REVIEW ARTICLE

Contemporary Fluid Management in Cardiac Anesthesia

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THE PRESCRIPTION OF perioperative fluids has been a persistent controversy among anesthesiologists, surgeons, and intensivists. Interestingly, disagreements within each specialty as to the appropriate types and amounts of fluids required are just as intense as that seen among the specialties. The challenge in navigating these waters is demanding because the safe harbor of optimal fluid administration is bounded by hypovolemia and end-organ hypoperfusion (resulting from inadequate fluids) and congestive heart failure and the negative effects of edema formation on respiration and wound healing (resulting from excessive fluids). The clinician typically is equipped with limited useful monitoring data and no consensus guidelines on the optimal fluid strategy. In effect, clinicians are navigating through rough waters with neither a compass nor a chart. Not surprisingly, outcomes have been less than satisfactory because the need for rescue therapy for the hypovolemic shock patient and prolonged mechanical ventilation and congestive heart failure remain all-too-frequent events in the operating room and the intensive care unit (ICU).

The robust debate over best practice for fluid management that emerged in the 1960s continues to shape contemporary thinking. Francis Moore, then Chief of Surgery at the Peter Bent Brigham Hospital in Boston, MA, and his contemporary, Tom Shires, Chief of Surgery at the University of Texas Southwestern, Dallas, TX, held contrasting viewpoints on the effects of surgical procedures on the body's mechanism for sodium and fluid homeostasis. Moore argued that the primary responses of an individual to surgical stress were elevations in aldosterone and antidiuretic hormone, and these led to the inappropriate retention of salt and water. He advised a "restrictive" fluid policy to avoid excessive fluid retention.[1,2] To the contrary, Shires advanced a more "liberal" policy of fluid management. His work led him to conclude that extravasations of fluid from the extracellular compartment to the 3rd space along with evaporative losses led to an extracellular fluid deficit in surgical patients and the consequent and appropriate elevations of aldosterone and antidiuretic hormone.[3,4] The replacement of these losses was advised, and a strategy of aggressive fluid replacement emerged as the mainstay of perioperative care.[5,6]

More recently, with the increasing recognition of the adverse effects of excessive fluid accumulations in surgical patients, restricted fluid strategies as well as the administration of fluid as directed by specific physiologic parameters, such as stroke volume (SvO_2), have attracted new advocates. In addition, the choice of fluid solutions available to the clinician has increased. Particularly noteworthy is the development of newer colloid formulations with altered molecular weight and substitution.

The cardiac anesthesiologist faces specific challenges in fluid management. Comorbidities, including reduced ventricular systolic and diastolic function and renal and pulmonary impairments, are prevalent in cardiac surgery patients and impact fluid-management decisions. Surgical blood loss, cardiopulmonary bypass, and inflammatory responses further challenge the care of these patients. This review focused on the recent data examining fluid management in cardiac surgery. The objective was to identify the supporting evidence for fluid-management strategies in the cardiac surgical patient, the use of monitoring to guide therapy, and the various fluid formulations available in current practice.

LIBERAL VERSUS RESTRICTIVE FLUID MANAGEMENT

The term of "liberal" or "restrictive" fluid administration was used to define algorithms using greater or lesser amounts of fluid for maintenance and substitution for losses caused by bleeding, preoperative fasting, and perspiration. The studies by Brandstrup et al as well as others[7,8] in patients undergoing colonic surgery led to the re-emergence of restrictive fluid administration because the authors were able to show improved postoperative performance in their restrictive compared with their liberal group. However, the controversy remains because others were not able to confirm these findings.[9-11] Furthermore, no studies have made such comparisons in the cardiac surgical population. One of the main difficulties with the interpretation of these publications is that the definition of restrictive or liberal fluid administration differs among centers. In fact, what is deemed restrictive at one center is often considered liberal at another (Table 1). The difference in results among studies may reflect the vagaries of "standard fluid therapy," often chosen as the control group in fluid therapy trials, resulting in the testing of various "standard fluid regimens" versus "even more fluid" (Table 2).[7] Also problematic is that fixed-volume algorithms

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Table 1. Comparison of a Restricted Fluid Regimen to a More Liberal, Standard Regimen

Intraoperative Fluid Therapy	Restricted Regimen	Standard Regimen
Preloading of epidural analgesia	No preloading.	500 mL HAES 6%.*
Third-space loss	No replacement.	Normal saline 0.9%: 7 mL/kg/h first hour; 5 mL/kg/h second and third hours; 3 mL/kg/h in the following hours.
Loss during fast (maintenance)	500 mL of glucose 5% in water less oral fluid intake during fast.	500 mL of normal saline 0.9% independent of oral intake.
Blood loss	Volume-to-volume with HAES 6% with allowance for max. 500 mL extra.	Loss up to 500 mL: 1000-1500 mL of normal saline; Loss >500 mL, additional HAES 6%.
	Blood component therapy started at approximate loss >1500 mL dependent on hematocrit.	Blood component therapy started at approximate loss >1500 mL dependent on hematocrit.

