Fluid Balance And Therapy
Why use iv fluid

• Think about why you're ordering IVF
  - NPO
  - significant volume deficit
  - ongoing loss
  - specific goal to fluid therapy (hydration prior to contrast dye)
• Consider appropriateness of IVF daily in each patient
• Do not use IVF if they are unnecessary, complications: fluid overload, electrolyte disturbance, line infection.
Outline of Talk

- Fluid compartments
- What can go wrong
- Calculating fluid requirements
- Principles of fluid replacement
- Scenarios
Where is the Fluid?
Where is the Fluid?

- 60% of body weight is fluid
- 2/3 is intracellular and 1/3 extracellular
- 2/3 of extracellular is interstitial and 1/3 intravascular
fluid compartments within the body

<table>
<thead>
<tr>
<th>Intracellular fluid</th>
<th>Extracellular fluid</th>
</tr>
</thead>
<tbody>
<tr>
<td>2/3 of TBW</td>
<td>1/3 of TBW</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Intravascular fluid</th>
<th>Interstitial fluid</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/3 of ECF</td>
<td>2/3 of ECF</td>
</tr>
</tbody>
</table>

F | NonF
CSF + J fluid
So for a 70kg person...

- 60% of body weight is fluid (55)
- 2/3 is intracellular and 1/3 extracellular
- 2/3 of extracellular is interstitial and 1/3 intravascular

<table>
<thead>
<tr>
<th></th>
<th>Intravascular</th>
<th>Interstitial</th>
<th>Intracellular</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>5 litres</td>
<td>10 litres</td>
<td>30 litres</td>
</tr>
</tbody>
</table>
Fluid Compartments
• 70 kg male:
• TBW = 42 L
• Intracellular volume = \(0.66 \times 42\) = 28 L
• Extracellular volume = \(0.34 \times 42\) = 14 L

- Interstitial volume = \(0.66 \times 14\) = 9 L
- Intravascular volume = \(0.34 \times 14\) = 5 L
What is normal fluid intake and output?
What is normal fluid intake and output?

**Normal intake**
- Fluid 1400 ml/day
- Food 750 ml/day
- Metabolism 350 ml/day

**Intravascular**
- 5 litres

**Interstitial**
- 10 litres

**Intracellular**
- 30 litres

**Normal Output**
- Renal losses 1500 ml/day
- Insensible losses 500 ml/day
- Skin 500 ml/day
- Lung 400 ml/day
- Faeces 100 ml/day

**Normal intake**
- Fluid 1400 ml/day
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**Intravascular**
- 5 litres

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- 10 litres

**Intracellular**
- 30 litres

**Normal Output**
- Renal losses 1500 ml/day
- Insensible losses 500 ml/day
- Skin 500 ml/day
- Lung 400 ml/day
- Faeces 100 ml/day
What can go Wrong?
What can go wrong?
1. Imbalance between input and output (Volume)

- Intravascular: 5 litres
- Interstitial: 10 litres
- Intracellular: 30 litres

Inadequate or overhydration

XS losses
Vomiting
Diarrhoea
Drains
Fever
Poor Output
Oliguria
What can go wrong?

2. Redistribution

<table>
<thead>
<tr>
<th>Intravascular</th>
<th>Capillary leakage</th>
<th>Plasma oncotic pressure (hypoalbuminemia)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intravascular pressure</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Peripheral +/- pulmonary oedema</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Interstitial
What can go wrong?
3. Osmolar problems

<table>
<thead>
<tr>
<th>Interstitial</th>
<th>Intracellular</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hypertonic fluid causes water to move out of intracellular space</td>
<td>Hypotonic fluid causes water to move into intracellular space</td>
</tr>
</tbody>
</table>

Water moves in and out of intracellular space with changes in extracellular osmolarity.
What can go wrong?

4- concentration

5- composition

6- Acid Base Balance
Purpose of Fluid Replacement

To maintain tissue perfusion by:

1) Maintaining intravascular fluid volume of about 5 litres
2) Correcting any deficits
3) Allowing for ongoing losses
How to Calculate Daily Fluid Requirements

Requirement = Deficit + Maintenance + Ongoing Losses
How to Calculate Daily Fluid Requirements?

- Normal adult requires approximately 35cc/kg/d.
- This assumes normal fluid loss.

- Urine
- Stool
- Insensible
- Watch I/O carefully and be aware of other losses.

