Types of Intravenous Fluids

Intravenous fluids are most commonly administered in acute and severe hypovolemic conditions. In the therapeutics, two classes of i.v. fluids are most commonly utilized: crystalloids and colloids; both have their own advantages and disadvantages. The effect of various clinical conditions on the volume of ICF and ECG can be best studied by Darrow-Yannet diagrams.

Definitions of Intravenous Fluids

Osmosis

The spontaneous movement of water across a semipermeable membrane, from a region of low solute concentration to a region of high solute concentration, tends to equalize the solute concentrations on either side of the membrane.

Osmotic pressure

The hydrostatic pressure is necessary to counteract the process of osmosis.
Osmolality
The osmolar concentration of a solution, called osmolality, is expressed as osmoles/Kg of water.

Osmolarity
The osmolar concentration of a solution, called osmolarity, is expressed as osmoles/L of water. About 80% of the total osmolarity of the interstitial fluid and plasma is due to sodium and chloride ions. Half of the intracellular fluid’s total osmolarity is due to potassium ions, and the remainder is due to other intracellular substances.

Osmotic gradient
This term refers to the difference in the osmolarity of two solutions on either side of a semipermeable membrane.

Distribution of Fluids Within the Body
The human body is comprised of approximately 60% water; out of which 2/3\textsuperscript{rd} of total body water (TBW) is present inside the cells, i.e., the intracellular fluid compartment (ICF). The remaining 1/3\textsuperscript{rd} of TBW is present outside the cells, i.e., extracellular compartment (ECF).

The ECF is further sub-divided into plasma, which comprises ¼\textsuperscript{th} of ECF or 1/12\textsuperscript{th} of TBW, and interstitial fluid, which comprises about 3/4 of ECF or 3/12 of TBW.

\[ TBW = ICF \ (2/3^{th}) + ECF \ (1/3^{th}) \]
\[ ECF = Plasma \ (1/4^{th}) + Interstitial \ Fluid \ (3/4^{th}) \]

The interstitial fluid is comprised of electrolytes, amino acids, glucose, hormones, and various other products of metabolism. It is essential for the cells’ membrane potential as well as for moving substances back and forth between cells and blood vessels.

Intracellular fluid and interstitial fluid are separated by a relatively impermeable cell membrane, which allows water, but no other substances, to move across the membrane spontaneously. The interstitial space and plasma are separated by a capillary membrane, which is relatively permeable, allowing the molecules to easily move across the membrane.

An exception to this is albumin, an intravascular protein that does not move easily along the capillary membrane. It exerts osmotic pressure to keep the fluid within the blood vessels, protecting it from being drawn into the interstitial space. If this would happen, it would result in low blood pressure and extravascular fluid accumulation, which is edema if it is localized, and anasarca if it is systemic throughout the body. The osmotic pressure exerted by proteins, such as albumin, is called oncotic pressure.

**Tonicity:** This refers to the measure of the effective osmotic gradient between two fluids separated by a semipermeable membrane. It is influenced only by the solutes, which cannot cross the membrane.

**Based on the tonicity, fluids are divided into three types:**
Hypertonic solution

A hypertonic solution has a **higher concentration of solutes** outside the cell than inside the cell. When a cell is immersed into a hypertonic solution, the water tends to flow out of the cell to balance the concentration of the solutes, causing the cell to **shrink in size**.

![Solute molecules](Image: "A red blood cell in a hypertonic solution, causing water to move out of the cell." by BruceBlaus. License: CC-BY 3.0)

Hypotonic solution

A hypotonic solution has a lower concentration of solutes outside the cell than inside the cell. When a cell is immersed into a hypotonic solution, water will rush into the cell in an attempt to balance the concentrations of solutes inside and outside the cell. This action will cause the cell to expand in size and **burst**.

![Water molecules](Image: "A red blood cell in a hypotonic solution, causing water to move out of the cell." by BruceBlaus. License: CC-BY 3.0)
Hypotonic Solution
(Osmotic Flow into Cell)

Isotonic
An isotonic solution has an effective osmolar concentration. Its solute concentration is not the same as the one inside the cell. In this case, the cell neither swells nor shrinks because there is no concentration gradient for water across the cell membrane.

The osmolarity of **water is zero**; an infusion of water causes an immediate decrease in plasma osmolarity, making the blood hypotonic relative to the RBC interior. There will be a flow of water into the RBC until the concentration gradient is the same. This results in the swelling of the RBC and eventual lysis.

The osmolality, intracellular volume, and extracellular volume are represented by the Darrow-Yannet diagram (this will be discussed in a later section).

