Crystalloids for Shock Resuscitation

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1935-1949

Half of what we have taught you is wrong.
Unfortunately, we don’t know which half!

Evidence-based medicine
Crystalloids for shock resuscitation

- Physiology of body fluid

- Crystalloids
  - Types and basic components
  - Clinical studies
Fluid for shock resuscitation

- Hypovolemic
- Distributive
- Cardiogenic
- Obstructive
Transcapillary filtration

Starling’s equation

\[ J_v = K \left[ (P_c - P_i) - \sigma (\Pi_c - \Pi_i) \right] \]

- \( P \): hydrostatic pressure
- \( \Pi \): osmotic pressure
- \( c \): capillary / intravascular
- \( i \): interstitium
Transcapillary filtration

- **Hydrostatic pressure** ($P$)
  - Water moves from high $P$ to low $P$

- **Osmotic pressure** ($\Pi$)
  - $\Pi = 19.3 \times \text{osmolality}$
  - Plasma osmolality = $2(\text{Na}) + \underline{\text{glucose}} + \underline{\text{BUN}}$
    
    
    \[
    \begin{array}{c}
    18 \\
    2.8
    \end{array}
    \]
  - Water moves from low $\Pi$ to high $\Pi$
Crystalloids for shock resuscitation

- Physiology of body fluid

- Crystalloids
  - Types and basic components
  - Clinical studies
Crystalloids

- Fluid comprise of water and electrolytes
- Highly permeable from intravascular into interstitium
- $\leq 25\%$ remains intravascularly
- Higher volume must be required to replace blood loss
Crystalloids

- High volume resuscitation may cause
  - Increase intravascular hydrostatic pressure
  - Decrease intravascular osmotic pressure
Crystalloids

• Disadvantages
  – Fluid leakage
    • Tissue edema
  – Short intravascular duration
    • More volume is required
  – Dilutional coagulopathy
    • Trauma patients, bleeding
Crystalloids

• Advantages
  – Save, cost-effectiveness
  – Almost always available
  – Low risk of complications

• Allergic reactions
• Renal toxicity
Crystalloids in septic shock


Crystalloids in septic shock


Table 6 Recommendations: hemodynamic support and adjunctive therapy

G. Fluid therapy of severe sepsis
1. Crystalloids as the initial fluid of choice in the resuscitation of severe sepsis and septic shock (grade 1B).
2. Against the use of hydroxyethyl starches for fluid resuscitation of severe sepsis and septic shock (grade 1B).
3. Albumin in the fluid resuscitation of severe sepsis and septic shock when patients require substantial amounts of crystalloids (grade 2C).

C. Fluid resuscitation
1. In the industrialized world with access to inotropes and mechanical ventilation, initial resuscitation of hypovolemic shock begins with infusion of isotonic crystalloids or albumin with boluses of up to 20 mL/kg crystalloids (or albumin equivalent) over 5–10 minutes, titrated to reversing hypotension, increasing urine output, and attaining normal capillary refill, peripheral pulses, and level of consciousness without inducing hepatomegaly or rales. If hepatomegaly or rales exist then inotropic support should be implemented, not fluid resuscitation. In non-hypotensive children with severe hemolytic anemia (severe malaria or sickle cell crises) blood transfusion is considered superior to crystalloid or albumin bolusing (grade 2C).
Crystalloids in trauma

- **Advanced trauma life support**
  - Initial resuscitation with 1-2 L of crystalloids

- **Resuscitation with at least 1 L of crystalloid per unit of PRC**
  - Associated with improved mortality

Crystalloids in trauma

• Crystalloid resuscitation $\geq 1.5$ L
  – Associated with increased mortality

• Crystalloid resuscitation up to 1 L
  – Not associated with increased mortality

Ley EJ. J Trauma 2011;70:398-400.
Crystalloids

- **Isotonic solution**
  - NSS, LRS, ARS

- **Hypertonic solution**
  - NaCl 3%, 5%, 7.5%

- **Hypotonic solution**
  - Dextrose in water: 5%, 10% D/W
  - 5% D/N/2, 5% D/N/3
Crystalloids

<table>
<thead>
<tr>
<th>Fluids</th>
<th>Na (mEq/L)</th>
<th>K (mEq/L)</th>
<th>Cl (mEq/L)</th>
<th>Lactate/(\text{HCO}_3) (mEq/L)</th>
<th>Ca (mmol/L)</th>
<th>Osm (mOsm/L)</th>
<th>pH</th>
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<tr>
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<td>28</td>
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<td></td>
<td>154</td>
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<tr>
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<td>513</td>
<td></td>
<td>1026</td>
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</tbody>
</table>
Normal saline solution

- Isotonic solution
- One of the most common crystalloid for fluid resuscitation
- Slightly hypernatremic than plasma
  - 154 vs 142
  - Preferred in brain injury or hyponatremia
Normal saline solution

- Markedly hyperchloremic than plasma
  - 154 vs 103
  - **Large** volume resuscitation may cause hyperchloremic **metabolic acidosis**
- 35 ml/kg in healthy patient
- Caution in trauma, operative patients
Lactated Ringer’s solution

- Balanced salt solution
- Slightly hyponatremic than plasma
- Provide Cl, K, Ca, HCO$_3^-$
- HCO$_3^-$ derived from lactate metabolites
  - Acetated Ringer’s solution in liver diseases
- Lower risk of hyperchloremic metabolic acidosis, compared to NSS
NSS vs LRS

- Infants with diarrhea, severe dehydration
  - Initial resuscitation with NSS or polyelectrolytes fluid
  - Mean fluid volume 90-92 ml/kg in 2.4 hours
  - Successful shock recovery in both groups
  - NSS group had more incidence of metabolic acidosis

NSS vs LRS

• Hemorrhagic hypovolemic shock
  – NSS resuscitation associated with
    • Significant higher volume required
    • Significant higher incidence of
    – Hyperchloremia, metabolic acidosis
    • Significant lower fibrinogen level
    – Dilutional coagulopathy

Hypertonic saline solution (HSS)

- Hypertonic than plasma
- Increase intravascular osmotic pressure
- Plasma volume expander
  - 4 fold of infused HSS
Hypertonic saline solution (HSS)

- Considered in
  - Refractory hypovolemic shock
  - High risk of tissue edema
    - Intracranial hypertension
    - Brain edema
    - Prolonged GI surgery
    - Burn
Hypertonic saline solution (HSS)

- Short plasma half-life
- Plasma expansion lasts quite short
- Combined with colloids
  - Albumin, HES, dextran
  - RR death 0.5, 0.25 and 0.91 (p > 0.05)

HSS: Effects on preload and C.O.

Increase preload
(Plasma volume expander)
HSS: Effects on contractility

Increase myocardial contractility
• Hyperosmolar effect
• Decrease myocardial edema
• Restore transmembrane potential
HSS: Effects on afterload

- Improve microcirculation
- Reduce tissue edema
- Reduce endothelial cell edema
- Widening of capillary lumen
Crystalloids: conclusion

- Cost-effectiveness, available, safe
- Leakage can cause tissue edema
- Initial fluid in hypovolemic & septic shock
  - Appropriate volume is the key to success
- NSS: hyperchloremic acidosis, coagulopathy
- LRS: less side effects than NSS
- HSS: volume expander, cardiac function, microcirculation, immunomodulation, edema