intravascular volume deficit, that is at least partly induced by anesthetic agents. Consequentially, the ASA guidelines -as do the ESA guidelines- allow preoperative intake of clear fluids up to 2 hours before surgery[48]. After all, preoperative dehydration should be avoided. Not only does this benefit patient comfort, reduces hunger and thirst, it also reduces the acidity of the diluted gastric juices without increasing gastric content, hence benefitting the aspiration risk. In addition, other initiatives such as the various ERAS-protocols also intend to prevent perioperative fluid imbalances, among others by limiting bowel preparation and limiting preoperative fasting. Also, the early transition from intravenously administered fluids to oral fluid intake within 24 hours after surgery can promote gastrointestinal motility, thus limiting additional postoperative fluid loss.

Discussion

Although studies have not well established as of when a restrictive fluid therapy is less beneficiary, evidence of a restrictive approach has shown favourable outcomes when major surgery with a low perioperative risk is considered. This restrictive therapy has been widely implemented in ERAS-

protocols[49]. Yet, more and more, a plea is heard in favour of being less restrictive in order to avoid adverse effects, in particular kidney injury. Some authors mention a moderately liberal approach[5], others do mention a moderately restrictive approach[19]. In any case, this trend might be moving fluid therapy more close to the safer top of Bellamy's parabola.

One can easily understand that as a procedure lingers on and fluid losses are accumulating, it becomes more and more difficult to adequately assess measured and estimated fluid losses, especially if fluid shifts are beginning to build up. A goal-directed approach is then better suited to provide guidance, even if fluid losses were never correctly logged in the first place. It is therefore a more widely applicable approach. GDT could be a valuable addition to ERAS-protocols[25].

Still, there are some drawbacks. Several important terms regarding fluid therapy are not well-defined, most notably restrictive fluid therapy, liberal fluid therapy and goal-directed therapy. Also, a lot of evidence with regard to fluid therapy is derived from research in critically ill patients, who by definition have to a lesser or greater extent a disintegrated vascular barrier[46]. These findings cannot be extrapolated to the perioperative setting without reservation.

Also, one of the major gaps in the literature on fluid management in major surgery, is the lack of integration of fluid therapy and drug policy regarding administration of vaso-active agents and inotropes.

Extensively addressing this integration, is beyond the scope of this review. In any case, in different studies, some goal-directed but also other approaches have included a protocol that indicates when vasopressors should be initiated. Needless to say, these thresholds greatly vary from study to study. A good example of such a study is the INPRESS trial[50]. This study first optimized stroke volume in the groups to be compared. Afterwards, certain blood pressures were targeted using either noradrenaline or ephedrine. Ultimately, the study was able to determine a lower incidence of complications in the noradrenaline group. The idea behind this study -first optimizing fluid status and then maintaining blood pressure through vaso-active medication as long as the patient is not fluid responsive- is especially important.

These findings bring about what might ultimately be pursued, especially during extensive surgery. Integrating administration of vaso-active agents into a combined goal-directed fluid therapy with association of vaso-active drugs, can further optimize fluid therapy in se, particularly regarding oversubstitution, thus creating a yet more widely applicable approach of hemodynamic perioperative management. As such, a patient should be first volume-optimized. If the patient is no longer fluid responsive, while remaining hypotensive, vaso-active medication should be given.

Nevertheless, a lot of research regarding specific procedures with more well-defined patient populations will still be needed to make general statements about the ideal perioperative policy regarding adequate global tissue perfusion and the integration of fluid management and pharmacotherapy.

Choice of fluid remains until this day a subject of debate. Considering its physiologic profile -creating a more extensive intravascular volume effect- colloids are widely used as volume therapy. However, this has not yet led to markedly improved outcomes. First, the context-sensitivity of a fluid bolus has to be considered. In a hypovolemic patient, a crystalloid or a colloid bolus will have a similar effect[14]. For example, according to the CHEST-trial[11] a 1:1.3 ratio colloids to cristalloids seemed to result in similar hemodynamic resuscitation goals, albeit in critically ill patients. Second, the adverse effects of colloids can counterbalance their volume-effectiveness.