**Types of IV Fluids**

**Crystalloids**

Crystalloids contain organic or inorganic salts dissolved in sterile water. The most commonly used solutes in crystalloids are glucose and sodium chloride. Crystalloids are electrolyte solutions that have a relatively low tendency to cross plasma membranes.

- The most commonly used crystalloids are **normal saline (NS)** and lactated Ringer’s (LR). Normal saline contain 0.9 % sodium chloride and lactated Ringer’s contain sodium chloride (6 g/L), sodium lactate (3.1 g/L), potassium chloride (0.3 g/L) and calcium chloride (0.2 g/L).
- **Half-normal saline** (1/2 NS) has half the concentration of NaCl i.e. 0.45 % NaCl.
- **D5W** composed of 5 % dextrose in water. D5W is isotonic to the serum. It contains glucose, which is instantaneously metabolized when D5W enters the circulation.

**Properties of crystalloids**

- They do not readily cross plasma membranes but do readily cross capillaries.
They remain in ECF. They are distributed evenly within the ECF, readily diffusing across capillary walls to equilibrate between intravascular (plasma, ECV) and interstitial volume. They are indicated in the loss of plasma (hypovolemia) that can occur in postoperative patients. It is also caused by trauma and burns. Crystalloids, compared to colloids, have low plasma expansion efficacy. Colloids are rapid plasma expanders. Both crystalloids and colloids have the same efficacy. Many studies reported an equal survival rate among patients treated for fluid resuscitation, whether with colloids or crystalloids. Examples of crystalloids are normal saline, ½ normal saline, D5W, and ringer lactate. Crystalloids are the fluid of choice because they are less expensive than colloids.

Table: Composition of common crystalloid solutions

<table>
<thead>
<tr>
<th>Fluid</th>
<th>Na⁺ meq/l</th>
<th>Cl⁻ meq/l</th>
<th>K⁺ meq/l</th>
<th>Ca²⁺ meq/l</th>
<th>Glucose g/l</th>
<th>Buffer meq/l</th>
<th>Osmolarity Mosm/l</th>
<th>Tonicity</th>
<th>Indication</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal Plasma</td>
<td>140</td>
<td>100</td>
<td>4</td>
<td>2.4</td>
<td>0.85</td>
<td>HCO₃ 24</td>
<td>290</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>0.9% saline</td>
<td>154</td>
<td>154</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>308</td>
<td>Isotonic</td>
<td>Resuscitation</td>
</tr>
<tr>
<td>0.45% saline</td>
<td>77</td>
<td>77</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>154</td>
<td>Hypotonic</td>
<td>Maintenance</td>
</tr>
<tr>
<td>Ringer lactate (Hartmann’s solution)</td>
<td>130</td>
<td>109</td>
<td>4</td>
<td>3</td>
<td>0</td>
<td>Lactate 28</td>
<td>273</td>
<td>Isotonic</td>
<td>Resuscitation</td>
</tr>
<tr>
<td>DSW</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>50</td>
<td>0</td>
<td>252</td>
<td>Hypotonic</td>
<td>Hypernatremia Hyperglycemia</td>
</tr>
</tbody>
</table>

Crystalloids, when administered in large volumes, can cause tissue edema (gastrointestinal). Infusion of large volumes of normal saline, even after correction of intravascular volume, can lead to a normal anion gap metabolic acidosis.

Ringer lactate is contraindicated in patients with:
- Hyperkalemia: due to presence of K⁺
- Concurrent blood transfusion: due to Ca binding with citrate in blood products.
- Drugs such as amphotericin, ampicillin, and thiopental (can bind with these drugs)

D5W can cause pediatric death due to hyponatremia, caused by the excess administration of dextrose solution.

Colloids

These are the electrolyte solutions, which have a relatively high tendency to stay intravascular. They contain large proteins that generally do not cross capillary walls.

Colloids are used as plasma expanders and are indicated in conditions such as burns, hypovolemic shock, trauma, and tissue damage. Colloids do not have the oxygen-carrying capacity.

Examples of colloids
Natural: Albumin, fresh frozen plasma
Synthetic: Dextran, hydroxyl ethyl starch (HES), gelatin.

