MARK A. HAMILTON, MBBS, MRCP, FRCA
Consultant and Honorary Senior Lecturer in Anaesthesia and Intensive Care Medicine,
St. George's Hospital and Medical School, London, UK

Perioperative fluid management: Progress despite lingering controversies

ABSTRACT

Perioperative fluid management remains controversial. Nevertheless, its optimization is essential to reducing the risk of postoperative complications, which have been shown to profoundly affect patients' short- and long-term outcomes. Current evidence favors a "flow-guided" approach to perioperative fluid administration, which uses variables such as stroke volume and cardiac output as the basis for guiding fluid requirements. The optimal fluid is controversial, although colloids appear to have some physiologic advantages over crystalloids. Minimally invasive technologies have emerged for intraoperative monitoring of blood flow, which may enable more precise fluid titration.

KEY POINTS

A flow-guided approach to fluid administration is associated with reductions in mortality, postoperative complications, and length of stay compared with fluid management guided by traditional physiologic targets.

Studies to date have shown no consistent difference between colloids and crystalloids in their effects on clinical outcomes.

Intraoperative esophageal Doppler monitoring is a simple technique for titrating boluses of fluid based on continuous estimations of stroke volume.

Administration of sufficient fluids early in the course of surgery may be more important than the total volume of fluid administered in improving patient outcomes.

Intraoperative fluid needs are highly variable, underscoring the need for individual monitoring and assessment.

See end of article for author disclosures. doi:10.3949/ccjm.76.s4.05

Perioperative fluid management remains controversial. Until recently, fluid management was guided by targets such as urine output, static pressures, blood pressure, and other physiologic variables. Such physiologic signs, however, are inadequate for detecting subclinical hypovolemia. This has prompted the emergence of an approach to fluid administration based on stroke volume and cardiac output—a "flow-guided" approach—designed to overcome the inadequacies of conventional physiologic signs and improve outcomes. Recent technological advances are permitting noninvasive guidance of intravenous fluid therapy to optimize intravascular volume status.

This article reviews the rationale for perioperative fluid management, strategies for perioperative fluid therapy and their associated outcomes, the types of volume expanders used, and considerations for improving perioperative fluid administration.

WHY FLUID MANAGEMENT MATTERS

Postoperative complications predict survival

In 2005, Khuri et al published a study of survival after major surgery that starkly illustrated the prognostic importance of postoperative complications.[1] In an effort to identify predictors of long-term survival, they analyzed a National Surgical Quality Improvement Program database of 105,951 patients who underwent eight common operations at Veterans Administration facilities. They found that the most important determinant of reduced postoperative survival over 8 years of follow-up was the occurrence of a complication within 30 days after surgery. The presence of a postoperative complication was a stronger predictor of death than any intraoperative or preoperative risk factor.

Fluid management is key to preventing complications

Optimizing perioperative fluid management is essential to reducing the risk of postoperative complications and mortality. Surgical patients are more likely to have serious complications and die if they have limited physiologic reserve. Adequate fluid administration may reduce the stress response to surgical trauma and support recovery.

Building on early work showing that survivors of major surgery have consistently higher postoperative cardiac output and oxygen delivery (DO_2) than do nonsurvivors,[2,3] a seminal study by Shoemaker et al showed

that these types of blood flow–related parameters are predictive of both survival and complication-free survival.[4] Specifically, Shoemaker and his team showed that a protocol designed to achieve DO_2 of at least 600 mL/min/m^2 was associated with reductions in both postoperative complications and death.[4]

PROBLEMS WITH PERIOPERATIVE FLUID THERAPY—AND EFFORTS TO OVERCOME THEM

Despite the utility of fluid management in reducing postoperative complications, perioperative fluid therapy is fraught with several fundamental problems:

- Blood volume cannot be evaluated accurately.
- Fluid overload cannot be identified accurately, apart from tissue edema as a result of gross fluid overload.
- Hypovolemia cannot be identified accurately. Commonly measured variables (heart rate, blood pressure, base excess, lactate) are late markers, and the patient's status upon admission to the operating room is often unknown.
- Tissue perfusion cannot be evaluated accurately. Although lactate and venous oxygen saturation are surrogate markers, genuinely accurate markers for tissue perfusion are lacking.

For these reasons, fluids are commonly administered without the guidance of direct markers of fluid status.