- Fever increases insensible loss by 200cc/day for each degree (C).
- Monitor abnormal GI loss e.g. NGT suctioning
Fluid Requirements

“4,2,1” Rule

- First 10 kg = 4cc/kg/hr
- Second 10 kg = 2cc/kg/hr
- 1cc/kg/hr thereafter

In adults remember IVF rate = wt (kg) + 40.

70 + 40 = 110cc/hr

Assumes no significant renal or cardiac disease and NPO.

This is the maintenance IVF rate, it must be adjusted for any dehydration or ongoing fluid loss.

Conversely, if the pt is taking some PO, the IVF rate must be decreased accordingly.

Daily lytes, BUN, Cr, I/O, and if possible, weight should be monitored in patients receiving significant IVF
Electrolyte Requirements

- Potassium: 1 meq/kg/day
- K can be added to IV fluids. Remember this increases osm load.
- 20 meq/L is a common IVF additive.

- Na: 1-3 meq/kg/day
- 70 kg male requires 70-210 meq NaCl, 2600 cc fluid per day
Assessment of volume status

- Hypovolaemic (dehydrated)
- Hypervolaemic (overloaded)
Assessment of Volume Status
– are they dry, wet or euvolaemic?

• History
• Pulse
• BP incl Postural BP
• Skin Turgor
• Mouth Dryness
• Capillary Refill
• JVP
Assessment of Volume Status
– are they dry, wet or euvolaemic?

• Lung bases
• SpO2
• Body Weight
• Urine Output
• Fluid Balance Chart
• Serum Biochem
• Urine Biochem
Assessment of Volume Status
– are they dry, wet or euvolaemic?

- Lung bases
- SpO2
- Body Weight
- Urine Output
- Fluid Balance Chart
- Serum Biochem
- Urine Biochem
Urea:Creatinine Ratio

- Normal Blood Urea = 2-7 mmol/l
- Normal Serum Creatinine = 40-120 umol/l
- Normal Urea:Creatinine Ratio = 60-80:1

- Raised Ratio >100:1 suggests patient dehydrated. Why?
Why U:C Ratio >100:1 suggests Dry

- Both urea and creatinine freely filtered by glomerulus
- Urea reabsorbed passively with Na and water by PCT when dehydrated
- No such mechanism exists for creatinine which instead is secreted by PCT
- This leads to U:C ratio >100:1 when dry
Assessment of volume status

**Hypovolaemic**
(dehydrated)
M – M - S

- Reduced skin turgor
- Dry mouth
- Tachycardia
- Postural fall BP
- Poor cap refill

**Hypervolaemic**
(overloaded)

- Raised JVP
- S3 with functional MR
- Bibasal crackles
- Periph/sacral oedema
- Hypertension
To Determine the appropriate iv fluid you have to:

1- Assess the volume status, maintenance, ongoing losses
2- Determine the access
3- Select the type of fluid
4- Determine the rate
   in adult rate = wt(kg)+40
Composition of Losses

• Vomit is mostly HCl – contains very little K and a lot of chloride (hypokalaemia is due to renal K wasting)

• Diarrhoea is more alkaline – contains quite a lot of K and no chloride
Two Other Things it Helps to Know when Judging Fluid Requirements

Deficit
Maintenance
Ongoing Losses
Cardiac Status
Kidney Function
What Replacement Fluids are Available?
What Replacement Fluids are Available?

Crystalloid

Colloid

Synthetic

Human
What Replacement Fluids are Available?

Crystalloid

- Saline 0.9%
- Hartmanns
- Dextrose 5%
• Crystalloids

• Clear solutions, water & electrolyte, small molecules.

• Good for volume expansion, will cross a semi-permeable membrane into the interstitial space and achieve equilibrium in 2-3 hours.

• 3mL of isotonic crystalloid replace 1mL of patient blood (2/3rds of the solution will leave the vascular space in approx. 1 hour).
• Crystalloids

• **Advantages:**
  1. They are inexpensive.
  2. Easy to store with long shelf life.
  3. Readily available with a very low incidence of adverse reactions.
  4. There are a variety of available formulations that are effective for use as replacement fluids or maintenance fluids.

