Principles of Infusion Therapy: Fluids

Christie Heinzman, MSN, APRN-CNP
Acute Care Pediatric Nurse Practitioner
Cincinnati Children's Hospital Medical Center

May 22, 2018

INS2018

Conflict of Interest Disclosure

No conflict of interest exists

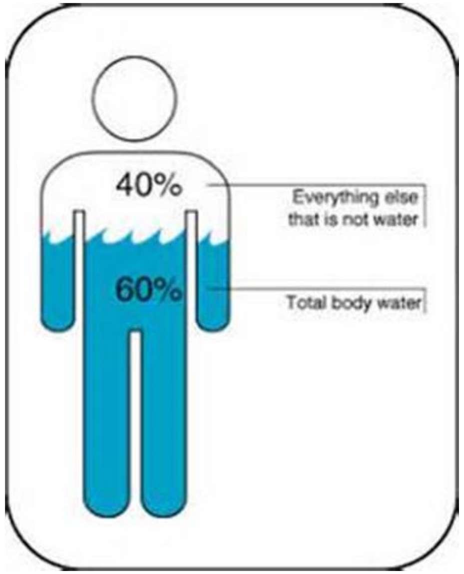
Objectives

- Discuss hydration and calculating maintenance fluid needs
- Discuss methods to assess fluid status
- Review types of intravenous fluids
- Review rehydration management

Total body water contents

- Percentage of total body water depends on age, gender, weight and percent of body fat
  - Average male 60% TBW
  - Average female 50% TBW

- 3 fluid compartments
  - Intracellular
  - Extracellular
  - Transcellular



INS2018

The need for water…

- The average person drinks water or water containing fluids throughout the day in response to an intact thirst mechanism

- In the person relying solely on IVF for hydration, the thirst mechanism has been bypassed so the prescriber must calculate their needs

INS2018

Calculating IVF: what you need to know

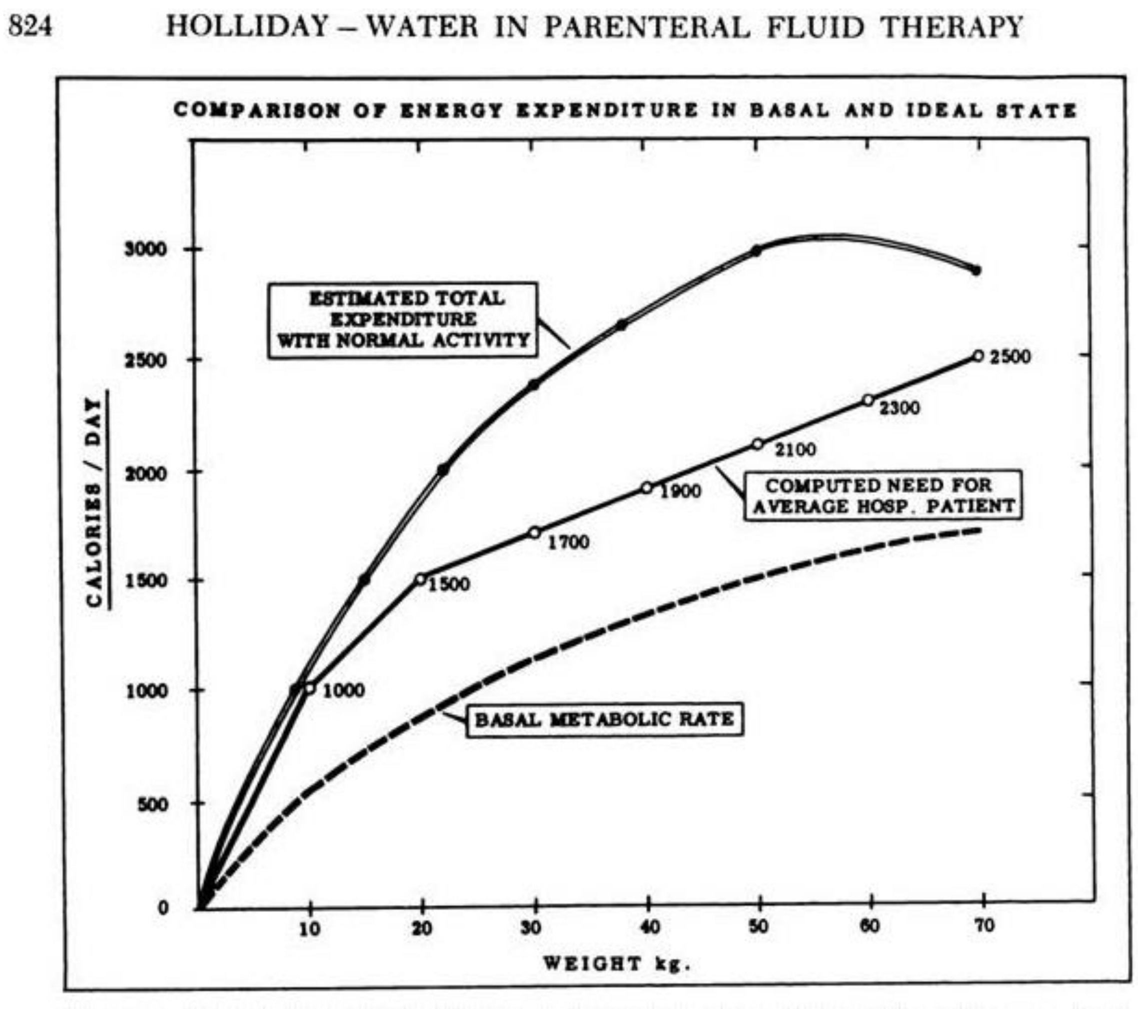
- Patient age
- Patient weight
- Underlying health condition
- Sensible losses
- Insensible losses