The beneficial hemodynamic effects of volume therapy through colloids in goal-directed therapy arms as compared to the control groups suggest but do not prove a benefit of using colloids[2]. However, to what extent is not yet known. In any case, the choice for a particular fluid strategy seems more important than the choice for a particular fluid type.

Overall, it can be stated that a more physiological approach should be used, whether it concerns fluid therapy or choice of fluids[2].

Conclusion

Although it is often stated that there is no sufficient evidence to prefer one fluid management strategy over another, concerning major surgery, this assumption does not seem to hold true. Indeed, certain approaches have significantly improved outcome. In particular, the goal-directed approach has shown its added value in major surgery regardless of the perioperative risk and proved to be the most complete and widely applicable strategy.

For major surgery with a rather low perioperative risk, a restrictive fluid policy can be justified. The pursuit of a slightly positive fluid balance can prevent some complications.

In regard to fluid type, the most important finding seems to be that the choice of a specific fluid is less

important than the choice of a specific fluid policy. Significant improvements in outcome through perioperative fluid management were therefore mainly achieved through fluid management rather than fluid choice.

Acknowledgements: There are no conflicts of interest and no funding was involved.

Authors contributions: Thibault Baert: literature search and manuscript preparation. Geertrui Dewinter: manuscript preparation.

References

1. Miller T, Pearse R, Perioperative fluid management: moving toward more answers than questions- a commentary on the RELIEF study, Perioper Med 2019, 8: 2.
2. Navarro L, Bloomstone J, Auler J et al., Perioperative fluid therapy: a statement from the international Fluid Optimization Group; Perioper Med 2015, 4: 3 (1-20).
3. Wrzosek A, Jakowicka-Wordliczek J, Zajaczkowska R et al., Perioperative restrictive versus goal-directed fluid therapy for adults undergoing major non-cardiac surgery, Cochrane Database Syst Rev. 2019 12: CD012767.
4. Chappell D, Jacob M, Hofmann-Kiefer K, et al. A rational approach to perioperative fluid management. Anesthesiology 2008; 109: 723-740.
5. Miller T, Myles P, Perioperative Fluid Therapy for Major Surgery, Anesthesiology 2019; 130: 825-831.
6. Brandstrup B., Fluid therapy for the surgical patient. Best Pract Res Clin Anaesthesiol 2006; 20: 265-283.
7. Joosten A, Delaporte A, Mortier J, et al., Long-term Impact of Crystalloid versus Colloid Solutions on Renal Function and Disability-free Survival after Major Abdominal Surgery, Anesthesiology 2019; 130: 227- 236.
8. Diaper J, Schiffer E, Keli Barcelos G et al., Goal-directed hemodynamic therapy versus restrictive normovolemic therapy in major open abdominal surgery: A randomized controlled trial, Surgery 2021, 169: 1164-1174.
9. Bentzer P, Griesdale D, Boyd J, et al., Will This Hemodynamically Unstable Patient Respond to a Bolus of Intravenous Fluids? JAMA 2016; 316: 1298- 1309.
10. Finfer S, Bellomo R, Boyce N, et al., A comparison of albumin and saline for fluid resuscitation in the intensive care unit, N Engl J Med. 2004; 350: 2247- 2256.
11. Myburgh J, Finfer S, Bellomo R, et al. Hydroxyethyl starch or saline for fluid resuscitation in intensive care, N Engl J Med 2012; 367: 1901-1911.
12. Myles P, Andrews S, Nicholson J, et al., Contemporary Approaches to Perioperative IV Fluid Therapy, World J Surg 2017; 41: 2457- 2463.
13. Hahn R, Fluid therapy in uncontrolled hemorrhage--what experimental models have taught us. Acta Anaesthesiol Scand. 2013; 57: 16-28.
14. Jacob M, Chappell D, Hofmann-Kiefer K, et al. The intravascular volume effect of Ringer's lactate is below 20%: a prospective study in humans. Crit Care. 2012; 16: R86 (1- 11).
