INTRA VENOUS FLUIDS

Ahmad AL-zu’bi
Types of IV fluids

- Crystalloids
- Colloids
Crystalloids

- Crystalloids are aqueous solutions of low molecular weight ions, with or without glucose.
- **Isotonic, Hypotonic, & Hypertonic Fluids**
Isotonic

- **Iso**: same/equal
- **Tonic**: concentration of a solution
- **Isotonic fluids**
  - 0.9% Saline
  - 5% dextrose in water (D5W)**also used as a hypotonic solution after it is administered because the body absorbs the dextrose BUT it is considered isotonic**
  - 5% Dextrose in 0.225% saline (D5W1/4NS)
  - Lactated Ringer’s
Hypotonic

- Hypo: "under/beneath"
- Tonic: concentration of a solution
- The cell has a low amount of solute extracellularly and it wants to shift inside the cell to get everything back to normal via osmosis. This will cause CELL SWELLING which can cause the cell to burst or lyses.
- Hypotonic solutions
  - 0.45% Saline (1/2 NS)
  - 0.225% Saline (1/4 NS)
  - 0.33% saline (1/3 NS)
- Hypotonic solutions are used when the cell is dehydrated and fluids need to be put back intracellularly. This happens when patients develop diabetic ketoacidosis (DKA) or hyperosmolar hyperglycemia.
- Important: Watch out for depleting the circulatory system of fluid since you are trying to push extracellular fluid into the cell to re-hydrate it. Never give hypotonic solutions to patient who are at risk for increased cranial pressure (can cause fluid to shift to brain tissue), extensive burns, trauma (already hypovolemic) etc. because you can deplete their fluid volume
Hypertonic solutions

- 3% Saline
- 5% Saline
- 10% Dextrose in Water (D10W)
- 5% Dextrose in 0.9% Saline
- 5% Dextrose in 0.45% saline
- 5% Dextrose in Lactated Ringer’s

When hypertonic solutions are used (very cautiously….most likely to be given in the ICU due to quickly arising side effects of pulmonary edema/fluid over load). In addition, it is preferred to give hypertonic solutions via a central line due to the hypertonic solution being vesicant on the veins and the risk of infiltration.
<table>
<thead>
<tr>
<th></th>
<th>Human Plasma</th>
<th>0.9% Sodium Chloride</th>
<th>Hartmann’s</th>
<th>Ringer’s Lactate</th>
<th>Ringer’s Acetate</th>
<th>Plasma-Lyte 148</th>
<th>Plasma-Lyte A pH 7.4</th>
<th>Sterofundin/Ringerfundin</th>
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<tbody>
<tr>
<td>Osmolarity (mOsm/L)</td>
<td>275–295</td>
<td>308</td>
<td>278</td>
<td>273</td>
<td>276</td>
<td>295</td>
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<tr>
<td>pH</td>
<td>7.35–7.45</td>
<td>4.5–7.0</td>
<td>5.0–7.0</td>
<td>6.0–7.5</td>
<td>6.0–8.0</td>
<td>4.0–8.0</td>
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<td>0</td>
<td>1</td>
<td>1.5</td>
<td>1.5</td>
<td>1</td>
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<td>Bicarbonate (mmol/L)</td>
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<td>0</td>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>5</td>
<td></td>
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<tr>
<td>Na:Cl ratio</td>
<td>1.21:1 to 1.54:1</td>
<td>1:1</td>
<td>1.18:1</td>
<td>1.19:1</td>
<td>1.16:1</td>
<td>1.43:1</td>
<td>1.43:1</td>
<td>1.14:1</td>
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</table>
Solutions are chosen according to the type of fluid loss being replaced:

- For losses primarily involving water, replacement is hypotonic solutions also known as maintenance type solutions like: Dextrose solution 5%
- If losses involve both water and electrolytes replacement is with isotonic electrolytes solutions or replacement type solutions like: ringer’s lactate
Normal saline or sodium chloride 0.9%

- is a mixture of sodium chloride in water that is slightly hypertonic and contains more chloride than ECF
- aggressive volume resuscitation with normal saline >>?
- Normal saline is the preferred solution for
  1. hypochloremic metabolic alkalosis
  2. diluting packed red blood cells prior to transfusion
Five percent dextrose in water (D5W)

- It is a hypotonic, isosmotic solution that doesn’t contain electrolytes.
- Dextrose solution is equivalent to administering water that’s why
  1. It is used for replacement of pure water deficits
  2. as a maintenance fluid for patients on sodium restriction (hypernatremia)
  3. It prevents the catabolic state (hypoglycemia and ketosis) that follows prolonged fasting
  4. More concentrated dextrose solutions (10%, 20% and 50%) are available but their use is limited to the management of diabetic patients and patients of hypoglycemia.
Ringer's lactate solution or (Hartmann's solution), is a mixture of sodium chloride, sodium lactate, potassium chloride, and calcium chloride in water.