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*Hydroxyethyl starch 6% in normal saline.

cannot account for individual variations in cardiovascular physiology, which are especially common in cardiothoracic surgery. For this reason, an individualized optimization of fluid administration using goal-directed volume management has been explored as an alternative to restrictive or liberal approaches based on algorithms (Fig 1).[12]

Goal-Directed Fluid Management

Hemodynamic monitoring and goal-directed therapeutic (GDT) approaches in surgical patients can reduce the length of intensive care unit treatment and improve outcome. As early as 1988, Shoemaker et al[13] published a positive effect on outcome in noncardiac high-risk patients undergoing surgery. A GDT aiming at pulmonary artery catheter (PAC)-derived hemodynamic goals led to a significant reduction of mortality in their protocol group. Another study with 62 noncardiac patients undergoing a GDT aiming at an oxygen delivery of 600 mL/min/m^2 led to decreased complications in the protocol group and a reduced length of hospital stay.[14,15] A recent meta-analysis confirmed that in patients undergoing major surgery GDT with maintenance of an adequate systemic oxygenation improves outcome (Fig 2).[16]

In cardiac surgery patients, only 1 study has shown that a PAC-driven treatment algorithm improves outcome. In this study, SvO_2-oriented therapy treatment was shown to be relevant in regard to morbidity and hospital length of stay in postoperative cardiac surgery patients.[17] To what extent using SvO_2 to guide therapy after cardiac surgery is superior to using central venous oxygen saturation ($ScvO_2$) remains unclear at the present time.[18] It is known that $ScvO_2$ can be used successfully to guide sepsis therapy.[19] However, in cardiac surgical patients, significant deviations between SvO_2 and $ScvO_2$ were reported.[18]

A recent study by Kapoor et al[20] was aimed at elucidating the impact of $ScvO_2$ and stroke volume–guided GDT on the postoperative outcome in 30 cardiac surgical patients. The authors used the Flotrac and Presept system (Edwards Life Science, Irvine, CA) to increase the cardiac index (CI) and oxygen delivery, and decrease stroke volume variation (SVV). In the GDT group, significantly more volume was given, and more adjustments to the vasoactive and inotropic therapy were observed. This therapeutic approach led to an insignificant decrease of ventilation time, days on inotropes, ICU stay, and hospital stay, so that the benefit of the approach used in this study warrants further investigation in a larger group of patients. In a randomized controlled trial, McKendry et al[21] assessed the impact of a nurse-driven hemodynamic optimization protocol in 174 postoperative cardiothoracic patients. In this study, patients were allocated to conventional fluid management or to a fluid-administration protocol guided by esophageal Doppler flowmetry to maintain a stroke index above 35 mL/m^2. The patients in the protocol group received 200 mL of colloids or blood products at arrival in the ICU; if the stroke index increased more than 10% after the fluid challenge, they repeated this volume challenge until the stroke index did not change more than 10% again. The authors were able to show that the duration of hospital stay in the treatment group was reduced significantly from a median of 9 days to a median of 7 days. This led to the conclusion that a nurse-delivered protocol for optimizing circulatory status in the early postoperative period after cardiac surgery may significantly shorten hospital stay. A further study compared 40 patients undergoing cardiac surgery with a historic control.[22] In the GDT group, fluid management was guided by an algorithm based on the global end-diastolic volume index (GEDVI), intrathoracic blood volume index (ITBVI), CI, and mean arterial pressure (MAP). The authors targeted a GEDVI above 640 mL/m^2, a CI above 2.5 L/min/m^2, and a mean arterial pressure (MAP) above 70 mmHg. The control group was treated at the discretion of the attending physician based on the central venous pressure (CVP), MAP, and clinical evaluation. In the GDT group, patients received more colloids and fewer vasopressors. The authors concluded that guiding therapy by GEDVI leads to a shortened and reduced need for vasopressors, catecholamines, mechanical ventilation, and ICU therapy in patients undergoing cardiac surgery. Another study by Smetkin et al[23] in patients undergoing off-pump coronary artery bypass (OPCAB) used a similar approach based on ITBVI, MAP, heart rate (HR), $ScvO_2$, and CI. In the GDT group, colloids and dobutamine were given more frequently and were accompanied by improvements in $ScvO_2$, CI, and oxygen delivery compared with baseline. They observed a shorter hospital stay and earlier achievement of ICU discharge criteria. The authors concluded that a goal-directed protocol can improve outcome in OPCAB surgery. In sum-