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Chapter 2:

Overview of Intravenous Fluids

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2 Overview of Intravenous Fluids

A significant number of hospitalized patients across various medical specialties require intravenous (IV) fluid therapy. Understanding the fundamental principles is crucial for the safe and effective administration of IV fluids [1]. Inadequate fluid management can exacerbate patient outcomes and prolong hospital stays [2].

To prescribe appropriate fluid therapy, it is essential to consider the following:

- The underlying cause of fluid deficit and the type of electrolyte imbalance present.
- Coexisting medical conditions (e.g., diabetes, hypertension, ischemic heart disease, renal or hepatic disorders).
- Clinical status, including factors like age, hydration level, vital signs, urine output, etc.

To ensure rational and adequate fluid therapy, it is imperative to address the following questions:

- When is IV fluid administration appropriate, and when should it be avoided?
- Which type of fluid should be infused, and why?
- How much fluid should be administered, and what is the calculation method?
- At what rate should IV fluid be infused, and how is the drop rate calculated?
- What are the contraindications for various types of IV fluids, and what are the reasons behind them?
- How do you select IV fluids to correct electrolyte imbalances?
- When and how should specific fluids be used?

Following a comprehensive evaluation, the necessary fluid therapy is planned and prescribed.

BASIC PRINCIPLES OF FLUID THERAPY

As a principle, the oral route is always preferred over the IV route. But IV fluid

Table 2.1 Composition of common IV solutions

	Dext.*	Calories	Na^+	K^+	Cl^-	Acet.	Lact.	NH_4	Ca^{2+}	Mg^{2+}	HPO_4	Gluc.	Citr.	Osm.	SID
	gm/L	kcals/L	mEq/L	mEq/L	mEq/L	mEq/L	mEq/L	mEq/L	mEq/L	mEq/L	mEq/L	mEq/L	mEq/L	mOsm/L	mEq/L
5% dextrose	50	170	-	-	-	-	-	-	-	-	-	-	-	252	0
10% dextrose	100	340	-	-	-	-	-	-	-	-	-	-	-	505	0
0.45% saline	-	-	77	-	77	-	-	-	-	-	-	-	-	154	0
D5W, 0.45% saline	50	170	77	-	77	-	-	-	-	-	-	-	-	406	0
Normal (0.9%) saline	-	-	154	-	154	-	-	-	-	-	-	-	-	308	0
Dextrose saline	50	170	154	-	154	-	-	-	-	-	-	-	-	560	0
Ringer's lactate	-	-	130	4.0	109	-	28	-	3.0	-	-	-	-	273	28
Ringer's acetate	-	-	130	5.0	112	27	-	-	3.0	2.0	-	-	-	276	27
PlasmaLyte	-	-	140	5.0	98	27	-	-	-	3.0	-	23	-	295	50
Sterofundin	-	-	145	4.0	127	24	-	-	5.0	2.0	-	-	-	309	29
Isolyte-G	50	170	63	17	150	-	-	70	-	-	-	-	-	578	NA
Isolyte-M	50	170	37	35	37	20	-	-	-	-	15	-	-	415	NA
Isolyte-P	50	170	25	20	24	23	-	-	-	3.0	3.0	-	-	348	NA
Isolyte-E	50	170	140	10	103	47	-	-	5.0	3.0	-	-	8.0	595	57
Isolyte-S	-	-	141	5.0	98	27	-	-	5.0	3.0	1.0	23	-	295	NA

Dext.: Dextrose	Cl^-: Chloride	NH_4: Ammonium	HPO4: Phosphate	SID: Strong ion difference
Na^+: Sodium	Acet.: Acetate	Ca^{2+}: Calcium	Citr.: Citrate	Gluc.: Gluconate
K^+: Potassium	Lact.: Lactate	Mg^{2+}: Magnesium	Osm.: Osmolality	

*Dextrose concentration is in gms/L

therapy has great importance and is life-saving in various clinical problems.

The basic principles of IV fluid therapy are summarized.