Assessing flow-guided fluid therapy

These shortcomings prompted me and several other researchers to assess the evidence regarding a flow-guided approach to fluid administration, which aims to achieve maximal cardiac output and stroke volume while avoiding excess fluid administration. We conducted a systematic literature search for randomized controlled trials evaluating the postsurgical effects of perioperative fluid therapy to increase global blood flow to explicitly defined goals, after which we performed a meta-analysis of the 22 qualifying studies.[5] The trials collectively included 4,546 patients undergoing relatively high-risk elective or emergency surgery, consisting of general, vascular, cardiac, orthopedic, and urologic procedures. Overall mortality in these trials was 10.6% (481 deaths). The primary outcome assessed was mortality; secondary outcomes included morbidity and length of stay in the hospital and in the intensive care unit. Outcomes were assessed according to the timing of the intervention, the fluid type, and explicit measured goals. Fluids were given to all patients, usually as a dynamic bolus, using a flow-guided approach above and beyond that of the control group.

Our analysis found that a flow-guided protocol was associated with a significant reduction in mortality compared with control protocols (odds ratio = 0.82 [95% CI, 0.67–0.99]; $P = .04$).[5] However, sensitivity analysis showed that the largest and best-designed studies tended to yield no significant differences in mortality between the groups, which highlights the remaining need for larger studies to more definitively clarify the effect on mortality.

Timing of administration (ie, whether fluid was given pre-, intra-, or postoperatively) influenced the primary outcome: compared with control, flow-guided fluid therapy was associated with a significant reduction in mortality only when administered intraoperatively, but not when given preoperatively or postoperatively.[5]

Length of hospital stay was reduced by approximately 1.6 days with flow-guided therapy compared with control ($P < .00001$), but there was no significant difference between approaches in terms of intensive care unit stay.[5]

Postoperative complication rates are difficult to compare, given the lack of a uniform definition of a complication and the relative importance of different complications. Nevertheless, when grouped as a whole, the rate of complications was 48% lower ($P < .00001$) with flow-guided therapy compared with control. Of all outcomes assessed, the effect on complications was the most consistent among all the studies in the analysis. To provide an example using one easily defined complication, the incidence of renal failure was reduced by 35% with flow-guided therapy compared with control ($P = .002$).[5]

COLLOID OR CRYSTALLOID?

Two pharmacologically distinct classes

Intravenous fluids can be broadly classified into colloid and crystalloid solutions, and the relative merits of these two fluid classes are at the center of an enduring debate that predates the advent of flow-based fluid administration. Despite fundamental differences in their pharmacokinetics and other characteristics, colloids and crystalloids are often not sufficiently distinguished from one another in discussions of perioperative fluid therapy.

The effect of a colloid depends on its molecular weight. Ninety minutes following administration, a significant proportion of a colloid with a high molecular weight (eg, hydroxyethyl starch) will be retained in the circulation. In contrast, crystalloid solutions (eg, 0.9% saline) readily disappear from the circulation, owing to the ease with which they travel across the cell membrane.[6]

No evidence of outcome differences

A systematic literature review by Choi et al reflects the current state of knowledge on the relative effects of colloids and crystalloids for fluid resuscitation.[7] It concluded that there are no apparent differences between these fluid classes in their effects on pulmonary edema, mortality, or length of stay. The authors noted that methodologic limitations of the available comparative studies prevent meaningful conclusions and that larger randomized controlled trials are needed to detect any differences in outcomes between the two classes.

Although using a crystalloid for fluid resuscitation probably results in a greater volume of fluid given, a study known as SAFE (Saline versus Albumin Fluid Evaluation),[8] published after the Choi analysis, showed no differences in 28-day all-cause mortality or other significant outcomes between patients randomized to the colloid (4% albumin) and those assigned to the crystalloid (0.9% saline). Patients receiving the colloid had a higher central venous pressure at all time points, a lower heart rate at the end of the first day, and less overall volume on days 1 and 2 compared with patients receiving the crystalloid. While SAFE was conducted in critically ill patients, these physiologic advantages of the colloid may have implications for results in the perioperative arena, although this remains speculative.

INTRAOPERATIVE MONITORING TO OPTIMIZE FLUID THERAPY

Another important issue is the emergence of minimally invasive technologies for monitoring hemodynamic measures intraoperatively. The aim is to enable more precise tailoring of fluid therapy to meet patient needs on a case-by-case basis.

One of the simplest of these techniques is esophageal Doppler monitoring to measure descending aortic blood flow using Doppler ultrasonography. The technique is used to titrate repeated boluses of fluid based on continuous estimations of stroke volume and surrogate markers of preload indices. Typical protocols for esophageal Doppler monitoring call for administration of colloid to maintain a descending thoracic corrected flow time of no more than 0.35 seconds and stroke volume increments of 10%.

