Applied Physiology of Fluid Resuscitation in Critical Illness

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KEYWORDS

• Effective circulating blood volume • Mean systemic pressure • Venous return
• Stressed volume • Unstressed volume

KEY POINTS

- Venous return defines cardiac output.
- Fluid resuscitation aims to increase mean systemic pressure.
- Both fluids and vasopressors can increase mean systemic pressure and cardiac output.
- Crystalloids distribute across the body, whereas colloids tend to remain intravascular longer.

Introduction:

- Not all causes of hypotension benefit from the administration of IVF
- The "best" type of fluid used for resuscitation is controversial
- Fluid therapy should be goal directed and individually tailored to each patient's needs

Summary:

- Goal of fluid therapy is to increase the MAP and improve venous return
- Increasing MAP is only beneficial if MAP>right atrial (RA) pressure
    - If RA pressure rises, venous return decreases
- MAP only starts to increase when blood volume> unstressed vascular volume
    - Unstressed vascular volume: volume contained by vessels WITHOUT causing vessel stretch (approx. 60-70% blood volume)
        - MAP=0
        - Varies based on vascular tone and distribution towards/away from high capacitance vessels
    - Stressed vascular volume: Volume in excess of unstressed vascular volume that contributes to vessel stretch (approximately 30-40% blood volume)
    - Vascular compliance= MAP/(stressed vascular volume- unstressed vascular volume)
- Types of shock
    - Cardiogenic shock
        - Causes:
            - Heart failure of any etiology (myocardial, valve disease,
        - Pathophys
            - SBP <90mmHg and hypoperfusion caused by arterial hypotension, increased cardiac filling pressure, increase venous pressure. Often causes pulmonary edema
        - Treatment/role of fluids:
            - Inotropic agents

        - Trade off of improved perfusion with increased ATP demand
    - Conservative fluid therapy to improve coronary perfusion
    - Avoid vasopressors- associated with poor outcome
- Obstructive Shock
  - Causes
    - PCE tamponade, pneumothorax, massive PTE
  - Pathophys
    - Impaired ventricular filling or ejection causing decreased CO
  - Treatment/Role of fluids:
    - Fluid therapy often contraindicated in massive PTE as it causes further dilation of RV
- Hemorrhagic (hypovolemic) Shock
  - Causes:
    - Traumatic injury
  - Pathophys
    - Loss of blood volume and/or trauma induced coagulopathy (10-34% of patients)
  - Treatment/Role of fluids:
    - Fluids indicated to restore volume
    - Crystalloids may cause interstitial edema, abdominal compartment syndrome
    - Blood products especially if rapid hemorrhagic losses- Consider 1:1 plasma: blood
- Distributive Shock
  - Causes
    - Sepsis, trauma, perioperative state
  - Pathophys
    - Vasoplegia, impaired bloodflow distribution causing increased unstressed vascular volume
  - Treatment/Role of Fluids
    - Aggressive fluid resuscitation if early

- Fluids
  - Balance between intracellular and extracellular (intravascular and interstitial)
    - Balance between oncotic and hydrostatic pressures. The glycocalyx has also become more known/important recently
  - Crystalloids:

- Tend to distribute into the intracellular spaces more than colloids

Table 1
Examples of commercially available crystalloid and colloid solutions

		Colloids				Crystalloids		
Solute	Plasma	4% Albumin	6% HES 130/0.4	Dextran	Gelatin	Normal Saline	Ringer Lactate	Plas
Sodium (Na^+)	135–145	148	154	154	154	154	130	140
Potassium (K^+)	4.0–5.0	0	0	0	0	0	4.5	5
Calcium (Ca^{+2})	2.2–2.6	0	0	0	0	0	2.7	0
Magnesium (Mg^{+2})	1.0–2.0	0	0	0	0	0	0	1.5
Chlorine $(Cl)^-$	95–110	128	154	154	120	154	109	98
Acetate	0	0	0	0	0	0	0	27
Lactate	0.8–1.8	0	0	0	0	0	28	0
Gluconate	0	0	0	0	0	0	0	23
Bicarb	23–26	0	0	0	0	0	0	0
Osmolarity	291	250	286–308	308	274	308	280	294
Colloid	35–45	20	60	100	40	0	0	0

Osmolarity (mOsm/L); Colloid (g/L); all other solutes (mmol/L).

- Studies have demonstrated improved outcomes when using balanced fluids (p-lyte, LRS) vs normal (0.9%) saline
    - 0.9% saline has supraphysiologic concentrations of Na and Cl and is acidifying
- Aggressive resuscitation can lead to extravasation into the interstitial space- especially in cases of vasoplegia/glycocalyx damage
    - Study of crystalloids vs albumin showed improved outcomes with albumin in septic shock

- Colloids
    - Tend to stay intravascular due to high molecular weight compounds that increase oncotic pressures.
    - In America, Albumin is the most commonly used colloid followed by hydroxylethyl starch (HES)
        - HES use banned in the UK due to association with AKI in septic patients
    - Studies
        - Saline vs Albumin Fluid Evaluation (SAFE) trial: compared 4% albumin with 0.9% saline
            - No difference in 28 day all-cause mortality
            - Relative risk of death increased when albumin used in TBI
            - Improved outcomes when albumin used in sepsis/septic shock
        - ALBOIS Study: compared albumin with normal saline
            - Septic shock patients were the only group that had better outcomes with albumin
        - Crystalloid vs Hydroxyethyl Starch Trial (CHEST): compared 6% HES to 0.9% saline
            - No difference in 90 day all-cause mortality
            - HES group had double the amount of adverse events (skin rash, pruritus, AKI)