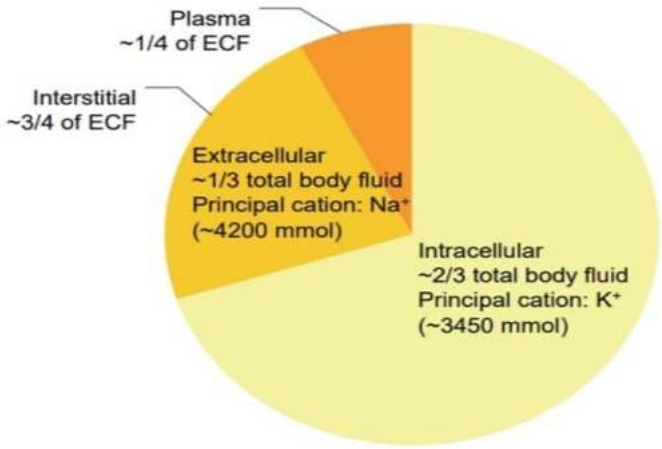
Fluid management in ICU

Fluid compartment & distribution

Fluid compartment of total body weight :

- Neonate: 75-80%
- Infant: 70-75%
- Adult male: 55-60%
- Adult female 50-55%
- Elderly 45-50%



Introduction

Intravenous fluid administration should be considered as any other pharmacological

Prescription.

There are three main indications :

- Resuscitation
- Replacement
- Maintenance

For maximizing benefits and minimizing harms intravenous fluid administration should follow the four Ds :

- Drug — consider the indication for the fluid and what effect is being sought.
- Duration of therapy — consider when to start and when to stop therapy.
- Dosing — consider how much fluid to give.
- De-escalation — consider when the fluid therapy is no longer effective or required.

Osmolarity and Tonicity of a solution

The osmolarity of a solution is equal to the number of osmoles per liter of solution.

Tonicity, a term that is often used interchangeably with osmolarity, refers to the effect a solution has on cell volume.

- An isotonic solution has no effect on cell volume.
- Hypotonic solutions increase cell volume.
- Hypertonic solutions decrease cell volume.

Tonicity describes the effective osmolality of a fluid.

Fluids classification

I.V fluids are classified as Crystalloids or Colloids based on their ability to diffuse through barriers separating body fluid compartments, i.e intravascular and extravascular (interstitial) fluid compartments.

Crystalloids passed readily through the membrane, whereas colloids did not (Greek word-glue).

Crystalloids and Colloids

A Crystalloid solution is an agueous solution composed of water and small solutes such as electrolytes and glucose. Crystalloid solutions can be further categorized as hypotonic, isotonic, or hypertonic.

A Colloid solution contains large molecular weight particles such as proteins or hydroxyethyl starches (HES) suspended in a crystalloid solution.

The intravascular half-life of a crystalloid solution is 20-30 min, most colloid solutions have intravascular half-lives between 3 and 6 h.

Crystalloids

Crystalloids when given in sufficient amounts:

1) Are just as effective as colloids in restoring intravascular volume.
2) Replacing an intravascular volume deficit with three to four times the volume needed when using colloid.
3) Severe intravascular fluid deficits can be more rapidly corrected using colloid solutions.
4) The rapid administration of large amounts of crystalloids (>4-5L) is more frequently associated with tissue edema.
5) Some evidence suggests that marked tissue edema can impair oxygen transport, tissue healing and return of bowel function following major surgery.

Comparsion of Plasma and Crystalloid Resuscitation Fluids
Infusion of common fluids

Fluid	mEq/L							Osmolality
	Na^+	Cl^-	K^+	Ca^{++}	Mg^{++}	Buffers	pH	(mOsm/L)
Plasma	140	103	4	5	2	Bicarbonate (25)	7.4	290
0.9% NaCl	154	154	-	-	-	-	5.7	308
Lactated Ringer's	130	109	4	3	-	Lactate (28)	6.4	273
Normosol Plasma-Lyte Isolyte[a]	140	98	5	-	3	Acetate (27) Gluconate (23)	7.4	295