Calculating IVF:
how much should you give them?

- Several methods to determine maintenance fluid requirements
  - Holliday-Segar method
  - 4-2-1 method
  - Body surface area (BSA) method

Holliday-Segar Method

- Water loss and therefore water requirement is a function of caloric expenditure.
- Total daily water requirement to replace insensible and urinary water loss in the hospitalized patient is approximately 100 mL/100 kcal/day. This means that for every 100 kcal burned, the patient utilizes 100 mL of fluid.
- Caloric expenditure, and therefore the water requirement, for the hospitalized patient can be estimated from the nomogram shown here.
- Not appropriate for neonates <14 days old



Source: Holliday, M. A., & Segar, W. E. (1957). The maintenance need for water in parenteral fluid therapy. *Pediatrics*, *19*(5), 823-832.

INS2018

Holliday-Segar Method

- 100 mL for each of the first 10 kg of weight PLUS
- 50 mL for each of the second 10 kg of weight PLUS
- 20 mL for each additional kg of weight over 20 kg = 24 hour goal
- Divide by 24 to get hourly infusion rate

Example:

- Calculate the hourly maintenance fluid rate for a child who weighs 25 kg
- (100 mL x 10 kg) + (50 mL x 10 kg) + (20 mL x 5 kg) / 24 hours

  (1000mL) + (500mL) + (100mL) = 1600mL / 24 hours = 66.7 mL/hr

  Using the formula method, the hourly rate for this child is 67 mL/hr

INS2018

4/2/1 Method

- 4 mL/kg for the first 10 kg of weight PLUS
- 2 mL/kg for kg 11-20 PLUS
- 1 mL/kg for every kg above 20 kg = hourly rate

Example

- Calculate the hourly maintenance fluid rate for a child who weighs 25 kg
- (4 mL x 10 kg) + (2 mL x 10 kg) + (1 mL x 5 kg) = hourly rate

(40 mL) + (20 mL) + (5 mL) = 65 mL/hr

Using the 4/2/1 method, this child's hourly maintenance fluid rate is 65 mL/hr

INS2018

BSA Method

- Based on the assumption that caloric expenditure is related to BSA, but should not be used for children <10 kg

- BSA equation

$$\text{surface area (m2)} = \frac{\text{height (cm)} \times \text{weight (kg)}}{3600}$$