- **Uses of ringer lactate**
  1. It is used for replacing fluids and electrolytes in those who have low blood volume or low blood pressure.
  2. It may also be used to treat metabolic acidosis in cases other than those caused by lactic acidosis.
  3. And to wash the eye following a chemical burn.
Other types of solutions:

- **Plasmalyte**: is a family of balanced crystalloid solutions with multiple different formulations available.
- It closely mimics human plasma in content of electrolytes, osmolality and pH that’s why it is a replacement type solution.
- **Hypertonic 3% saline**: is employed in therapy of severe symptomatic hyponatremia.
colloids

- Are those containing high mw substances that exert an oncotic pressure
- indications for colloids include
  1. fluid resuscitation in patients with severe intravascular fluid deficits (eg, hemorrhagic shock) prior to the arrival of blood for transfusion
  2. fluid resuscitation in the presence of severe hypoalbuminemia or conditions associated with large protein losses such as burns. (Replacing an intravascular volume deficit with crystalloids generally requires three to four times the volume needed when using colloids, this justifies their indication for the use where more than 3_4 liters of crystalloid solution has been injected)
colloids

- Natural (human albumin)
- Artificial (gelatins, dextrans and hydroxyethyl starches)
Albumin

- Half life = 1.6 hours in plasma
- Stays in intravascular space
- 5% solution isotonic 10% and 25% hypertonic
- Expands volume 5x in 30 minutes and its effect lasts 1-2 days
- Side effects: 1. volume overload
   2. Fever
   3. Defects in hemostasis
Advantages:

- Natural colloid: As albumin is a natural colloid it is associated with lesser side-effects like pruritus, anaphylactic reactions and coagulation abnormalities compared to synthetic colloids.

- Degree of volume expansion: 25% Albumin has a greater degree of volume expansion as compared to rest of colloids. 5% albumin solution has a similar degree of volume expansion as compared to hetastarch but greater than gelatins and dextrans.

- Other benefits: Albumin acts a principal binding protein of endogenous and exogenous substances. It also possesses antioxidant effects. Albumin being negatively charged protein contributes to the formation of normal anion gap, influencing the acid-base status.
Synthetic colloids

- gelatins
- dextrose starches
- Dextran • High molecular weight polysaccharide (40000 > coagulation effect than dextran 70000 )
- 10% solution in NS or D5W
- SE: anaphylaxis, coagulopathy, renal failure
- is used as a volume expander but also reduces blood viscosity, von Willebrand factor antigen, platelet adhesion, and red blood cell aggregation, that’s why it is used by microsurgeons to improve microcirculatory flow and decrease risk of microthrombus formation
hydroxyethyl starch

- is highly effective as a plasma expander and is less expensive than albumin. Allergic reactions are rare, but anaphylactic reactions have been reported.
- Hetastarch can decrease von Willebrand factor antigen levels, may prolong the prothrombin time, and has been associated with hemorrhagic complications. It is potentially nephrotoxic.
Differences

- Colloids are more expensive than crystalloids
- Colloids have higher molecular weight
- Half life of crystalloids is between 15 to 20 minutes while colloids last 2-3hrs
- Colloids act as plasma expanders
Intraoperative fluid requirements

- Optimal perioperative fluid therapy requires an understanding of the changes that occur in the volume and composition of the body fluid compartments.

- Intravenous fluids are used to replenish fluid losses while maintaining:
  - **intravascular volume** (which is essential for adequate perfusion of vital organs)
  - **cardiac preload**
  - **oxygen-carrying capacity**
  - **coagulation status**
  - **acid-base balance**
  - **electrolyte balance**
The total fluid requirement is composed of:

- compensatory intravascular volume expansion (CVE)
- maintenance fluids
- preoperative deficits (NPO, GI losses, blood loss)
- ongoing surgical losses (evaporation, blood loss)
- 3de space loss
compensatory intravascular volume expansion

- Intravascular volume must usually be supplemented to compensate for the venodilation and cardiac depression caused by anesthesia..
- Increasing cardiac preload by infusing fluid intravascularly to return stroke volume to an acceptable range..

- 5 mL/kg of balanced salt solution (Ringer's lactate) should be introduced before or simultaneous with the onset of anesthesia..
- Postoperatively; venodilation and cardiac depression rapidly subside when administration of the anesthetic is stopped..