Indications

Fluid therapy is widely used for resuscitation, for proving the maintenance need of fluids, replacing and restoring fluids and electrolytes deficits, as a drug carrier, and for nutrition [3]. The most common and important indications for fluid administration includes:

1. For resuscitation in moderate to severe dehydration and shock, where urgent and rapid fluid replacement is needed.
2. To provide maintenance need in conditions when oral intake is not possible or is insufficient (i.e., coma, anesthesia, surgery).
3. To restore or replace fluid losses (e.g., severe vomiting, diarrhea, fever, burns, etc.), third space fluid loss (e.g., sepsis, burns, ascites, pancreatitis, or ileus), or blood losses (e.g., trauma or surgery).
4. To correct electrolytes and acid-base disorders.
5. To correct severe hypoglycemia, where IV 25% dextrose is life-saving.
6. As a vehicle for various IV medications (e.g., antibiotics, chemotherapeutic agents, insulin, vasopressor agents, etc.).
7. To provide parenteral nutrition.
8. Treatment of critical problems: Shock, anaphylaxis, severe asthma, cardiac arrest, forced diuresis in drug overdose, poisoning, etc.
9. To monitor hemodynamic functions and administer diagnostic reagents.

Contraindications

1. IV fluid should be avoided if the patient can take oral fluid.
2. Preferable to avoid IV fluid in a patient with congestive heart failure or volume overload.

Advantages

1. A perfect, controlled, and predictable way of fluid administration.
2. Immediate response is achieved through direct infusion into the intravascular compartment.
3. Rapid correction of life-threatening fluid and electrolyte disturbances.

Disadvantages

1. More expensive and needs strict asepsis.
2. Feasible only in hospitalized patients under supervision.
3. Improper selection of the type of fluid used can lead to serious problems.
4. The inappropriate volume and rate of infusion of fluid can be life-threatening.
5. The incorrect administration technique can lead to complications.

Complications

1. **Local:** Haematoma, infiltration, and infusion phlebitis.
2. **Systemic:** Circulation overload with rapid or large volume infusion, especially in patients with cardiac problems. Rigors, air embolism, and septicemia.
3. **Others:** Fluid contamination, fungus in IV fluids, mixing of incompatible drugs, an incorrect infusion technique, IV set or IV catheter-related problems, and human error-related problems.

OVERVIEW OF COMPOSITION OF IV FLUIDS

It is important to know the compositions of different commercially available IV fluids (Table 2.1) when making an appropriate choice for specific situations.

Bird's eye view of IV fluid characteristics

Before discussing the detailed composition and pharmacology of IV fluids, let's first assess and clarify the fundamental concept of IV fluids.

The physiological IV fluids

Balanced crystalloids such as Ringer's lactate (RL), PlasmaLyte, and Sterofundin are physiological IV fluids. Among these, RL is the most commonly used balanced crystalloid, with its electrolyte contents similar to the composition of the extracellular fluid (ECF) (Na^+-130 mEq/L, K^+-4 mEq/L, Cl^-109 mEq/L, lactate (bicarbonate) 28 mEq/L, and Ca^{2+}-3 mEq/L).

Daily normal maintenance requirement and preventing starvation ketosis in adults

Understanding the daily normal maintenance requirements for water, sodium, potassium, and the amount of dextrose needed to prevent starvation ketosis in adults is essential. These details are summarized in Table 2.2 [4].

Sodium content in various IV fluids

Understanding the sodium content in commonly used IV fluids is crucial. Among these fluids, normal saline (NS) and dextrose saline (D5NS) contain the maximum amount of sodium, with 154 mEq/L or 9 gm of NaCl per liter. (Note: 1 gm of NaCl contains 17.1 mEq Na^+). For detailed information on the sodium content of various IV fluids, refer to Table 2.3.

Chloride content in various IV fluids

Determining the chloride content in commonly used IV fluids is important. Among these fluids, normal saline, D5NS, and Isolyte-G all contain the maximum chloride concentration at 154 mEq/L.

Potassium content in various IV fluids

Understanding the potassium content in different IV fluids is essential. The potassium content of various IV fluids is summarized in Table 2.4.

It's crucial to note that Isolyte-M has the highest potassium content, with 35 mEq/L. In contrast, balanced crystalloids such as RL, PlasmaLyte, and Sterofundin contain only 4–5 mEq/L of potassium.

Table 2.2 Maintenance requirement of water, sodium, potassium and dextrose

	Water	Sodium	Potassium	Dextrose
Normal requirement	25–30 mL/kg/day	1 mEq/kg/day	1 mEq/kg/day	100 gm/day to prevent starvation ketosis

Table 2.3 Sodium concentration of IV fluids

IV Solutions	NS D5NS	Sterofundin	Plasma-Lyte	RL	0.45% NaCl	Isolyte-G	Isolyte-M	Isolyte-P	3% NaCl
Sodium mEq/L	154.0	145.0	140.0	130.0	77.0	63.0	37.0	25.0	513.0

Table 2.4 Potassium concentration of IV fluids						
IV solutions	**Isolyte-M**	**Isolyte-P**	**Isolyte-G**	**PlasmaLyte**	**RL and sterofundin**	**Inj. potassium chloride 15%**
Potassium (mEq/L)	35.0	20.0	17.0	5.0	4.0	20 mEq/10 ml

Magnesium content in various IV fluids

IV fluids that contain magnesium include Ringer's acetate and Sterofundin, which contain 2 mEq/L, and solutions like PlasmaLyte, Isolyte-P, Isolyte-E, and Isolyte-S, which contain 3 mEq/L.

