Crystalloids, colloids, blood products, and blood substitutes

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Abstract

Understanding the physiology of fluid distribution in the human body is fundamental to good clinical practice in anaesthesia and intensive care. Intravenous fluid therapies have a range of clinical and metabolic consequences and they should be context and patient specific. Inadequate or excessive fluid treatment is harmful to patients. There are numerous trials, both historical and current, investigating best practice in fluid therapy. New paradigms and guidelines are being published, and it is important for clinicians to keep up to date with current practice. There is a continued drive to improve the safety of donor blood and prevent transfusion errors. Knowledge of how blood products are collected, separated and stored is essential to prevent harm to patients through transfusions. The development of blood substitutes is progressing, with NHS trials due to start soon.

Keywords Blood; blood substitutes; coagulation; colloid; crystalloid; goal-directed fluid therapy; plasma; platelets

Royal College of Anaesthetists CPD Matrix: 1A01, 1A02, 1E04, 2A05

Learning objectives

After reading this article, you should be able to:

- describe the physiology of the body's fluid compartments
- recognize the effects of the commonly used non-blood fluids
- list the advantages and disadvantages of non-blood fluid therapy
- explain the methodology of blood collection and storage
- summarize current and prospective methods utilized to reduce the risks of donor blood transfusion

Physiology

Total body water accounts for 60% of body weight; however this varies with age, adiposity and gender. For a healthy adult male weighing 70 kg, this amounts to 42 litres of water (Figure 1).

The intracellular compartment contains 28 litres and the extracellular compartment holds the remaining 14 litres. This extracellular compartment is further subdivided into the interstitial and transcellular spaces (comprising 9.5 litres and 1 litre, respectively), and the plasma (comprising 3.5 litres) (Figure 2).

Starling forces and the Gibbs–Donnan equation help determine water distribution by osmosis across the capillary bed's semi-permeable membrane. Starling forces explain the balance of oncotic and hydrostatic pressures in the capillary bed and Gibbs–Donnan describes the demand for electrical neutrality across a semi-permeable membrane.

We can describe fluids (or solutions) in terms of osmolality (osmoles of solute per kilogram of solvent [Osm/kg]), and tonicity (effective osmolality; equal to the sum of the concentrations of the solutes which have the capacity to exert an osmotic pressure gradient across the membrane). Fluids in relation to plasma are hypotonic (fewer solutes), isotonic (same amount of solutes) or hypertonic (greater amount of solutes). Traditional physiology indicated that a solution containing small, rapidly and easily metabolized molecules would quickly re-distribute as free water. Whereas one containing large, difficult to metabolize molecules will remain in the intravascular space for longer.

However, this long-held view has recently been challenged as the endothelial glycocalyx layer is becoming increasingly recognized as responsible for fluid movement across the capillary membrane. This is a complex luminal layer of glycoproteins and proteoglycans that lies between blood and the vessel wall. This membrane can become 'leaky' during insults such as sepsis, resulting in peripheral oedema. It provides a degree of mechanical protection (e.g. from shear stress), and houses vascular protective enzymes such as superoxide dismutase. The integrity of this layer is essential in maintaining fluid homoeostasis.[1]

Crystalloids

Crystalloids contain low-molecular-weight solutes dissolved in water. Conventionally we considered those with slowly metabolized molecules to remain in the circulation longer. The subsequent rise in oncotic pressure would draw water out of the intracellular space and into the intravascular space increasing the intravascular volume further. This would be sustained until the ions re-distribute into the intracellular space; a process dependent on the permeability of the cell membrane and activity of the ATPase pumps. The end result was believed to be a temporary expansion of the intravascular volume. However, ultimately a redistribution of free water into all compartments occurs and the respective volumes are reset to their original values. Small sugar solutions were considered to undergo this process rapidly, leaving behind free water to be re-distributed. This occurred as a result of the small molecular sugars being rapidly metabolized, and the solvent not being electronically bound to the solute (such as in electrolyte solutions). However this theory is likely to be modified in light of the identification of the endothelial glycocalyx layer.