- ** Note: Patients with impaired cardiac or renal responses may then become acutely hypervolemic!!
Maintenance fluids

- Maintenance fluid requirements for any body weight can be calculated using the: "4-2-1" rule for hourly fluid requirements or the "100-50-20" rule for daily fluid requirements. For example, a 75 kg adult will require:

  Per hour:
  - 10 kg x 4 ml/hr = 40 ml/hr
  - 10 kg x 2 ml/hr = 20 ml/hr
  - 55 x 1 ml/hr = 55 ml/hr
  Total: 75 kg 115 ml/hr

  Per day:
  - 10 kg x 100 ml/day = 1000 ml/day
  - 10 kg x 50 ml/day = 500 ml/day
  - 55 x 20 ml/day = 1100 ml/day
  Total: 75 kg 2600 ml/day
Preoperative deficits

1. as a result of a period of fasting (NPO deficit): In the absence of oral intake; fluid and electrolyte deficits can rapidly develop as a result of continued urine formation, gastrointestinal secretions, and insensible losses (from the skin and lungs). Can be calculated by multiplying the patient’s hourly maintenance requirements by the number of hours fasted. --- Maintenance requirements / hour x number of hours fasted

\[
\text{Maintenance requirements} / \text{hour} \times \text{number of hours fasted} \\
75 \text{ kg} \times 115 \text{ ml/hr} \times 8 = 920 \text{ ml}
\]

2. Preoperative losses from the gastrointestinal tract (e.g., vomiting or diarrhea), best replaced with a crystalloid of similar composition (0.9% NS or Ringer’s lactate).

** in surgery that takes 4 hrs for ex. we give half deficit in 1st hour (920/2 = 460) & other half divided by 3 hrs (460/3) per hr **
intraoperative deficits

- 3. Blood loss** < 15% blood loss we use crystalloids; If 1000 ml of NS is infused intravenously:
  
  only 1/3 (approx. 300 ml) will remain in the intravascular compartment, the remaining 2/3 (700 ml) will move into the interstitial and intracellular compartments.

  3 times the volume of blood lost must be infused when crystalloids (NS or RL) are used to maintain the intravascular volume (3:1 volume basis).

  15-30% blood loss use colloids;

  given in a volume similar to the estimated deficit to maintain the circulating volume (1:1 volume basis).
intraoperative deficits

- > 30% start to transfuse blood (unit-for-unit) esp in young patients..
- in children we start blood transfusion at 10% blood loss..
- in elderly & preexisting medical condition as in IHD start
- blood transusion at 20% blood loss ..
Blood loss

- **We prefer** to start with **crystalloids** in replacement of blood loss because they're safer.
- **We don't prefer** to use **colloids** because of the side effects (e.g., coagulopathy, anaphylaxis, ..)
- **We don't prefer** to transfuse blood because of the complications until the danger of anemia outweighs the risks of transfusion (transfusion point). Then, we should transfuse blood (red blood cells to maintain hemoglobin concentration or hematocrit at certain level).

- Usually, we start the procedure when Hb >10g/dl. Especially in **elderly and sicker patients with cardiac or pulmonary disease**. But could be acceptable >7-8 g/dl in younger & medically free patient.
Blood loss

- **The transfusion point** can be determined preoperatively from the hematocrit and by estimating blood volume.

- **Hematocrit**: volume percentage (%) of red blood cells in blood in (Men= 42-52%,, Women= 37-47%)

- **Blood volume**: can be either calculated in formula (plasma volume/1-hematocrit) or generally **estimated** as in table below:

<table>
<thead>
<tr>
<th>Age group</th>
<th>Average blood volume (ml/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Premature neonates</td>
<td>95</td>
</tr>
<tr>
<td>Full-term neonates</td>
<td>85</td>
</tr>
<tr>
<td>Infants</td>
<td>80</td>
</tr>
<tr>
<td>Adult male</td>
<td>75</td>
</tr>
<tr>
<td>Adult female</td>
<td>65</td>
</tr>
</tbody>
</table>
**the amount of blood loss** necessary for the hematocrit to fall to 30% can be calculated as follows:

1. Estimate **blood volume** from .
2. Estimate the red blood cell volume (RBCV) at the preoperative hematocrit (**RBCV preop**).
3. Estimate RBCV at a hematocrit of 30% (**RBCV 30%**), assuming normal blood volume is maintained.
4. Calculate the **RBCV lost** when the hematocrit is 30%; RBCV lost = RBCV preop – RBCV 30%.
5. **Allowable blood loss** = RBCV lost × 3
example: An 85-kg woman has a preoperative hematocrit of 35%. How much blood loss will decrease her hematocrit to 30%?

- Estimated blood volume = 65 mL/kg \times 85 kg = 5525 mL.
- RBCV 35% = 5525 \times 35\% = 1934 mL.
- RBCV 30\% = 5525 \times 30\% = 1658 mL.
- Red cell loss at 30\% = 1934 - 1658 = 276 mL.
- Allowable blood loss = 3 \times 276 mL = 828 mL.
ongoing surgical Losses

1. **Evaporation**:
   This can occur during body cavity surgery or when large areas of tissues are exposed, and here evaporation from exposed viscera is entirely water, but the electrolyte is left behind, leading to a need for free water.