Calcium content in various IV fluids

IV fluids that contain calcium include Ringer's lactate and Ringer's acetate, which contain 2 mEq/L, while Sterofundin, Isolyte-E, and Isolyte-S contain 5 mEq/L.

Phosphate content in various IV fluids

Phosphate-containing IV fluids include Isolyte-M, which contains 15 mEq/L, and Isolyte-P, which contains 3 mEq/L.

Correction of acidosis with IV fluids

Understanding which IV fluids can directly correct acidosis and its mechanism is essential. Some IV fluids contain bicarbonate precursors, such as lactate and acetate [5]. Ringer's lactate, for example, contains 28 mEq/L of lactate, which is converted into bicarbonate in the liver, effectively correcting metabolic acidosis. Additionally, fluids like PlasmaLyte, Sterofundin, Isolyte-P, and Isolyte-M contain acetate (PlasmaLyte = 27 mEq/L, Sterofundin = 24, Isolyte-P = 23, and Isolyte-M = 20 mEq/L). Acetate also undergoes conversion into bicarbonate, both in the liver and peripheral tissues, aiding in the correction of metabolic acidosis.

Correction of metabolic alkalosis with IV fluids

Understanding which IV fluids can directly correct metabolic alkalosis is important. Isolyte-G stands out as the only IV fluid capable of directly addressing metabolic alkalosis. This effect is achieved through the presence of ammonium chloride (NH_4Cl = 70 mEq/L) in Isolyte-G, which undergoes conversion into H^+ ions and urea in the liver. The addition of H^+ ions effectively corrects the alkalosis.

Cautious use of IV fluids in renal failure

It is essential to exercise caution when using certain IV fluids in patients with renal failure. IV fluids with high sodium content, such as normal saline, dextrose saline (154 mEq/L sodium or 9 gm of salt per liter), and Ringer's lactate (130 mEq/L or approximately 7 gm of salt per liter), are administered with care due to their potential risk of fluid overload.

Furthermore, IV fluids containing a high potassium content, such as Isolyte-M, Isolyte-P, and Isolyte-G, should also be used cautiously in renal failure patients because of the potential risk of hyperkalemia.

Additionally, it's important to note that ammonium chloride in Isolyte-G undergoes conversion into hydrogen ions and urea, which can potentially exacerbate uremic acidosis, further emphasizing the need for caution when administering this fluid to individuals with renal issues.

Glucose-free IV fluids

It's important to note that normal saline, Ringer's lactate, PlasmaLyte, and Sterofundin do not contain glucose. Therefore, they can be administered without the risk of worsening hyperglycemia.

Sodium and chloride free IV fluids

Among commonly used IV fluids, 5%,

10%, and 20%-dextrose are the only fluids that do not contain sodium and chloride. On the other hand, fluids like Isolyte-M and Isolyte-P have relatively low sodium and chloride content.

Potassium-free IV fluids

IV fluids such as normal saline, dextrose saline (D5NS), and 5%, 10%, and 20%-dextrose do not contain potassium.

CLASSIFICATION OF FLUIDS

The solutions used in intravenous fluid therapy are classified into the following based on the composition of fluids, osmolality, presence of buffers (in balanced solutions), and electrolytes.

A. Classification based on composition

The solutions used in intravenous fluid therapy are classified into three groups based on composition:

1. Crystalloids
2. Colloids
3. Whole blood and blood products

1. Crystalloids

Crystalloids are solutions in sterile water which contain varying concentrations of electrolytes and dextrose.

2. Colloids

Colloids are a solution containing water, electrolytes, and plasma-derived protein or semi-synthetic starch molecules that remain uniformly distributed and do not readily cross semi-permeable membranes. Colloids are frequently called volume expanders or plasma expanders. Commonly used Colloids include albumin, hydroxyethyl starch, gelatine, and dextran.

B. Classification of crystalloids based on osmolality

Crystalloids are classified into three categories according to their osmolality (Table 2.5).