15. Jacob M, Chappell D, Rehm M. The "third space" - fact or fiction? Best Pract Res Clin Anaesthesiol. 2009; 23: 145-157.
16. Myles P, Andrews S, Nicholson J, et al. Contemporary Approaches to Perioperative IV Fluid Therapy. World J Surg 2017; 41: 2457-2463.
17. Brandstrup B, Tonnesen H, Beier-Holgersen R, et al., Effects of intravenous fluid restriction on postoperative complications: Comparison of two perioperative fluid regimens: A randomized assessor-blinded multicenter trial. Ann Surg 2003; 238: 641- 648.
18. Corcoran T, Rhodes JE, Clarke S, et al. Perioperative fluid management strategies in major surgery: a stratified meta-analysis. Anesth Analg 2012; 114: 640-651.
19. Shin C, Long D, McLean D et al., Effects of Intraoperative Fluid Management on Postoperative Outcomes: a Hospital Registry Study, Ann Surg, 2018, 267: 1084- 1092.
20. Myles PS, Bellomo R, Corcoran T, et al., Australian and New Zealand College of Anaesthetists Clinical Trials Network and the Australian and New Zealand Intensive Care Society Clinical Trials Group: Restrictive versus liberal fluid therapy for major abdominal surgery. N Engl J Med 2018; 378: 2263- 2274.
21. Furrer M, Schneider M, Löffel L, et al. Impact of intra-operative fluid and noradrenaline administration on early postoperative renal function after cystectomy and urinary diversion: A retrospective observational cohort study. Eur J Anaesthesiol 2018; 35: 641-649.
22. Bellamy MC. Wet, dry or something else? Br J Anaesth 2006; 97: 755-757.
23. Hamilton M, Cecconi M, Rhodes A, A systematic review and meta-analysis on the use of preemptive hemodynamic intervention to improve postoperative outcomes in moderate and high-risk surgical patients. Anesth Analg 2011; 112: 1392- 1402
24. Wallman P, Perioperative care in adults, NICE guideline [NG180]Published: 19 August 2020, https://www.nice.org.uk/guidance/ng180, accessed 13 january 2022.
25. Miller T, Roche A, Mythen M. Fluid management and goal-directed therapy as an adjunct to Enhanced Recovery After Surgery (ERAS). Can J Anaesth 2015; 62: 158-168.
26. Carrara M, Babini G, Baselli G et al., Blood pressure variability, heart functionality, and left ventricular tissue alterations in a protocol of severe hemorrhagic shock and resuscitation, J Appl Physiol, 2018, 125: 1011- 1020.
27. Biais M, de Courson H, Lanchon R et al., Mini-fluid challenge of 100ml of crystalloid predicts fluid responsiveness in the operating room. Anesthesiology 2017; 127: 450- 456.
28. Varadhan K, Neal K, Dejong C et al., The enhanced recovery after surgery (ERAS) pathway for patients undergoing major elective open colorectal surgery: a meta-analysis of randomized controlled trials. Clinical Nutrition, 2010; 29: 434- 440.
29. Noblett S, Snowden C, Shenton B et al., Randomized clinical trial assessing the effect of Doppler-optimized fluid management on outcome after elective colorectal resection. Br J Surg 2006; 93: 1069-1076.
30. Srinivasa S, Taylor M, Singh P et al., Randomized clinical trial of goal-directed fluid therapy within an enhanced recovery protocol for elective colectomy. Br J Surg 2013; 100: 66- 74.
31. Pearse R, Harrison D, MacDonald N et al., OPTIMISE Study Group: Effect of a perioperative, cardiac output-guided hemodynamic therapy algorithm on outcomes following major gastrointestinal surgery: A randomized clinical trial and systematic review. JAMA 2014; 311: 2181- 2190.
32. 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. Br J Anaesth 2018; 120: 734- 744.
33. Rhodes A, Cecconi M, Hamilton M, et al. Goal-directed therapy in high-risk surgical patients: a 15-year follow-up study. Intensive Care Med 2010; 36: 1327- 1332.
34. Chong M, Wang Y, Berbenetz N, et al., Does goal-directed haemodynamic and fluid therapy improve peri-operative outcomes? A systematic review and meta-analysis. Eur J Anaesthesiol 2018; 35: 469- 483.
35. Joshi GP, Kehlet H., CON: Perioperative Goal-Directed Fluid Therapy Is an Essential Element of an Enhanced Recovery Protocol? Anesth Analg 2016; 122: 1261-1263.