• **Disadvantage:**

  1. It takes approximately 2-3 x volume of a crystalloid to cause the same intravascular expansion as a single volume of colloid.
  2. Causes peripheral edema.
  3. Dilute plasma proteins.
<table>
<thead>
<tr>
<th>Solution</th>
<th>Na</th>
<th>K</th>
<th>Cl</th>
<th>Ca</th>
<th>Bicarb</th>
<th>Glucos g/l</th>
<th>Tonicity</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.9% Sodium Chloride</td>
<td>154</td>
<td>154</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>isotonic</td>
</tr>
<tr>
<td>Hartmanns</td>
<td>131</td>
<td>111</td>
<td>5</td>
<td>2</td>
<td>29</td>
<td>-</td>
<td>isotonic</td>
</tr>
<tr>
<td>5% Dextrose</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>50</td>
<td>Isotonic hypotonic</td>
</tr>
<tr>
<td>10% Dextrose</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>100</td>
<td>Hypertonic hypotonic</td>
</tr>
<tr>
<td>4% glucose &amp; 0.18% sodium chloride</td>
<td>30</td>
<td>30</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>40</td>
<td>Isotonic</td>
</tr>
<tr>
<td>D5 / 0.45 NS</td>
<td>77</td>
<td>77</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>50</td>
<td>hypertonic</td>
</tr>
<tr>
<td>Solution</td>
<td>Glucose (g/L)</td>
<td>Na⁺</td>
<td>K⁺</td>
<td>Ca⁺²</td>
<td>Cl⁻</td>
<td>Lactate</td>
<td>PO₄⁻³</td>
</tr>
<tr>
<td>--------------------------</td>
<td>---------------</td>
<td>-----</td>
<td>----</td>
<td>------</td>
<td>-----</td>
<td>---------</td>
<td>-------</td>
</tr>
<tr>
<td>5% Dextrose (D₅W)</td>
<td>50</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>10% Dextrose (D₁₀W)</td>
<td>100</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Normal Saline (NS)</td>
<td>0</td>
<td>154</td>
<td>0</td>
<td>0</td>
<td>154</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>D₅NS</td>
<td>50</td>
<td>154</td>
<td>0</td>
<td>0</td>
<td>154</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>D₅½NS</td>
<td>50</td>
<td>77</td>
<td>0</td>
<td>0</td>
<td>77</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>0.2% NS</td>
<td>0</td>
<td>31</td>
<td>0</td>
<td>0</td>
<td>31</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>3% NaCl</td>
<td>0</td>
<td>513</td>
<td>0</td>
<td>0</td>
<td>513</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Ringer's Lactate (LR)</td>
<td>0</td>
<td>130</td>
<td>4</td>
<td>3</td>
<td>109</td>
<td>28</td>
<td>0</td>
</tr>
<tr>
<td>D₅LR</td>
<td>50</td>
<td>130</td>
<td>4</td>
<td>3</td>
<td>109</td>
<td>28</td>
<td>0</td>
</tr>
</tbody>
</table>
• **Colloids**

• Solutions that contain high molecular weight proteins as well as electrolytes, MW > 30,000 daltons.

• Unable to diffuse through normal capillary membranes

• Stay almost entirely in the intravascular space for a prolonged period of time compared to crystalloid.
• **Colloids**

• **Advantages of Colloids:**
  
  1- ↑ plasma volume.
  2- Less peripheral edema.
  3- Smaller volumes for resuscitation.
  4- Intravascular half-life 3-6 hrs.

• **Disadvantages of Colloids:**

  1- Much higher cost than crystalloid solutions.
  2- Small but significant incidence of adverse reactions.
  3- Because of gelatinous properties, these can cause platelet dysfunction and interfere with fibrinolysis and coagulation factors thus possibly causing coagulopathy in large volumes.
  4- These fluids can cause dramatic fluid shifts which can be dangerous if they are not administered in a controlled setting.
<table>
<thead>
<tr>
<th>Solution</th>
<th>Na</th>
<th>Cl</th>
<th>K</th>
<th>Mg</th>
<th>HCO₃⁻</th>
<th>MW Daltons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gelofusine</td>
<td>145</td>
<td>120</td>
<td>0,4</td>
<td>0,4</td>
<td>-</td>
<td>30,000</td>
</tr>
<tr>
<td>Voluven 6%</td>
<td>145</td>
<td>154</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>130,000</td>
</tr>
<tr>
<td>Volulyte 6%</td>
<td>137</td>
<td>110</td>
<td>4</td>
<td>1,5</td>
<td>34 as acetate</td>
<td>130,000</td>
</tr>
</tbody>
</table>
Distribution of IV fluids

- Colloid
- Saline
- Dextrose
## Initial Distribution of IV Fluids (1 Litre)