1. Isotonic crystalloids

A crystalloid solution that has the same concentration of electrolytes as the body plasma. Isotonic fluids have an osmolality of 270–310 mOsm/L. When an isotonic crystalloid is administered, the infused isotonic solution remains within the extracellular fluid compartment (distributed between the intravascular and interstitial spaces), and therefore, isotonic IV fluids expand the intravascular compartment more effectively than hypotonic IV fluids [3]. Isotonic fluids don’t move into cells, and thus cells neither swell nor shrink with the isotonic fluid infusion.

Examples of isotonic solutions with their respective osmolarity values include 0.9% sodium chloride (308 mOsm/L), Ringer's lactate (273 mOsm/L), Ringer's acetate (276 mOsm/L), PlasmaLyte (295 mOsm/L), and Sterofundin (309 mOsm/L).

2. Hypotonic crystalloids

Crystalloid solutions with a lower concentration of electrolytes than body plasma are hypotonic fluids. Hypotonic fluids have an osmolality of less than 270 mOsm/L (lower than serum osmolarity). When hypotonic crystalloid is administered, the fluid will quickly move from the intravascular space into the cells and interstitial spaces. These solutions will hydrate cells causing them to swell. Examples of hypotonic solutions are 0.45% sodium chloride, 0.33% sodium chloride, 5% dextrose, 10% dextrose and D5W + 0.45% NaCl.

Table 2.5 Classification of crystalloid solutions according to osmolality						
Characteristics	**Isotonic solutions**		**Hypotonic solutions**		**Hypertonic solutions**	
Osmolality (mOsm/L)	270–310		Lesser than 270		Greater than 310	
Distribution and effect on fluid compartment	Remains within ECF and expands ECF compartment		Fluid quickly moves from the intravascular space into the cells		Pull water from the cells into the intravascular space	
Effect on cell size	No effect		Swollen		Shrink	
Examples	Solutions	Osmolality mOsm/L	Solutions	Osmolality mOsm/L	Solutions	Osmolality mOsm/L
Normal serum osmolality is 275–295 mOsm/kg	0.9% NaCl	308	0.45% NaCl	154	3% NaCl	1026
	Ringer's lactate	273	0.33% NaCl	103	D5W + 0.9% NaCl	560
	PlasmaLyte	290	-	-	-	-

The 5% dextrose solution, with an osmolality of 252 mOsm/L, is often considered near isotonic in the bag. However, once it enters the body, dextrose is rapidly metabolized, leaving behind pure water, which becomes hypotonic. Similarly, the 10% dextrose solution has an osmolality of 505 mOsm/L in vitro, but it becomes pure hypotonic water in vivo with zero osmolality.

Additionally, D5W + 0.45% NaCl is hypertonic in the bag, with an osmolality of 406 mOsm/L. Nevertheless, once administered in the body, dextrose is rapidly metabolized, leaving behind a solution containing only 0.45% NaCl, which offers an osmolality of just 154 mOsm/L, making it hypotonic. Therefore, when using the above-mentioned IV fluids, selection should be based on the expected in vivo osmolality rather than what is mentioned on the package label [6].

Use hypotonic fluid with caution. As hypotonic fluid quickly moves from the intravascular space into the cells, vascular bed volume decrease. Depletion of intravascular fluid volume can exacerbate preexisting hypovolemia and hypotension and carries the risk of cardiovascular collapse. As hypotonic fluid can cause or exacerbate cerebral edema, avoid it in patients who are at risk for increased intracranial pressure (stroke, head injury, or neurosurgery) [7].

3. Hypertonic crystalloids

Crystalloid solutions with a higher concentration of electrolytes than body plasma are considered hypertonic fluids, which have an osmolarity of more than 310 mOsm/L or higher. Among the most widely used hypertonic solutions are 3% sodium chloride and 5% dextrose in 0.9% saline.

When hypertonic crystalloid solutions are administered, they draw water from the cells into the intravascular space, causing the cells to shrink and increasing extracellular fluid volume. This characteristic makes 3% sodium chloride a mainstay of treatment for cerebral edema since it can shrink brain cell size without the risk of hypotension, due to its ability to expand the extracellular fluid volume.

5% dextrose in 0.9% saline is not used for the treatment of cerebral edema because, in vivo, after the metabolism of glucose, it becomes similar to normal saline, which is an isotonic fluid.

As hypertonic fluid increases extracellular fluid volume, it carries the risk of volume overload and pulmonary edema and, therefore, should be avoided in cardiac or renal patients with circulatory overload. As hypertonic fluid causes cell shrinkage, it should be avoided in conditions causing cellular dehydration.