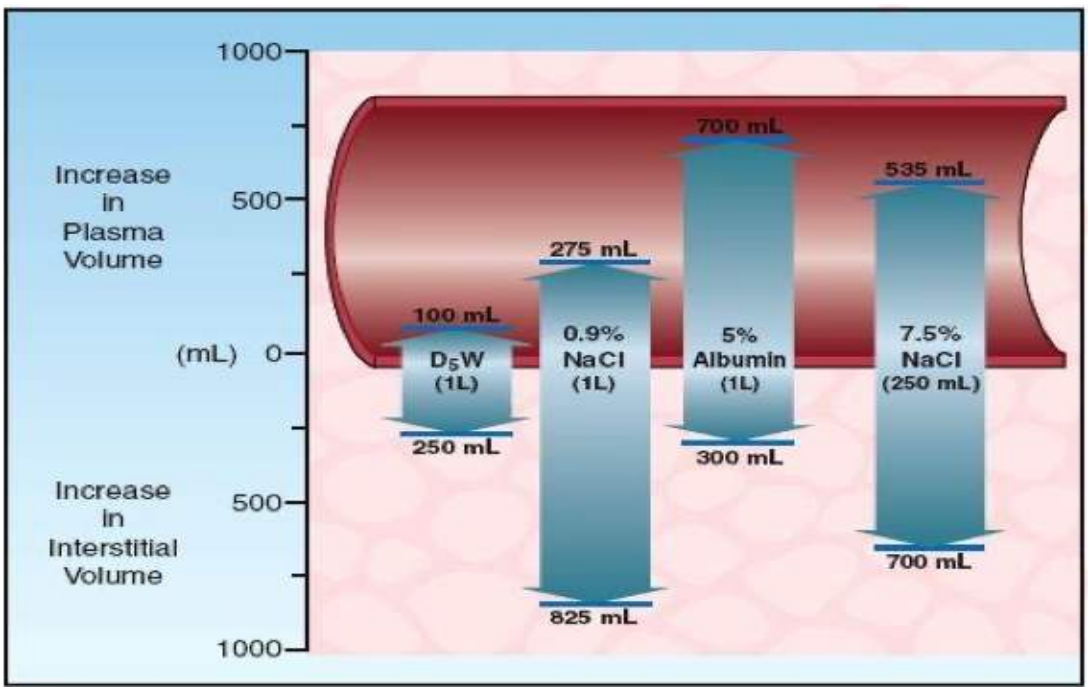
Infusion of Common Fluids

Infusion of 1 L of 0.9% NACL adds 275 mL to the plasma volume and 825 mL to the interstitial volume.

Note: the total volume expansion (1100 mL) slightly greater than the infused volume.

This is the result of a fluid shift from the ICF to extracellular space, because isotonic saline is slightly hypertonic to the Plasma

Volume Effects



1. 0.9% Sodium Chloride (Normal Saline)

Indications for the use of normal saline infusion that have been approved by the FDA:

- Extracellular fluid replacement (e.g.,, dehydration, hypovolemia, hemorrhage, sepsis).
- Treatment of metabolic alkalosis in the presence of fluid loss.
- Mild sodium depletion.

Additionally: diluents for the infusion of compatible drug additives.

Other indications

- Used also in traumatic brain injury or any brain edema.
- Replacement fluid in hyperkalemia.
- It is the preferred solution for diluting packed red blood cells prior to transfusion.
- It is used in DKA when there is severe hypovolemia and when serum sodium less than 140meq/L.7

2. Hypertonic saline

Hypertonic 3% saline is employed in therapy of severe symptomatic hyponatremia. Hypertonic 3%, 7.5% or 23.4% saline can be used in case of severe brain edema.

3. 0.45% Sodium Chloride

A hypotonic concentration of sodium chloride. Hypotonic concentrations of sodium chloride (0.45%) are best for parenteral maintenance fluids rather than aggressive intravascular volume repletion.

4. Lactated Ringer's

Ringer's solution: introduced in 1880 by Sydney Ringer (UK) who studied mechanisms of cardiac contraction. The solution was designed to promote the contraction of isolated frog hearts, and contained Ca+ and K+ in a sodium chloride diluent.

In the 1930s Alexis Hartmann (American pediatrician) proposed the addition of sodium lactate buffer to Ringer's solution for the treatment of

metabolic acidosis. The lactated Ringer's solution is also known as Hartmann's solution.

Lactated Ringer's uses

- Have sodium, potassium and chloride contents similar to extracellular fluid have fewer adverse effects on acid-base balance (in case of hyperchloremic metabolic acidosis).
- It is used as a replacement fluid in burn patients when BSA >20% (Parkland formula).