36. Chappell D, Jacob M, Hofmann-Kiefer K, et al. A rational approach to perioperative fluid management. Anesthesiology 2008; 109: 723- 740.
37. Self W, Semler M, Wanderer J, Wang L, Byrne D et al., Balanced crystalloids versus saline in noncritically ill adults. N Engl J Med 2018; 378: 819–828.
38. Lobo D, Stanga Z, Aloysius M et al., Effect of volume loading with 1 liter intravenous infusions of 0.9% saline, 4% succinylated gelatine (Gelofusine) and 6% hydroxyethyl starch (Voluven) on blood volume and endocrine responses: a randomized, three-way crossover study in healthy volunteers. Crit Care Med 2010; 38: 464-470.
39. 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. JAMA 2013; 310: 1809-1817.
40. Lewis S, Pritchard M, Evans D, et al. Colloids versus crystalloids for fluid resuscitation in critically ill people. Cochrane Database Syst Rev 2018; 8: CD000567.
41. Myles P, Andrews S, Nicholson J, et al. Contemporary Approaches to Perioperative IV Fluid Therapy. World J Surg 2017; 41: 2457- 2463.
42. Caironi P, Tognoni G, Masson S et al., Albumin replacement in patients with severe sepsis or septic shock. N Engl J Med. 2014; 370: 1412- 1421.
43. Navickis R, Haynes G, Wilkes M. Effect of hydroxyethyl starch on bleeding after cardiopulmonary bypass: a meta-analysis of randomized trials. J Thorac Cardiovasc Surg 2012; 144: 223- 230.
44. Khan S, Brohi K, Chana M, et al. Hemostatic resuscitation is neither hemostatic nor resuscitative in trauma hemorrhage. J Trauma Acute Care Surg. 2014; 76: 561–567.
45. Sperry J, Guyette F, Brown J, et al. Prehospital plasma during air medical transport in trauma patients at risk for hemorrhagic shock. N Engl J Med. 2018; 379: 315- 326.
46. Milford E, Reade M, Resuscitation Fluid Choices to Preserve the Endothelial Glycocalyx, Critical Care 2019, 23: 77 (1-11).
47. Bundgaard-Nielsen M, Jorgensen C, Secher N et al., Functional intravascular volume deficit in patients before surgery. Acta Anaesthesiol Scand. 2010; 54: 464- 469.
48. Apfelbaum J, Madulhika Agarkar J, Connis R, et al., Practice guidelines for preoperative fasting and the use of pharmacologic agents to reduce the risk of pulmonary aspiration: Application to healthy patients undergoing elective procedures: An updated report by the American Society of Anesthesiologists Task Force on Preoperative Fasting and the Use of Pharmacologic Agents to Reduce the Risk of Pulmonary Aspiration. Anesthesiology 2017; 126: 376- 393.
49. Feldheiser A, Aziz O, Baldini G et al., Enhanced Recovery After Surgery (ERAS) for gastrointestinal surgery, part 2: Consensus statement for anaesthesia practice. Acta Anaesthesiol Scand 2016; 60: 289–334.
50. Futier E, Lefrant J, Guinot P et al., INPRESS Study Group: Effect of individualized vs standard blood pressure management strategies on postoperative organ dysfunction among high-risk patients undergoing major surgery: A randomized clinical trial. JAMA 2017; 318: 1346- 1357.

doi.org/10.56126/73.S1.38