

Fluid resuscitation: the good, the bad and the ugly

AB Johan Groeneveld, Polderman KH

Abstract

Fluid resuscitation is one of the most common therapeutic steps in the critically ill. In this brief overview, the goals and potential adverse effects of fluid resuscitation are addressed. The contention is that the value of many of the fluid resuscitation goals in hypovolemic patients has not been unequivocally estab-

lished, that overhydration is a significant problem and that certain types of fluids can be associated with major adverse effects. Hence, fluid loading should be carefully done and adequately monitored to avoid these effects and to improve survival of patients with hypovolemia and hemodynamic insufficiency.

Keywords: hypovolemia, shock, fluid resuscitation, cardiac function, critically ill, colloids versus crystalloids, fluid overloading.

Introduction

Fluid administration is one of the most common therapeutic steps in the intensive care unit (1). In the critically ill, fluid therapy may be undertaken in case of oliguria/impending renal failure, hypotension, shock, lactic acidemia, low cardiac output, and other conditions in which underfilling, a low plasma volume and cardiac output are thought to be insufficient for organ perfusion, oxygenation and function (1,2). However, the knowledge on the fate of artificial colloids or plasma replacement/expanding fluids, and even of crystalloids, in the critically ill, is limited, and this may contribute to the seemingly endless debate on the relative merits and detriments of colloid versus crystalloid fluid resuscitation in the critically ill (3-6). Here, we have summarised some controversial aspects of fluid resuscitation, with respect to volume rather than type of fluid, the prediction of fluid responsiveness and the endpoints towards which fluid therapy should be targeted (Table 1).

TABLE 1. CONTROVERSIAL ISSUES IN FLUID RESUSCITATION

Unrelated to type of fluid:

Fluid responsiveness
Propensity for pulmonary edema formation
Hemodynamic, metabolic goals
Effect on, and of hemodilution
Adverse effects of fluid overloading
Renal dysfunction
Increasing (hyperchloremic) acidemia
Increased risk of bleeding

Related to fluid type:

Plasma volume and fluid responsiveness
Propensity for pulmonary edema formation
Specific effects on heart, lung, coagulation and renal function
Specific side effects

The good

Goal-directed therapy is a term used to describe the aiming for specific and well-defined hemodynamic goals, presumably associated with optimal tissue oxygenation, in the treatment of hemodynamically unstable, critically ill patients, after surgery or in the course of sepsis, trauma, etc (1,2,6-8). Whether aiming at these goals actually improves survival remains controversial and depends on the

From the Department of Intensive Care, VU medical center, Institute for Cardiovascular Research, Amsterdam, the Netherlands

Address requests for reprints to:

Prof dr ABJ Groeneveld FCCP FCCM, Department of Intensive Care, VU Medical Center, De Boelelaan 1117, 1081 HV Amsterdam, the Netherlands. Tel 31-20-4444178, Fax 31-20-4442392, E-mail: johan.groeneveld@vumc.nl

condition being studied, the heterogeneity of patient groups, the use of vasopressor and inotropic drugs, the timing and dosing of therapeutic interventions to reach the defined goals, etc (1,2,7,8). Nevertheless, it is commonly believed that in hemodynamically unstable patients, optimization of cardiac output is associated with increased tissue oxygen delivery, even in case of hemodilution by asanguinous fluid loading, and improved tissue oxygenation (1,2). This may translate into increased arterial blood pressure and urinary output, decreasing lactate levels, amelioration of metabolic acidemia, etc. Indeed, vigorous fluid resuscitation, particularly with saline, may promote renal perfusion and function, in the treatment of patients with traumatic shock and crush injury (9). Optimal fluid loading after cardiac surgery or early in the course of septic shock also may ameliorate morbidity and mortality (7,8). Taken together, fluid therapy should aim at physiologically and clinically relevant endpoints, in order to improve outcome, but further refinement of these endpoints seems warranted (6).

The bad

The cardiac response to fluid loading is difficult to predict, and may even depend on the type of fluid and hemodynamic monitoring applied (10-13). Preload recruitability or fluid responsiveness is difficult to predict on the basis of central venous (right atrial) pressure or pulmonary capillary wedge pressure alone, particularly in mechanically ventilated patients when end-expiratory pressures are unpredictably confounded by airway pressure (positive end-expiratory pressure). Cardiac filling volumes and dynamic parameters such as pressure or stroke volume variations following mechanical breaths may be better indicators of preload recruitability than filling pressures. It is unknown, however, if fluid treatment guided by one or the other indicator of preload has a favourable effect on morbidity and mortality. The ultimate proof that the flat portion of the ventricular function curve has been reached is, of course, the observation that fluid loading does not further increase cardiac output. Hence, fluid loading guided by cardiac output instead of indicators of filling may help to optimize oxygen delivery to the tissues in the hemodynamically compromised patients, while limiting the risk of overhydration.