Lactated Ringer's disadvantages

- The calcium in lactated Ringers can bind to certain drugs and reduce their bioavailability and efficacy e.g. Amphoterecin, Ampicillin, Thiopentone etc.
- Calcium binding to the citrated anticoagulant in blood products can inactivate the anticoagulant and promote the formation of clots in donor blood.
- For this reason, lactated Ringer's solution is contraindicated as a diluent for blood transfusions.

5. Dextrose solutions

D5% is used to prevent protein breakdown in an NPO patients after consumption of endogenous glycogen (24-48hr).

- D5% (D5W) is used for replacement of pure water deficits and as a maintenance fluid for patients with hypernatremia.
- D10%, D20% or D50% are used in hypoglycemia.
- D20%, D25% or D50% are used in TPN (The use of 5% dextrose solutions to provide calories is obsolete).

When glucose gets utilized, only water remains,

Distribution:

- <10% remains in Intra vascular space
- <30% in Interstitium
- >50% in Intra cellular space. This cause Cellular swelling
- 5% dextrose-in-water solution is not an effective volume expander.

Dextrose solutions disadvantages

Lactate Production: The proportion of a glucose load that contributes to lactate formation

- 5% in healthy subjects
- 85% in critically ill patients

Thus, in patients with circulatory compromise, abnormal glucose metabolism can transform glucose from a source of useful energy to a source of toxin production.

Disadvantages of Glucose infusions

- Enhanced CO2 production (which can be a burden in ventilator-dependent or COPD patients).
- Hyperglycemia.
- Increased risk of infection, Neuropathy.
- Aggravation of ischemic brain injury.
- Increased mortality in septic shock.

Colloids

Do not pass across diffusional barriers as readily as crystalloids.

- Natural (plasma-derived) colloids:
  - Human albumin.
- Synthetic colloids:
  - Dextran (e.g. dextran 40 and dextran 70).
  - Gelatin (e.g. gelofusine and hemaccel).
  - Starch (e.g.hydroxyethyl starch (HES)).

1. Albumin Solution

Responsible for 75% of the oncotic pressure of plasma. Acts as buffer, antioxidant and transport protein. Commercially is available as 5% solution or 20% solution in an isotonic saline diluent. 5% solution has colloid oncotic pressure (COP) 20 mm Hg (similar in oncotic activity to plasma).

Approximately half of the infused volume of 5% albumin stays in the vascular space. The oncotic effects of albumin last 12-16 hours12

2. Albumin Solution 20%

- COP of 70 mm Hg
- Expands the plasma volume by 4 to 5 times the volume infused.
- Infusion of 100 mL of 20% albumin can increase the plasma volume 400 to 500 mL.
- It is intended for shifting fluid from the interstitial space to the vascular space in hypoproteinemia conditions.
- Should not be used for volume resuscitation in hypovolemia.

3. Gelatins

- COP 27-34 mmHg
- The cheapest colloid available.
- Unlimited volume for resuscitation.
- Unimpaired renal function and hemostasis.
- Rapidly excreted by the kidneys (shorter duration 3-4 hr).
- Anaphylactoid reactions: direct histamine release.
- Gelofusine is compatible with blood but hemaccel contains ca+2.
- Hemaccel and gelofusine have the same concentration of sodium (154 meq/L) but gelofusine contain less chloride (120 meq/L).

4. Hydroxyethyl starches

- COP 28 mm Hg
- Long elimination half-life (17 days) but The oncotic effects of hetastarch disappear within 24 hours
- The earlier HES fluids were associated with coagulation dysfunction and pruritis, but the tetrastarches used these days have no effect on bleeding times.
- Renal impairment in critically ill patients is associated with osmotic nephrosis like lesions in the proximal and distal tubules.

5. Dextrans

- COP 40 mm Hg (greater increase in plasma volume).

- Not used for volume expansion because of a high incidence of anaphylactic reactions and negative effects on coagulation.
- Decrease in blood viscosity and inhibition of erythrocyte aggregation. Interfere with cross-matching.