C. Classification of crystalloids based on buffers and electrolytes

For proper selection of crystalloids, we need to know the composition, pharmacological basis, important indications, and contraindications of commonly used IV fluids. The following crystalloids are discussed here.

1. **Dextrose and sodium chloride solutions**

   5% dextrose, normal saline, dextrose saline, half normal saline, and half normal saline with dextrose.

2. **Balanced crystalloids**

   Ringer’s lactate, Ringer's acetate, PlasmaLyte, and Sterofundin.

3. **Multiple electrolyte solutions**

   Isolyte-G, Isolyte-M, Isolyte-P, Isolyte-E and Isolyte-S.

METHODS FOR CALCULATING DROP RATES PER MINUTE FOR FLUID INFUSION

In most non-ICU setups, electronic pump systems are unavailable, and fluids are administered via either macrodrip tubing (conventional, routine IV sets) or microdrip tubings. In such scenarios, manual calculation is necessary to determine the volume of fluid administered within a given time frame at required rates of drops per minute. It's essential to verify the drop factor of the administration set, which is used to ensure accurate fluid delivery during infusion therapy. Calculations differ based on either macrodrip tubing, which delivers larger-sized drops, or microdrip tubing, which provides smaller-sized drops.

A. Calculation for macro drip tubing

Commercially available macro drip tubing delivers larger drops, with the specific drop factor varying depending on the manufacturer's location and practices worldwide. Each milliliter of fluid administered through macro drip tubing typically delivers 10, 15, or 20 drops of fluid, known as the administration set drop factor (drops/mL).

- A drop factor of 10 drops/mL means that 10 drops of fluid will equal one milliliter.
- A drop factor of 15 drops/mL means that 15 drops of fluid will equal one milliliter.
- A drop factor of 20 drops/mL means that 20 drops of fluid will equal one milliliter.

The method used to calculate macro drop rates per minute for fluid infusion:

Step 1: First, convert the total volume of fluid to be delivered over a given time period into volume in an hour.

Volume/hour = Total Volume of Fluid (ml) / Duration of Time (hour)

Step 2: Convert the volume of fluid to be delivered in an hour into the volume given in a minute.

Volume/min = Total Volume of Fluid (ml) / 60

Step 3: Convert the volume of fluid to be delivered in a minute into the number of macro drops to be delivered in a minute.

Macro Drops/min = Total Volume of Fluid (ml) × Drop Factor of Macro Drip Tubing

Example: A patient needs 600 mL of intravenous fluids over 5 hours using macrodrip tubing with a drop factor of 15 drops/mL. Calculate the macro drop rates per minute.

- Volume/hour = 600 ml/5 hours = 120 ml/hour
- Volume/min = 120 ml/60 min = 2 ml/min
- Macro drops/min = 2 ml × 15 = 30 macro drop rates per min

Simple formulas for macro drip tubing with a drop factor of 15 drops/mL: A simple, practical, and user-friendly method for roughly calculating drop rates when macro drip tubing with a drop factor of 15 drops/mL is used to infuse IV fluids is summarized below.

Rule of ten: Multiply the volume of IV fluid to be delivered in liters over 24 hours by ten to obtain the drop rate per minute.

IV Fluid in Liters/24 hours × 10 =
Macro Drop Rate/min

- 2.0 liters in 24 hours = 2.0 × 10 = 20 macro drops/min
- 3.5 liters in 24 hours = 3.5 × 10 = 35 macro drops/min
- Calculation for 1 liter in 8 hours = 3.0 liters in 24 hours = 3.0 × 10 = 30 macro drops/min
- Calculation for 1 liter in 6 hours = 4.0 liters in 24 hours = 4.0 × 10 = 40 macro drops/min

Rule of four: Divide the volume of fluid (in ml) to be infused in one hour by four to obtain the macro drop rate per minute.

Volume in ml/hour ÷ 4 =
Macro drop rate/min

- 60 ml/hour = 60 ÷ 4 = 15 drops/min
- 200 ml/hour = 200 ÷ 4 = 50 drops/min

B. Calculation for micro drip tubing

Commercially available micro drip tubing delivers small-sized drops, with typically 1 mL providing 60 micro drops.

The formula to calculate micro drop rates per minute is simple.

Volume in ml/hour =
Number of Micro drops/min

- 30 ml/hour = 30 Micro drops/min
- 45 ml/hour = 45 Micro drops/min

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