Potential adverse effects of fluids, such as normal saline and colloids when dissolved in saline, include hyperchloremic acidemia (14), a fall in renal filtration (pressure, colloids and starches, 15-17), renal tubular toxicity and microalbuminuria (gelatins, 18), and tissue accumulation (starches) resulting in hepatic dysfunction (19) or prolonged pruritus (20).

The ugly

Another side effect includes fluid overloading resulting in edema formation, both systemically and in the lungs, even though edema safety factors, ie decreased interstitial colloid pressure and increased lymph flow may be more effective in the lungs than systemically. Many critically ill patients after major surgery, trauma or sepsis, develop some degree of lung vascular injury and thus increased permeability edema (21). These patients may be prone for developing pulmonary edema even if filtration pressures, eg pulmonary capillary wedge pressure, are not severely elevated (21-23). A positive fluid balance may therefore predict prolonged mechanical ventilation and impaired weaning (22-24), while fluid therapy guided by direct measurements of lung edema, ie extravascular lung water, as opposed to that guided by a wedge pressure (<18 mm Hg), may be able to prevent this (22).

Overhydration is also a major risk factor for compartment syndromes, either in injured extremities or in the abdomen after trauma (25,26). Accumulation of pleural or ascitic effusions can indeed be viewed as physiologic overflow of intravascular overhydration (26). Compartment syndromes result in reduced perfusion pressures and thus perfusion, and this is an example of a counterproductive effect of overzealous fluid resuscitation. In contrast, liberal (crystalloid-based) rather than small (hypertonic) volume fluid therapy in the course of brain injury or other catastrophies leading to disruption of the blood-brain barrier, may not promote edema formation and may even improve outcome, contrary to current paradigms (2,27,28).

Perioperative fluid overload may be a risk factor for postoperative pulmonary edema and cardiac arrest, impaired wound healing, intolerance to enteral feeding, a prolonged hospital stay, etc (29-31). A restrictive perioperative fluid regimen may attenuate adverse effects of a liberal fluid strategy (30,31). Restrictive versus liberal fluid loading in the initial treatment of trauma patients is also hotly debated, since liberal fluid administration may dilute coagulation factors and hemoglobin, and restore arterial pressure, thereby aggravating further, uncontrolled bleeding (2,5).

Conclusion

In this overview, we have tried to summarize currently recognized merits and detriments of (excessive) fluid therapy in the critically ill. These considerations prompt us to carefully consider our resuscitation strategies, and to use fluid loading judiciously with specific targets in mind, while carefully monitoring our patients.