- Standard values for use in BSA Method
  - 1500 mL/m^2/24 hours

INS2018

Assessment of fluid status

- Assessment of hydration based on physical exam & history
- Fluid deficit based on pre-illness weight and illness weight
- Percent dehydration based on pre-illness and illness weight

INS2018

Assessment of fluid status

- Head to toe physical exam
  - Airway/breathing
  - Circulation
  - Neurological
  - Gastrointestinal
  - Genitourinary
  - Fluid losses

Clinical Observations in Dehydration			
Older child	3% weight loss	6% weight loss	9% weight loss
Infant	5% weight loss	10% weight loss	15% weight loss
Examination			
Dehydration	Mild	Moderate	Sever
Skin tugor	Normal	Tenting	None
Skin (touch)	Normal	Dry	Clammy
Buccal mucosa/lips	Moist	Dry	Parched/Cracked
Eyes	Normal	Deep set	Sunken
Tears	Present	Reduced	Absent
Fontanelle	Flat	Soft	Sunken
CNS	Consolable	Irritable	Lethargic/obtunded
Pulse rate	Normal	Slightly increased	Increased
Pulse quality	Normal	Weak	Feeble/impalpable
Capillary refill	Normal	~ 2 seconds	> 3 seconds
Urine Output	Normal	Decreased	Anuric

Source: Custer, J. W., & Rau, R. E. (2008). *The Harriet Lane Handbook: Mobile Medicine Series-Expert Consult*. Elsevier Health Sciences.

INS2018

Potential GI volume and electrolyte losses

Source	Volume (mL/day)	Na^+ (meq/L)	K^+ (meq/L)	Cl^- (meq/L)	HCO_3^- (meq/L)
Saliva	1500	10	26	10	30
Stomach	1500	60	10	130	0
Duodenum	Variable	140	5	80	0
Ileum	3000	140	5	104	30
Colon	Variable	60	30	40	0
Pancreas	Variable	140	5	75	115
Bile	Variable	145	5	100	35

Canada, T., Tajchman, S. K., Tucker, A. M., & Ybarra, J. V. (2015). The ASPEN Fluids, Electrolytes, and Acid-Base Disorders Handbook.

INS2018

Assessment of fluid status

- Fluid deficit based on pre-illness weight

  Fluid deficit (L) = pre-illness weight (kg) - illness weight (kg)

Example

- Calculate fluid deficit for a child with a pre-illness weight 40 kg and illness weight of 37 kg

  Fluid deficit (L) = 40 kg – 37 kg

  Fluid deficit = 3 liters

INS2018

Assessment of fluid status

Percentage of dehydration based on pre-illness and illness weight

- Percent dehydration = $\frac{\text{(pre-illness weight – illness weight)}}{\text{pre-illness weight}} \times 100\%$

Example

- Calculate fluid deficit for a child with a pre-illness weight 40 kg and illness weight of 37 kg
- Percentage dehydration = (40 kg- 37 kg) / 40 kg x 100%

  3 kg/4 kg

  7.5% percentage dehydration

INS2018

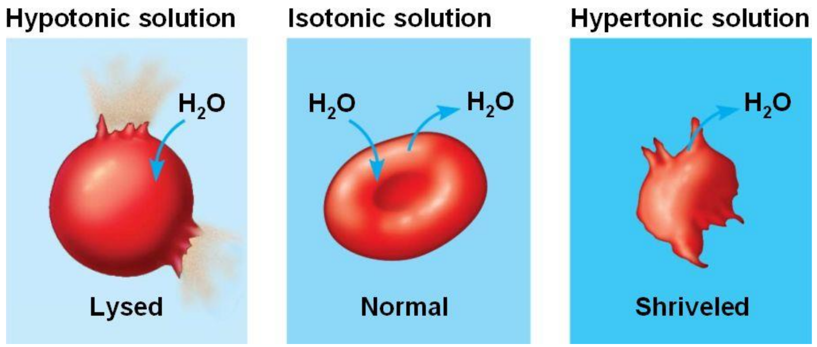
Types of IV fluids

- Crystalloid fluids
- Colloid fluids
- Free water solutions

INS2018

Crystalloid fluids

- Crystalloid fluids are a hydration solution containing only electrolytes that can pass through a semi-permeable membrane
- Can be stored at room temperature
- Categorized by tonicity
  - Hypotonic
  - Isotonic
  - Hypertonic