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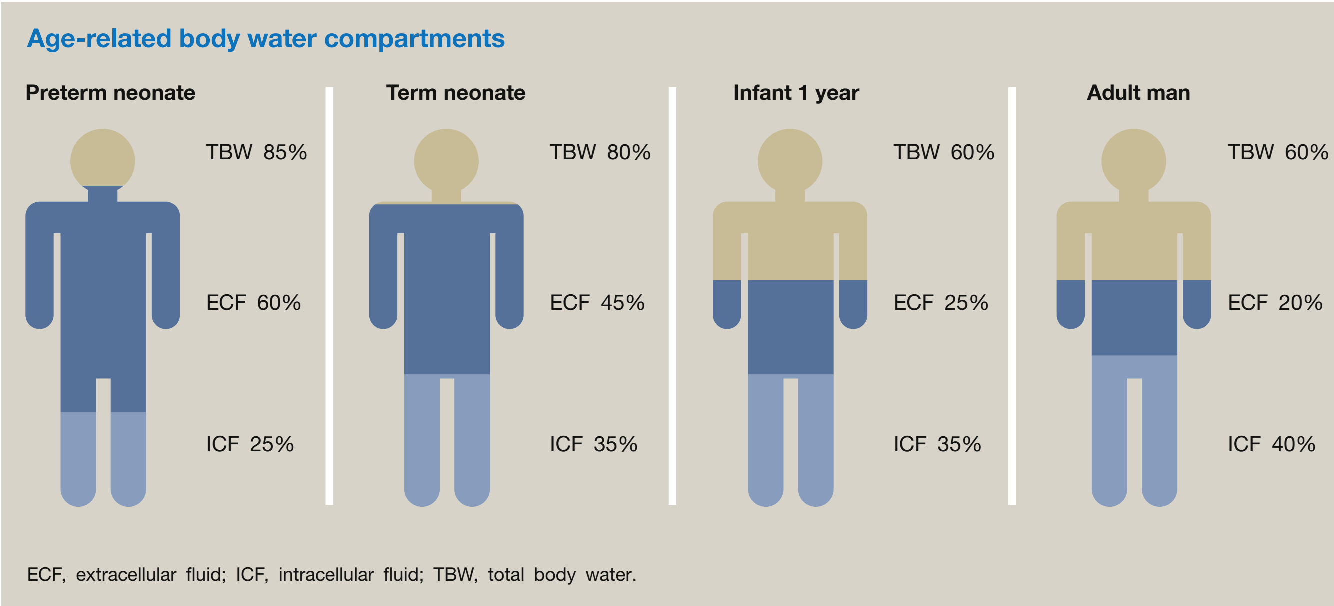

Figure 1

Salt solutions

Most salt solutions are isotonic and isosmotic and can further be divided into non-balanced and balanced solutions. There is also a recognized role for hypertonic solutions.

0.9% Sodium chloride solution: is an isotonic and isosmotic solution when compared to plasma. However the solution contains a far higher chloride concentration compared to that of plasma (Table 1), which has led to criticism of its use. The concern is that an infusion of large volumes will lead to a hyperchloraemic metabolic acidosis (HCMA). The British Consensus Guidelines on Intravenous Fluid Therapy for Adult Surgical Patients (GIFTASUP) recommends the use of balanced salt solutions over 0.9% sodium chloride when crystalloid resuscitation and replacement is indicated in surgical patients.[2] They quote the risk of HCMA as the reason for this with level 1b evidence.

The mechanism behind the resultant HCMA is best understood using Stewart's approach to acid–base balance.[3] This approach relies on the theory that electrical neutrality must always be maintained and therefore the addition of an anion needs to be balanced by the production of cations.

Stewart proposed that three independent variables influence plasma pH: carbon dioxide, strong ion difference (SID) and the sum total of weak acids (A_{TOT} – which is almost entirely due to albumin). Most infusions of intravenous fluid do not change

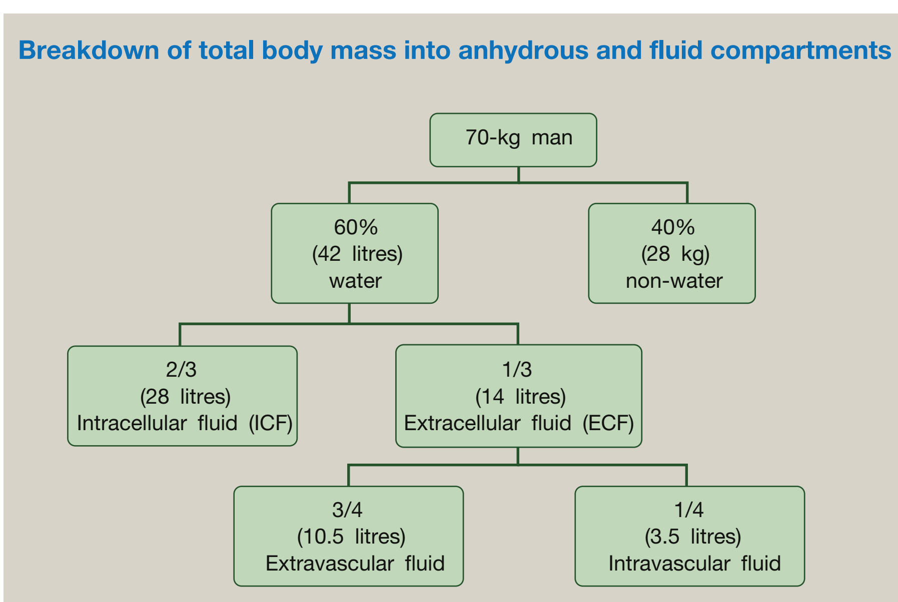

Figure 2