References

1. Girbes ARJ, Groeneveld ABJ (2000) Circulatory optimization of the patient with or at risk for shock. *Clin Intensive Care* 11:77-88
2. Moore FA, McKinley BA, Moore EE (2004) The next generation in shock resuscitation. *Lancet* 363:1988-1996
3. Nolan J (1999) Fluid replacement. *Br Med Bull* 55:821-843
4. Grocott MP, Hamilton MA (2002) Resuscitation fluids. *Vox Sang* 82:1-8
5. Boldt J (2004) Fluid choice for resuscitation of the trauma patient: a review of the physiological, pharmacological, and clinical evidence. *Can J Anaesth* 51:500-513
6. Vincent J-L, Gerlach H (2004) Fluid resuscitation in severe sepsis and septic shock: an evidence-based review. *Crit Care Med* 32:S451-S454
7. Rivers E, Nguyen B, Havstad S, Ressler J, Muzzin A, Knoblich B, Peterson E, Tomlanovich M, Early Goal-Directed Therapy Collaborative Group (2001) Early goal-directed therapy in the treatment of severe sepsis and septic shock. *N Engl J Med* 345:1368-1377.
8. McKendry M, McGloin H, Saberi D, Caudwell L, Brady AR, Singer M (2004) Randomised controlled trial assessing the impact of a nurse delivered, flow monitored protocol for optimisation of circulatory status after cardiac surgery. *BMJ* 329:258-261
9. Gunal AI, Celiker H, DOgukan A, Ozalp G, Kirciman E, Simsekli H, Gunay I, Demircin M, Belhan O, Yildirim MA, Sever MS (2004) Early and vigorous fluid resuscitation prevents acute renal failure in the crush victims of catastrophic earthquakes. *J Am Soc Nephrol* 15:1862-1867
10. Schneider AJ, Teule GJ, Groeneveld AB, Nauta J, Heidendal GA, Thijs LG (1988) Biventricular performance during volume loading in patients with early septic shock, with emphasis on the right ventricle: a combined hemodynamic and radionuclide study. *Am Heart J* 116:103-112
11. Michard F, Teboul JL (2002) Predicting fluid responsiveness in ICU patients: a critical analysis of the evidence. *Chest* 121:2000-2008
12. Groeneveld ABJ, Breukers RBGE, Verheij J (2004) Clinical value of intra-thoracic volumes from transpulmonary indicator dilution. In: Pinsky M, Payen D (Eds) *Functional hemodynamic monitoring. Update in Intensive Care and Emergency Medicine* volume 42, Springer Verlag, pp 153-165
13. Groeneveld ABJ, Breukers RBGE (2005) Preload recruitability as a guide to fluid therapy in shock. In: Redl H (Ed) *11th Congress of the European Shock Society. Medimond*, pp 23-27
14. Ho AM, Karmakar MK, Contardi LH, Ng SSW, Hewson JR (2001) Excessive use of normal saline in managing traumatized patients in shock: a preventable contributor to acidosis. *J Trauma* 51:173-177
15. Ragaller MJ, Theilen H, Koch T (2001) Volume replacement in critically ill patients with acute renal failure. *J Am Soc Nephrol* 12: S33-S39
16. Schortgen F, Lacherade JC, Bruneel F, Cattaneo I, Hemery F, Lemaire F, Brochard L (2001) Effects of hydroxyethylstarch and gelatin on renal function in severe sepsis: a multicentre randomised study. *Lancet* 357:911-916
17. Boldt J, Priebe HJ (2003) Intravascular volume replacement therapy with synthetic colloids: is there an influence on renal function? *Anesth Analg* 96:376-382
18. ten Dam MA, Branten AJ, Klasen IS, Wetzels JF (2001) The gelatin-derived plasma substitute Gelofusine causes low-molecular-weight proteinuria by decreasing tubular protein reabsorption. *J Crit Care* 16:115-120
19. Christidis C, Mal F, Ramos J, Senejoux A, Callard P, Navarro R, Trinchet J-C, Larrey D, Beaugrand M, Guettier C (2001) Worsening of hepatic dysfunction as a consequence of repeated hydroxyethylstarch infusions. *J Hepatol* 35:726-732
20. Bork K (2005) Pruritus precipitated by hydroxyethyl starch: a review. *Br J Dermatol* 152:3-12
21. Groeneveld AB (2002) Vascular pharmacology of acute lung injury and acute respiratory distress syndrome. *Vascular Pharmacol* 39:247-256
22. Mitchell JP, Schuller D, Calandrino FS, Schuster DP (1992) Improved outcome based on fluid management in critically ill patients requiring pulmonary artery catheterization. *Am Rev Respir Dis* 145:990-998
23. Groeneveld AB, Polderman KH (2005) Acute lung injury, overhydration or both? *Crit Care* 9:136-137
24. Sakr Y, Vincent JL, Reinhart K, Groeneveld J, Michalopoulos A, Sprung CL, Artigas A, Ranieri VM, on behalf of the "Sepsis Occurrence in Acutely Ill Patient" investigators (2005) High tidal volume and positive fluid balance are associated with worse outcome in acute lung injury. *Chest*, in press.
25. Balogh Z, McKinley BA, Cocanour CS, Kozar RA, Holcomb JB, Ware DN, Moore FA (2002) Secondary abdominal compartment syndrome is an elusive early complication of traumatic shock resuscitation. *Am J Surg* 184:538-544
26. Mayberry JC, Welker KJ, Goldman RK, Mullins RJ (2003) Mechanism of acute ascites formation after trauma resuscitation. *Arch Surg* 138:773-776
27. York J, Arrillaga A, Graham R, Miller R (2000) Fluid resuscitation of patients with multiple injuries and severe closed head injury: experience with an aggressive fluid resuscitation strategy. *J Trauma* 48:376-380
28. Clifton GL, Miller ER, Choi SC, Levin HS (2002) Fluid thresholds and outcome from severe brain injury. *Crit Care Med* 30:739-745
29. Arieff AI (1999) Fatal postoperative pulmonary edema. Pathogenesis and literature review. *Chest* 115:1371-1377
30. Lobo DN, Bostock KA, Neal KR, Perkins AC, Rowlands BJ, Allison SP (2002) Effect of salt and water balance on recovery of gastrointestinal function after elective colonic resection: a randomised controlled trial. *Lancet* 359:1812-1818
31. Brandstrup B, Tonnesen H, Beier-Holgersen R, Hjortso E, Ording H, Lindorff-Larsen K, Rasmussen MS, Lannig C, Wallin L, Iversen LH, Gramkow CS, Okholm M, Blemmer T, Svendsen PE, Rottensten HH, Thage B, Riis J, Jeppesen IS, Teilmann D, Christensen AM, Graungaard B, Pott F; Danish Study Group on Perioperative Fluid Therapy (2003) Effects of intravenous fluid restriction on postoperative complications: comparison of two perioperative fluid regimens: a randomized assessor-blinded multicenter trial. *Ann Surg* 238:641-648