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Clinical Practice

Are we close to the ideal intravenous fluid?

N. MacDonald[1] and R. M. Pearse[2,*]

[1]Department of Perioperative and Pain Medicine, Barts Health NHS Trust, London E1 1BB, UK and [2]Barts and The London School of Medicine and Dentistry, Queen Mary University of London, London EC1M 6BQ, UK

*Corresponding author. E-mail: r.pearse@qmul.ac.uk

Abstract

The approach to i.v. fluid therapy for hypovolaemia may significantly influence outcomes for patients who experience a systemic inflammatory response after sepsis, trauma, or major surgery. Currently, there is no single i.v. fluid agent that meets all the criteria for the ideal treatment for hypovolaemia. The physician must choose the best available agent(s) for each patient, and then decide when and how much to administer. Findings from large randomized trials suggest that some colloid-based fluids, particularly starch-based colloids, may be harmful in some situations, but it is unclear whether they should be withdrawn from use completely. Meanwhile, crystalloid fluids, such as saline 0.9% and Ringer's lactate, are more frequently used, but debate continues over which preparation is preferable. Perhaps most importantly, it remains unclear how to select the optimal dose of fluid in different patients and different clinical scenarios. There is good reason to believe that both inadequate and excessive i.v. fluid administration may lead to poor outcomes, including increased risk of infection and organ dysfunction, for hypovolaemic patients. In this review, we summarize the current knowledge on this topic and identify some key pitfalls and some areas of agreed best practice.

Key words: colloids; Crystalloid solutions; fluid therapy

During the past 100 yr, i.v. fluid therapy has become an integral part of perioperative care, and yet the question of the 'ideal' fluid remains elusive. For both the intensive care physician and the anaesthetist, i.v. fluid resuscitation is considered a core skill, which we expect to deliver safely and effectively. Despite this, the evidence base for fluid therapy remains a hotly debated topic. In this review, we explore the reasons behind these debates and provide an objective summary of the current knowledge on this topic. The scope of this review includes manufactured i.v. fluid solutions used for fluid resuscitation. With the exception of albumin solution, we do not cover the use of blood products or the use of i.v. fluids for specialized indications, such as traumatic brain injury.

Historical context

In 1831, William O'Shaughnessy wrote to *The Lancet* to report some fascinating and remarkably detailed observations on the blood drawn from cholera sufferers.[1] His account included a detailed description of reduction in water content, low bicarbonate concentrations, and uraemia '… where suppression of urine has been a marked symptom'. A few months later, Thomas Latta achieved some success with the i.v. administration of a solution of saline and sodium bicarbonate to moribund cholera victims in Sunderland. In another detailed letter to *The Lancet*, he provided a fascinating account of the clinical response to fluid therapy.[2] We can trace the history of fluid therapy as modern medicine itself has evolved. Hartmann used a modified Ringer's solution to rehydrate children suffering from gastroenteritis in the 1930s, and by World War II the benefits of i.v. fluid in the treatment of haemorrhagic shock were widely acknowledged.[3] Four million bottles of i.v. fluid solutions were purchased by the US Army during this period.[4] The improvement in outcome associated with the use of fluid therapy during surgery for combat casualties was subsequently reported during the Korean War.[5] Improvement in patient outcomes remains the

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driving factor in fluid therapy research, which continues to highlight the importance of choosing the optimal type and dose of fluid for each individual patient.

Relevant physiology

It is important to separate fluid therapy into fluid maintenance and fluid resuscitation (or volume replacement). This is helpful because there is comparatively little debate about maintenance fluid therapy. The daily requirements for water and electrolytes are well described[6] and easily delivered either enterally or intravenously. It is usually best to view replacement of fluid deficits after prolonged preoperative fasting as part of the maintenance fluid strategy, by calculating water and electrolyte needs based on body mass and the time since last intake. Most controversies around fluid therapy centre on the replacement of hypovolaemia or significant fluid losses (i.e. fluid resuscitation). Each doctor's approach to fluid resuscitation is heavily influenced by their beliefs about the pathophysiology of the acute disease states characterized by significant fluid loss and the pharmacokinetics and pharmacodynamics of the fluid agents used to replace this loss. The major causes of hypovolaemia are dehydration, haemorrhage, sepsis, and the systemic inflammatory response to other acute disease, such as trauma or pancreatitis. The pathophysiology of the main categories of hypovolaemia is summarized in Table 1. The immediate purpose of fluid resuscitation is quickly to replace circulating volume to restore organ perfusion. However, the heterogeneity of acute illness results in wide variation in the precise nature and volume of fluid lost, from whole blood in acute haemorrhage to almost pure water in some forms of gastroenteritis. Fluid resuscitation is further complicated by the presence or absence of continued fluid loss and the associated mechanism. In the event of dehydration, this may be simple to treat, whereas continued bleeding and the need for haemorrhage control may greatly complicate resuscitation for victims of trauma.

Concepts and misconceptions in the pathophysiology of hypovolaemia

Fluid compartments and the pharmacokinetics of i.v. fluid

The intravascular half-life of i.v. fluid is thought to vary depending on the pharmacokinetic and pharmacodynamic properties of the fluid. All fluids will redistribute throughout the body eventually, but longer intravascular half-lives may make effective fluid resuscitation easier. Dextrose solutions are thought to remain in the circulation for only a very short period because the small amount of sugar is rapidly metabolized, leaving free water to diffuse throughout the fluid compartments. Thus, although dextrose 5% and similar solutions may be suitable as part of a calculated maintenance fluid regimen, they are of limited value in fluid resuscitation, where maintaining the intravascular volume is important. The sodium, chloride, and other electrolyte content in isotonic fluids is believed to help retain water in the circulation, resulting in a volume expansion effect lasting between 20 and 100 min depending on the concentration and quantity of fluid.[7 8] In the case of colloid solutions, expansion effects of 2–5 h have been quoted.[7 9] However, it is important to understand that much of this teaching is based on theoretical principles or the effects of fluids on healthy volunteers.[10] The actions of i.v. fluids may differ widely between patients and disease states, or the differential effects of solutions may be much less than previously thought. It is essential to balance theoretical benefits of any given fluid against what we know about potential harm. Important examples include the risk of coagulopathy[11 12] and nephrotoxicity[13 14] associated with hydroxyethyl starch solutions, and the endocrine effects of total

Table 1 Summary of principal causes of hypovolaemia, current understanding of pathophysiology, and treatment

Cause of hypovolaemia	Examples	Pathophysiology	Mechanism of continued fluid loss	Common beliefs about fluid therapy
Dehydration	Vomiting Gastroenteritis Burns	Normal regulation mechanisms overwhelmed	Ongoing fluid loss outstrips homeostatic mechanisms	Replace with fluid that will rehydrate intra- and extravascular space. Electrolyte replacement is required
Haemorrhage	Trauma Major surgery	Breech of vasculature leading to obvious or concealed blood loss	Ongoing bleeding or failure in haemorrhage control	Replace with blood products at 1:1:1 ratio of packed red cells/fresh frozen plasma/platelets in massive haemorrhage
Sepsis	Pneumonia Body cavity infection	Infection resulting in a systemic inflammatory response	Abnormal vascular permeability, leading to fluid loss from circulation. Pathological vasodilation, causing relative hypovolaemia	Early goal-directed therapy is as effective as usual care; excessive fluid may be harmful
Systemic inflammatory response	All of the above	Inflammatory response to any of the major insults described above	Abnormal vascular permeability, leading to fluid loss from circulation. Pathological vasodilation, causing relative hypovolaemia	Early goal-directed therapy is as effective as usual care; excessive fluid may be harmful