Phan et al recently published a meta-analysis to assess the effect of intraoperative esophageal Doppler monitoring in guiding fluid therapy to optimize intravascular volume status.[9] The analysis, which included nine randomized controlled trials in a total of 920 patients, found statistically significant reductions in the rate of complications and in length of hospital stay with the use of esophageal Doppler monitoring; there was no difference in mortality. Use of Doppler monitoring was associated with an increase (+671 mL) in the volume of colloid administered and a decrease (–156 mL) in the volume of crystalloid.

Timing of fluid administration can be critical

One of the trials in the above meta-analysis illustrated that the timing of fluid administration might be more critical than the volume of fluid given. Noblett et al placed an esophageal Doppler probe in each of a series of 108 patients undergoing colorectal resection;[10] the control group received perioperative fluid at the anesthesiologist's discretion, whereas the intervention group received additional colloid boluses based on Doppler assessment. While the overall volume of colloid given was comparable between the two groups, the intervention group received nearly 100% of the total volume during the first quarter of surgery. The intervention group had significantly fewer postoperative complications than the control group as well as a 2-day reduction in average length of stay. Circulating levels of interleukin-6 and cytokines also were significantly lower in the intervention group, which suggests that the intervention blunted the inflammatory response to surgery.

Fluid management must be individualized

Intraoperative fluid needs are highly variable and patient-specific. Parker et al tested an approach in which they universally administered 500 mL of a gelatin colloid solution prior to hip fracture surgery and compared it with a conventional intravenous saline crystalloid solution; neither approach used invasive intraoperative monitoring.[11] They found no significant difference in length of stay, 30-day mortality, or postoperative complications between the two study arms. They concluded that more invasive investigation of patients before or during surgery may have been able to identify a subgroup in whom the colloid therapy or more precise fluid control would have been beneficial.

THE ROAD AHEAD

Fluid management remains suboptimal

Despite being a fundamental component of surgical and perioperative care, fluid management remains suboptimal in clinical practice. I can speak most directly to the practice of fluid management in the United Kingdom (UK), but the same types of shortcomings apply broadly to the United States as well.

In 1999, the UK's National Confidential Enquiry into Patient Outcome and Death examined perioperative death in the UK, concluding that patients were dying as a result of too much or too little perioperative fluid administration.[12] Their report cited staff inexperience as an important contributor to the problem, as junior physicians order and deliver the majority of postoperative fluid regimens.

This cautionary report from 10 years ago appears not to have produced substantial improvements in practice, at least according to a recent study by Walsh et al.[13] These researchers prospectively audited postoperative fluid management practices in 106 consecutive patients undergoing laparotomy in a UK general surgical unit over a 6-month period in 2003. They found no correlation between available fluid balance data and the quantities of fluids prescribed, suggesting that physicians routinely ignore such data when prescribing. Fifty-four percent of the patients developed at least one fluid-related complication. Patients routinely received significantly greater amounts of fluid and

sodium than were physiologically needed, and multivariate analysis showed that mean daily fluid load predicted development of fluid-related complications.

Guidance from a new British consensus document

Where can clinicians turn for a good synthesis of current evidence to guide better perioperative fluid management? I would recommend the newly released British Consensus Guidelines on Intravenous Fluid Therapy for Adult Surgical Patients,[14] which are available on the Evidence Based Peri-Operative Medicine Web site (*http://www.ebpom.org*). These guidelines were developed by a multidisciplinary team of clinicians to improve perioperative fluid prescribing. They cover principles of preoperative, intraoperative, and postoperative fluid management, as well as fluid therapy in acute kidney injury. They present 28 recommendations in all, at least 12 of which are based on high-level (grade 1a or 1b) evidence.

DISCUSSION

Question from the audience: What is the relationship between perioperative fluid management, gut edema from perioperative fluid use, and postoperative ileus?

Dr. Hamilton: There's no easy answer. Excessive administration of sodium and fluid does predispose to gut and tissue fluid edema. Many of the enhanced surgery recovery programs require no preoperative fasting. There's no bowel prep. The enteral route is used primarily as quickly as possible. In the UK, we no longer use nasogastric tubes for many of those programs. But there's no doubt that tissue edema still occurs with excess fluid therapy.

The premise for individualizing fluid therapy is that less is not more but that more is not the right approach either. The stroke volume approaches or the corrected flow time approaches have been related to return of gastrointestinal function and return of flatus, which is a function of gastrointestinal recovery.