Comparison between Colloids

Colloid	Concentration	Oncotic pressure mmHg/ osmolarity/mOsm/l	Initial volume expansion %	Persistence in body	Maximum dose
Albumin	4%	20–29	80	t ½ 20 days intravascular expansion 16–24 hours	
Albumin	25%	100–120	200–400		
HES *(Voluven)*	6% in normal saline	20–29/308	80	Intravascular expansion 8–12 hours	50 ml/kg
HES *(Voluven Lyte)*	6% in a balanced salt solution	20–29 286.5 mOsm/l	80	8–12 hours	50 ml/kg
Gelatin *(gelofusine, haemacel)*	3% in saline Na 154, Cl 120	26–29 274 mOm/l	70	Intravascular expansion: 2–7 hours	
Dextran 70	6%	168–191	200	6 days	1.5 g

Indications for Colloids:

1) Fluid resuscitation in patients with severe intravascular fluid deficits (e.g. hemorrhagic shock) prior to the arrival of blood for transfusion (in conjunction with crystalloids).
2) Fluid resuscitation in the presence of severe hypoalbuminemia or conditions associated with large protein losses such as burns. It should be noted that colloid solutions are prepared in normal saline (Cl-145-154 mEq/L) and thus can also cause hyperchloremic metabolic acidosis

What option for fluid resuscitation would you choose?



Crystalloids and Colloids

	advantages	disadvantages
Crystalloid	Cheap	Only 25% remains in circulation
	Available	Most goes interstitial
	Less side effects.	Larger resuscitation volume (X3)
	Resuscitate the ECF space	More resuscitation time
		Shorter half-life Pulmonary & peripheral oedema
Colloid	Spares pulmonary + peripheral interstitial space	Expensive Doesn't restore interstitial volume Enters interstitial space if leaky (sepsis)
	Shorter resuscitation time Longer half-life 50-100% remains in intravascular space (depending on type)	More side effects Immune reactions
		Interference with hemostasis X-matching problems Use of starches may be associated with worse outcome

Calculation of maintenance fluid

Rule of 4:2:1 (infusion per hour)

- 4 mL/kg/hr. for kg 1-10
- + 2 mL/kg/hr. for kg 10-20
- +1 mL/kg/hr. above 20 kg
    - A patient who weighs 40 kilograms would require:
        - 40 mL/hr + 20 mL/hr + 20 mL = 80 mL/hr
    - Shortcut formula :
        - body weight + 40 (= 80 mL/hr in this example)
    - (Working if body weight >20kg)

Further consideration

Once the maintenance requirements have been calculated, additional potential losses need to be considered to avoid under or over hydration, the following sources of fluid loss and the electrolyte composition of these fluids need to be appreciated:

- Nasogastric aspirates
- Vomit
- Diarrhea
- Stoma, drains, fistula etc.
- Polyuria

MCQ TEST

1- The fluid compartment of total body weight(which one is true)
a) Neonate: 40%
b) Infant: 70-75%
c) Adult male: 80-85%
d) Adult female 90-95%
e) Elderly

2- Disadvantages of glucose infusion
a) Decreased CO_2 production
b) Hyperglycemia.
c) Increased risk of infection.

d) Aggravation of ischemic brain injury.
e) Increased mortality in septic shock.

3- Indications of normal saline(all true except one)
a) Dehydration
b) Hypovolemia
c) Hemorrhage
d) sepsis).
e) sever sodium depletion

4- best for parenteral maintenance fluids rather than aggressive intravascular
volume repletion
a) 0.9% normal saline
b) 0.45% saline
c) Dextrose 5%
d) Ringer lactate
e) Albumin

5- Dextran(all true except one)
a) Not used for volume expansion19
b) high incidence of anaphylactic reactions
c) negative effects on coagulation .
d) Decrease in blood viscosity .
e) Not Interfere with cross-matching .

6- Regarding disturbiution of Glucose solutions
a) <30% remains in Intra vascular space
b) <10% in Interstitium
c) >50% in Intra cellular space
d) More than 30% remain intravascular
e) Less than 20% intracellular space

7- Colloid fluids(which one is true)
a) Natural colloid is starch
b) Rate of replacement 1:3
c) Almost hypertonic

d) No risk for anaphlaxsis
e) Cheaper than crystalloid

8- Hartman solution is
a) Dextrose
b) Dextran
c) Ringer lactate
d) Normal saline
e) Dextrose saline

9- lactated Ringer's solution is contraindicated as a diluent for blood transfusions because of a) high Ph.
b) High lactate level
c) Calcium binding to the citrated anticoagulant
d) Potassium binding to calcium
e) Non of the above

10- Infusion of 1 L of 0.9% normal saline adds
a) 275 mL to the plasma volume and 825 mL to the interstitial volume
b) 275 275 mL to the interstitial volume and 825 mL to the plasma volume
c) 825 mL to the plasma volume and 275 mL to the interstitial volume
d) 500 mL to the plasma volume and 500 mL to the interstitial volume
e) 800 mL to the plasma volume and 200 mL to the interstitial volume