Properties of colloids

- Colloids are expensive; however, they exhibit fast plasma expansion. They also have a longer action duration.
- Volume expansion due to colloid is determined by its molecular weight and concentration.
- Colloids are typically used for resuscitation in severe hypovolemia. Major side effects of synthetic colloids include allergic reactions (anaphylaxis), coagulation abnormalities, and renal failure.
- The most commonly used colloids are HES and gelatin. HES is a natural polysaccharide and the least allergenic among the colloids.
- The recommendation to use colloids was restricted in October 2013 due to studies that showed an increase in renal failure and a decrease in the overall survival rate. However, in September 2014, methodical flaws and contradictions in those studies could be shown. The use of colloids and their side effects is still the subject of research and, if possible, treatment with crystalloids is preferable until further studies provide clarification.
- Colloids interfere with the coagulation factor VII, causing coagulation abnormalities.
- Gelatins are obtained from degraded animal collagen. Gelatin shows a short duration of action.
- Albumin and dextran (use is abandoned due to adverse effects) are rarely used. Dextran is a linear polysaccharide. It is available as dextran-40 (molecular weight 40.000) and dextran-70 (molecular weight 70.000).

Distribution of IVFs

1. Infusion of 1 L of normal saline (NS)
   - The entire liter will remain in ECF
   - Will distribute within ECF, equilibrating between intravascular and interstitial spaces:
     - 250cc (1/4) will remain in intravascular space (plasma)
     - 750cc (3/4) will enter interstitial space

2. 1 L of ½ NS: Equivalent to 500cc of free water + 500cc of NS
   - 500cc free water will distribute within TBW: Equilibrating between ECF and ICF, 167cc (1/3) will remain in ECF, and 333cc (2/3) will enter ICF
   - 500cc equivalent to NS: will distribute within ECF; 667cc total will remain within ECF and will equilibrate between intravascular and interstitial volumes, while 167cc (1/4) will remain in intravascular space, and 500cc (3/4) will enter the interstitial space.

3. 1 L of D5W: Equivalent to 1 L of pure water
   Will completely equilibrate between ECF and ICF, 333cc (1/3) will remain in ECF, and
667cc (2/3) will enter ICF. 333cc in ECF will equilibrate between intravascular and interstitial volumes, 83cc (1/4) will remain in intravascular space, and 250cc (3/4) will enter interstitial space.

**Darrow-Yannet Diagrams**

- A **Darrow-Yannet diagram** is used to study the effects of various clinical conditions, such as dehydration, shock, vomiting, and diarrhea on osmolality and volume of extracellular and intracellular fluid.
- Osmolality (on the Y-axis) is represented by mOsm/kg H₂O, while volume (on the X-axis) is represented in liters.
- In a Darrow-Yannet diagram, a solid line signifies normal values and the dashed lines signify a change in volume and osmolality (concentration of solutes in ICF and ECF).

**Changes in fluid compartments in various clinical scenarios**

- In acute fluid loss conditions like hemorrhage, diarrhea, and vomiting, there is a decrease in ECF Volume and no change in body osmolality and ICF Volume. The Darrow-Yannet diagram for such conditions is depicted here:

- In the loss of hypotonic fluid in conditions like dehydration, diabetes insipidus, and alcoholism, there is a decrease in ECF volume and ICF volume, but an increase in body osmolality. The Darrow-Yannet for such conditions is depicted here:
In conditions with a gain of isotonic saline, there is an increase in ECF volume, but no change in osmolality and ICF volume. The Darrow-Yannet diagram for such conditions is depicted here:

In conditions with a gain of hypotonic fluid as in infusion of hypotonic saline or water intoxication, there is an increase in ECF and ICF volume, but a decrease in body osmolality. The Darrow-Yannet diagram for such conditions is depicted here:

In conditions with a gain of hypertonic saline as in infusion of hypertonic saline or hypertonic mannitol, there is an increase in ECF volume and body osmolality, but a decrease in ICF volume. The Darrow-Yannet diagram for such conditions is depicted here:
## IVFs Summary

<table>
<thead>
<tr>
<th>Component</th>
<th>Clinical effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Packed RBCs</td>
<td>Increase Hb and O₂, carrying capacity in conditions such as acute blood loss and severe anemia</td>
</tr>
<tr>
<td>Platelets</td>
<td>Stop significant bleeding in quantitative and qualitative platelet dysfunction conditions</td>
</tr>
<tr>
<td>Fresh Frozen Plasma (FFP)</td>
<td>Increase levels of coagulation factors in coagulation consuming conditions such as DIC and cirrhosis. It is also used to manage immediate warfarin reversal</td>
</tr>
<tr>
<td>Cryoprecipitate</td>
<td>Contains fibrinogen, fibronectin, factor VIII, vWF, and factor XIII used to treat factor VIII dysfunction diseases, including hemophilia A, and vWD</td>
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</tbody>
</table>

**Blood transfusion risks include transfusion reactions (TACO, TRALI), hemochromatosis, citrate chelation of Ca²⁺, hyperkalemia from lysing of RBCs from old blood units**

## References