2. **Blood loss**:
   Depends upon the type and site of surgery.

3. **Third space loss**: -->
third space

- first (intravascular) and second (interstitial) spaces are the constituents of the ECF which are normal physiological compartments.
- "third space" is a space in the body where fluid does not normally collect in larger amounts, it's related to and formed from the ECF, examples:
  - peritoneal cavity (e.g. ascites)
  - pleural cavity (e.g. pleural effusion)
  - lumen of the gastrointestinal tract (as in a patient with ileus)
  - swelling of the tissues after surgical trauma or burns.

Replacing third space fluid losses is a (4-6-8 ml/kg/hr) rule:
- 4 for minor trauma (e.g. hernia, tonsillectomy),
- 6 for moderate trauma (e.g. hysterectomy),
- 8 for major trauma (e.g. AAA repair)
<table>
<thead>
<tr>
<th>Time</th>
<th>Compensatory</th>
<th>Deficit</th>
<th>Maintenance</th>
<th>Blood Loss*</th>
<th>Third Space</th>
<th>This Hour*</th>
<th>Cumulative*</th>
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<tbody>
<tr>
<td>Preinduction</td>
<td>350</td>
<td>220</td>
<td>110</td>
<td>0</td>
<td>0</td>
<td>680</td>
<td>680</td>
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<tr>
<td>I-S(^{\dagger})</td>
<td>—</td>
<td>220</td>
<td>110</td>
<td>0</td>
<td>0</td>
<td>330</td>
<td>1010</td>
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<tr>
<td>First hour(^{\dagger})</td>
<td>220</td>
<td>110</td>
<td>300</td>
<td>350</td>
<td>980</td>
<td>1990</td>
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<td>Second hour(^{\dagger})</td>
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<td>350</td>
<td>980</td>
<td>2970</td>
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<tr>
<td>Third hour(^{\dagger})</td>
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<tr>
<td>Fourth hour(^{\dagger})</td>
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<td>0</td>
<td>200</td>
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<td>4110</td>
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</table>

Key assumptions:
- Patient weight = 70 kg, starting hemoglobin 15 g/dL
- Compensatory volume expansion 5 mL/kg
- Maintenance fluids (by 4-2-1 rule) = 110 mL/hour
- Preoperative deficit = maintenance fluid rate × 10 hours NPO
- Crystalloid fluid replacement for 250 mL blood loss = EBL × 3 = 750 mL
- Third space fluid loss = 5 mg/kg/hour for first 3 hours, 3 mg/kg/hour for last hour of surgery
- Patient was hemodynamically stable throughout case, with satisfactory urine output

*Reflects fluid replacement for blood loss.
\(^{\dagger}\)Total fluid administered during the hour.
\(^{\ddagger}\)Grand total since beginning the case.
\(^{\dagger\dagger}\)Induction until intra-abdominal surgical entry (assumed to be 1 hour).
\(^{\ast}\)Operative time.

EBL, estimated blood loss; I-S, induction until intra-abdominal surgical entry (assumed to be 1 hour); NPO, nil per os (fasted).
Liberal versus Restrictive Fluid Management

- routine intraoperative fluid management strategy has been criticized
- ex. in lung surgery: the risk of postpneumonectomy pulmonary edema is clearly associated with the amount of administered fluid
  **As a result, “fluid-conservative” or “dry” fluid strategies are now commonly employed for patients undergoing lung surgery.

- another ex. gastrointestinal surgery: Excessive perioperative fluid administration may also lead to edema of the gastrointestinal tract contributing to ileus
  **perioperative fluid restriction can lead to improved outcomes after major elective gastrointestinal surgery.
Restrictive Fluid Management

There are several approaches to fluid restriction:

** Replacement of blood loss on a “mL per mL” basis with colloid..
** No replacement of third space loss during surgery..
** No fluid loading prior to general anesthesia..
** Postoperative restriction of fluids with administration of diuretics ..
Monitoring Adequacy of Fluid Replacement

**Vital Signs**: BP and HR
- If patient gets hypotensive during surgery, most likely cause is hypovolemia and 1st sign is tachycardia, but Anesthetic drugs can cause hypotension and mask traditional signs of hypovolemia such as tachycardia.

**Urine output**:
- Nl --> 1.0 ml/kg/hr

Decreased intraoperative urine output does not necessarily indicate hypovolemia but could be of help.

**Periodic monitoring of** hemoglobin and hematocrit.

**Invasive monitoring**:
- Central venous pressure (It is a good approximation of right atrial pressure, used as a surrogate for preload, changes in CVP in response to infusions of intravenous fluid have been used to predict volume-responsiveness)
- Transesophageal echocardiography