INS2018

Hypotonic solutions

- Hypotonic solutions have a lower tonicity than ICF because it has a lower solute concentration
- ICF become more concentrated as it pulls water from the ECF, resulting in cellular edema
- Used to provide free water and treat cellular dehydration

Examples

- 0.33% NaCl
- 0.45% NaCl
- 2.5% dextrose in water

Isotonic solutions

- Isotonic solutions have a concentration of dissolved particles or tonicity equal to the ICF
- Osmotic pressure is equal in both the ICF and ECF
- There is no water displacement, thus no effect on the cell
- Used to re-establish vascular volume

Examples

- 0.9% NS
- D5% W
- LR

INS2018

Hypertonic solutions

- Hypertonic solutions have a higher tonicity than the ICF because they have a higher solute concentration
- ICF becomes even less concentrated as fluids are pulled by osmotic pressure from the ICF into the ECF resulting in cell shrinkage
- Used for patients with hyponatremia and edema

Examples

- D5% NS
- D5% 1/2NS
- D5% LR
- D10%W

Most commonly used crystalloid fluids

- Normal saline
- D5% containing fluids
- Lactated Ringers

Normal Saline

- Normal saline (0.9%) is the most commonly used crystalloid solution globally, especially in the United States
- Contains equal concentrations of sodium and chloride, making it an isotonic solution with an osmolality close to plasma
- Used to correct hypovolemia but can result in hyperchloremic metabolic acidosis if too much is given
- Also available in hypotonic (<0.9%) or hypertonic (>0.9%) concentrations

Source: Myburgh, J. A., & Mythen, M. G. (2013). Resuscitation fluids. *New England Journal of Medicine*, *369*(13), 1243-1251.

INS2018

D5% containing fluids

- Used to correct volume depletion and for maintenance fluids
- D5% commonly added to fluids containing less than 0.9% NS
  - Any solution with less than 0.9% NS is hyper-osmolar. Rapid infusion of a hyperosmolar fluid can cause an osmolar water shift into the cells and lead to detrimental effects, such as hemolysis. Adding D5% changes the osmolality to equal or just higher than plasma regardless of the salt concentration.
  - Adding D5% to the solution will provide some calories and reduce risk of catabolism

Lactated Ringers

- Used to counteract or prevent metabolic acidosis
- An isotonic solution that contains Na, K, Ca, and lactate
- Available with or without dextrose (5%)
- Lactate is metabolized by the liver to form bicarbonate

Colloid fluids

- Colloid fluids are solutions that often contain complex and large molecules that cannot freely pass a semi-permeable membrane
- Also known as plasma expanders
- Draw fluid into the intravascular space via oncotic pressure
- Any fluid that contains a protein is colloidal
- Generally require refrigeration and can only be stored for a limited period of time

Most commonly used colloid fluids

- Blood products including: albumin, whole blood, packed red blood cells, fresh frozen plasma, cryoprecipitate, platelets, and albumin
- Hetastarch
- Pentastarch

INS2018

Hetastarch

- An artificial colloid pharmacologically classified as a plasma volume expander; used for hypovolemia when plasma volume expansion is desired
- Not a substitute for blood products or plasma
- The amount usually administered for adults is 500 to 1000 mL. Higher doses have been reported in postoperative and trauma patients where severe blood loss has occurred
- AVOID in critically ill adult patients, including patients with sepsis, due to increased risk of mortality and renal replacement therapy and in patients with severe liver disease, pre-existing coagulation or bleeding disorders
- Efficacy and safety not established in pediatrics