- H₂O follows ions/molecules to their respective compartments

<table>
<thead>
<tr>
<th>Solution</th>
<th>ECF Intravasc.</th>
<th>ECF Extravasc.</th>
<th>ICF</th>
</tr>
</thead>
<tbody>
<tr>
<td>NS</td>
<td>333</td>
<td>667</td>
<td>0</td>
</tr>
<tr>
<td>1/2 NS</td>
<td>222</td>
<td>445</td>
<td>333</td>
</tr>
<tr>
<td>1/3 NS</td>
<td>185</td>
<td>370</td>
<td>445</td>
</tr>
<tr>
<td>Ringers</td>
<td>333</td>
<td>667</td>
<td>0</td>
</tr>
<tr>
<td>D5W*</td>
<td>111</td>
<td>222</td>
<td>667</td>
</tr>
<tr>
<td>2/3 1/3</td>
<td>135</td>
<td>271</td>
<td>593</td>
</tr>
<tr>
<td>Colloid</td>
<td>1,000</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

*assuming glucose metabolized*
### So What’s in the Fluid?

<table>
<thead>
<tr>
<th>Type</th>
<th>Sodium mmol/l</th>
<th>Potassium mmol/l</th>
<th>Chloride mmol/l</th>
<th>Osmolarity mosm/l</th>
<th>Other per litre</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plasma</td>
<td>136-145</td>
<td>3.5-5.2</td>
<td>98-105</td>
<td>280-300</td>
<td></td>
</tr>
<tr>
<td>Saline 0.9%</td>
<td>154</td>
<td>0</td>
<td>154</td>
<td>308</td>
<td></td>
</tr>
<tr>
<td>Dextrose 5%</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>278</td>
<td>Dextrose 50g</td>
</tr>
<tr>
<td>Hartmann’s</td>
<td>131</td>
<td>5</td>
<td>111</td>
<td>275</td>
<td>Lactate 29mmol</td>
</tr>
<tr>
<td>Gelofusin</td>
<td>154</td>
<td>&lt;0.4</td>
<td>125</td>
<td>290</td>
<td>Gelatin 40g</td>
</tr>
</tbody>
</table>
Where does the Fluid Go?
(Volume of Distribution)

<table>
<thead>
<tr>
<th>Type</th>
<th>Volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intravascular</td>
<td>5 litres</td>
</tr>
<tr>
<td>Interstitial</td>
<td>10 litres</td>
</tr>
<tr>
<td>Intracellular</td>
<td>30 litres</td>
</tr>
</tbody>
</table>

Saline
Gelofusine
Hartmanns
Dextrose 5%
Blood

- Indicated to correct hypovolaemia due to blood loss
- NB Aggressive correction of anemia in critically ill patients does not improve outcome – target Hb 70-90g/l gives same outcomes as target Hb 100-120g/l
• Types:

• There are Three main types of IVF:
  • Isotonic fluids.
  • Hypotonic fluids.
  • Hypertonic Fluids.
Isotonic fluids have a total osmolality close to that of extra cellular fluids (ECF) and don’t cause RBCs to shrink or swell.

• **Isotonic have a tonicity equal to the body plasma. When administered to a normally hydrated patient, isotonic crystalloids do not cause a significant shift of water between the blood vessels and the cells. Thus, there is no (or minimal) osmosis occurring.**

• Helpful with patients who are hypotensive or hypovolemic.

• Examples: NS, RL, D5W(isotonic in the bag, once infused the glucose is utilized leaving just water)
Hypotonic Fluids

- Less osmolarity than serum. (meaning: in general less sodium ion concentration than serum)
- These fluids DILUTE serum thus decreasing osmolarity.
- Water moves from the vascular compartment into the interstitial fluid compartment. Interstitial fluid becomes diluted, osmolarity decreases, water is drawn into adjacent cells.
- Caution with use because sudden fluid shifts from the intravascular space to cells can cause cardiovascular collapse and increased ICP in certain patients.
- Examples: half normal saline 0.45%, 1/3 NS 0.33%, dextrose 2.5% (D2.5W)
Hypertonic Fluids

- These have a higher osmolarity than serum.
- These fluids pull fluid and sometimes electrolytes from the intracellular/interstitial compartments into the intravascular compartments.
- Useful for stabilizing blood pressure, increasing urine output, correcting hypotonic hyponatremia and decreasing edema.
- These can be dangerous in the setting of cell dehydration.
- Examples: 5% dextrose in 0.9% NaCl (D5NS), D5RL, D5 ½ NS, 3% NaCl, 10% dextrose in water (D10W)
Choose the Correct Venflon

IV sizes are identified by the colors of the hub. From left to right in decreasing size, 14 gauge (orange), 16 gauge (gray), 18 gauge (green), 20 gauge (pink), 22 gauge (blue), and (not pictured) 24 gauge (yellow).
Theory of Fluid Flow

- Flow = \( \frac{\text{diameter}^4}{\text{length}} \)
- Larger catheters = higher flow
- Short catheters = somewhat higher flow

- Other factors affecting flow
  - Tubing length
  - Size of Vein
  - Temperature and viscosity of fluid
- Warm fluids flow better than cold
There are 4 types of patients:

1- **Hypovolemic Patient:**
Pneumonia, Sepsis, Hemorrhage, Gastroenteritis.