Question from the audience: Can you comment on the perioperative use of the Swan-Ganz catheter for fluid management?

Dr. Hamilton: I don't use it intraoperatively, and not many hospitals in the UK use it apart from liver resection surgery. Having said that, Swan-Ganz catheters were the predominant monitor for 30% to 40% of the original studies of hemodynamic optimization. I cannot give you intraoperative data to support the use of Swan-Ganz catheters for monitoring, but if you lift evidence from the other methods of monitoring hemodynamics, if you're optimizing flow in a bolus and dynamic fashion, then you should see the kinds of improvements in outcomes that are associated with the other modalities.

The drawback with the Swan-Ganz catheter, obviously, is the morbidity associated with its insertion and its interpretation. But if you're confident in doing those things, I think it's a perfectly good monitor.

DISCLOSURES

Dr. Hamilton has indicated that he has no financial relationships with commercial interests that have a direct bearing on the subject matter of this article.

This article was developed from an audio transcript of Dr. Hamilton's lecture at the 4th Annual Perioperative Medicine Summit. The transcript was edited by the *Cleveland Clinic Journal of Medicine* staff for clarity and conciseness, and was then reviewed, revised, and approved by Dr. Hamilton.

REFERENCES

1. **Khuri SF, Henderson WG, DePalma RG, et al; Participants in the VA National Surgical Quality Improvement Program.** Determinants of long-term survival after major surgery and the adverse effect of postoperative complications. Ann Surg 2005; 242:326–343.
2. **Boyd AD, Tremblay RE, Spencer FC, Bahnson HT.** Estimation of cardiac output soon after intracardiac surgery with cardiopulmonary bypass. Ann Surg 1959; 150:613–626.
3. **Clowes GH Jr, Del Guercio LR.** Circulatory response to trauma of surgical operations. Metabolism 1960; 9:67–81.
4. **Shoemaker WC, Appel PL, Kram HB, Waxman K, Lee TS.** Prospective trial of supranormal values of survivors as therapeutic goals in high-risk surgical patients. Chest 1988; 94:1176–1186.
5. **Grocott MPW, Hamilton MA, Bennett ED, Harrison D, Rowan K.** Perioperative increase in global blood flow to explicit defined goals and outcomes following surgery (Protocol). Cochrane Database Syst Rev 2006; Issue 2. Art. No.: CD004082. doi:10.1002/14651858.CD004082.pub4.
6. **Lamke LO, Liljedahl SO.** Plasma volume changes after infusion of various plasma expanders. Resuscitation 1976; 5:93–102.
7. **Choi PT, Yip G, Quinonez LG, Cook DJ.** Crystalloids vs. colloids in fluid resuscitation: a systematic review. Crit Care Med 1999; 27:200–210.
8. **The SAFE Study Investigators.** A comparison of albumin and saline for fluid resuscitation in the intensive care unit. N Engl J Med 2004; 350:2247–2256.
9. **Phan TD, Ismail H, Heriot AG, Ho KM.** Improving perioperative outcomes: fluid optimization with the esophageal Doppler monitor, a metaanalysis and review. J Am Coll Surg 2008; 207:935–941.
10. **Noblett SE, Snowden CP, Shenton BK, Horgan AF.** Randomized clinical trial assessing the effect of Doppler-optimized fluid management on outcome after elective colorectal resection. Br J Surg 2006; 93:1069–1076.
11. **Parker MJ, Griffiths R, Boyle A.** Preoperative saline versus gelatin for hip fracture patients: a randomized trial of 396 patients. Br J Anaesth 2004; 92:67–70.
12. National Confidential Enquiry into Patient Outcome and Death (NCEPOD) Web site. http://www.ncepod.org.uk. Accessed March 25, 2009.
13. **Walsh SR, Cook EJ, Bentley R, et al.** Perioperative fluid management: prospective audit. Int J Clin Pract 2008; 62:492–497.
14. **Powell-Tuck J, Gosling P, Lobo DN, et al.** British consensus guidelines on intravenous fluid therapy for adult surgical patients; 2009. Evidence Based Peri-Operative Medicine (EBPOM) Web site. http://www.ebpom.org. Accessed March 26, 2009.

Correspondence: *Mark A. Hamilton, MBBS, MRCP, FRCA, Anaesthesia and Intensive Care Medicine, St. George's Hospital, Blackshaw Road, London SW17 8QT, United Kingdom; markhamilton@nhs.net*