2- **Hypervolemic Patient:**
CHF, renal failure, cirrhosis.

3- **NPO Patient, surgical patient, euvolemic:**
Awaiting surgery, unsafe swallow.

4- **Eating/drinking normally.**
Hypovolemic patients:

- True volume depletion (hypovolemia):
  • usually refers to a state of combined salt and water loss exceeding intake which leads to ECF volume contraction.
  • ECF volume contraction is manifested as a decreased plasma volume and hypotension.

  • Signs of intravascular volume contraction include decreased jugular venous pressure, postural hypotension, and postural tachycardia.

  • Larger and more acute fluid losses lead to hypovolemic shock and manifest as hypotension, tachycardia, peripheral vasoconstriction, & hypoperfusion.
Treatment of Hypovolemia:

• The goals of treatment is to restore normovolemia with fluid similar in composition to that lost and replace ongoing losses.
• Mild volume losses can be corrected via oral route.
• More severe hypovolemia requires IV therapy.
• Isotonic or Normal Saline (0.9% NaCl) is the choice in normonatremic and mildly hyponatremic patients and should be administered initially in patients with hypotension or shock.
In *Hypernatremic patient*, there is a proportionately greater deficit of water than sodium, therefore to correct this patient you will use a *Hypotonic solution* like $\frac{1}{2}$ NS (0.45% NaCl) or D5W. For The *Hypernatremic Patient*: **STOP THE ONGOING LOSS!**

To Calculate Water Deficit:
- Estimate TBW: 50-60% body weight (KG) depending on body composition (W vs M)
- Calculate Free-Water deficit: $[(Na^+ - 140)/140] \times TBW$
- Administer deficit over 48-72 hrs

**Insensible Losses:**
- Approximately 10mL/kg per day: less if ventilated, more if febrile.
Hypervolemic Patient:

-Avoid additional IVF

-Maintain access IV access with Hep-Lock (A small tube connected to a catheter in a vein in the arm for easy access. It is an alternative in some cases to using an IV. It's called heplock because of the order of medicating using it which is saline, medication, saline then heparin)
NPO Patient now euvolemic

- Administer maintenance fluids. Goal is to maintain input of fluids to keep up with ongoing losses and normal fluid needs
- For average adult NPO for more than 6-12 hours, consider D5 1/2NS at 75-100cc/hr
- Constantly reassess, at least 2x day or with any change
- Don’t give fluids blindly ie: if the patient is pre-procedure but has history of CHF, be CAREFUL!
- The reason for giving dextrose (D5) is to prevent catabolism
- Normal PO Intake:
- No need for fluids if they are taking PO without problems! Avoid IVF
Post-operative patients:

- Pain and narcotics can be powerful stimulants of inappropriate ADH secretion (SIADH)
- Giving hypotonic fluids in this setting can (but usually does not) cause dangerous hyponatremia.
- This makes 0.9% saline a safer fluid but realize that it will also deliver free water in the setting of SIADH. (stay tuned for a future lecture).
Examples

• 35 y/o female NPO for elective lap chole. Afebrile HR 72 BP 120/80 Wt 85 kg. Na 140 K 4.0. Fluid Orders:
•D5 0.45% saline with 20meq KCl @ 125 cc/hr.
Examples

- 89 y/o nursing home pt. admitted for diverticulitis. T 38.0 HR 90 BP 145/85. wt 70 kg Na: 140, K: 3.7. Not eating. Fluid Orders:
  - Basal needs 70 + 40 = 110 cc/hr
  - Additional loss from fever = approx. 10 cc/hr
  - Total rate = 120 cc/hr: IVF?
  - (D5) 0.45% saline with 20 meq KCl
Examples

• 65 y/o male hospitalized with pneumonia. Temp 38.5, HR 72, BP 125/72. Wt 75 kg. Na:165 K: 4.0.

Orders:
• Basal needs 115 cc/hr + 12 cc/hr for fever.
• Also:
  • Free water deficit of (.6)(75)\[(165/140) – 1\] = 7.6 liters.
  • IV # 1: 0.45% saline @ 130 cc/hr.
  • IV # 2: D5W @ 150cc/hr for 50 hrs.