Pentastarch

- Used for plasma volume expansion as an adjunct in the management of shock due to hemorrhage, surgery, sepsis, burns or other trauma.
- Not a substitute for red blood cells or coagulation factors in plasma.
- Max dose: 2000 mL per day (adults)
- AVOID in patients with hypersensitivity to hydroxyethyl starch or with bleeding disorders, congestive heart failure, or renal disease with oliguria or anuria not related to hypovolemia
- Efficacy and safety not established in pediatrics

INS2018

Free water solutions

- Provide water that is not bound by macromolecules or organelles, free to pass a semi-permeable membrane

Examples

- D5%W
- D10%W
- D20%W
- D50%W

INS2018

Rehydration Management: what you need to know

- Age and weight (approximate in emergency situations)
- Degree of dehydration
- Labs – specifically serum Na level

Rehydration Management: Resuscitation for severe dehydration/shock

- Assess degree of dehydration using of the methods described
- Administer 20 mL/kg 0.9% NS or LR bolus push/pull
- Repeat bolus up to 40-60 mL/kg total then consider colloid (albumin, blood, or plasma) if additional fluids needed
- Assess vital signs and tissue perfusion throughout resuscitation

Source: The Pocket 2012-2013, CCHMC

Rehydration Management: Isonatremic dehydration

- Isonatremic dehydration – serum Na 130-149 mEq/L
- Implies proportional Na and water losses
- Assess severity of dehydration and resuscitate first as discussed on prior slide

Isonatremic dehydration rehydration plan

<u>Replacements</u>

- Total 24 hour fluid/water deficit replacement volume
  - (% dehydration x pre-illness wt) – volume given during resuscitation=___L; choose IVF and replace over 24 hours

- Total 24 hour Na deficit=fluid deficit (L) x (% fluid deficit from ECF) x 145 mEq/L = ___ mEq
  - (% fluid from ECF is 0.2 if symptoms < 3 days and 0.6 if symptoms > 3 days)

- Total 24 hour K deficit = fluid deficit (L) x (% fluid deficit from ICF) x 150 mEq/L = ___ mEq
  - (% fluid from ICF is 0.2 if symptoms < 3 days and 0.4 if symptoms > 3 days)

INS2018

Isonatremic dehydration rehydration plan

	Fluid/Water	Na	K	Rate
1st 8 hours	1/3 maintenance L and 1/2 deficit L	1/3 maintenance mEq and 1/2 deficit mEq	1/3 maintenance and 1/2 deficit mEq	• Combine 1/3 maintenance and 1/2 deficit then divide by 8 hours = mL/hr • %Na = mEq Na/water volume (L) – choose closest available mEq • mEq/L KCL = divide mEq by water volume (L)
Next 16 hours	2/3 maintenance L and 1/2 deficit L	2/3 maintenance and 1/2 deficit mEq	2/3 maintenance and 1/2 deficit mEq	• Combine 2/3 maintenance and 1/2 deficit then divide by 16 hours = mL/hr • %Na = mEq Na/water volume (L) – choose closest available mEq • mEq/L KCL = divide mEq by water volume (L)

*In general, D5 ½ NS 20 mEq/L KCL is an effective fluid choice for most clinical scenarios. Do not give KCL until patient voids.

Rehydration Management: Hyponatremic dehydration

- Hyponatremic dehydration – serum Na <130 mEq/L
- Implies losses of Na in excess of water
- Treat hyponatremic seizures with a 5 mL/kg bolus of 3% saline

Rehydration Management: Hyponatremic dehydration

Replacements

- Total 24 hour fluid/water deficit replacement volume
  - (% dehydration x pre-illness wt) – volume given during resuscitation=___L; choose IVF and replace over 24 hours
- Total Na deficit (for HYPOnatremic dehydration, you need 2 calculations)
  - Na deficit due to dehydration =fluid deficit (L) x (% fluid deficit from ECF) x 145 mEq/L = ___ mEq (% fluid from ECF is 0.2 if symptoms < 3 days and 0.6 if symptoms > 3 days)
  - Excess Na deficit – current weight (kg) x (desired Na – initial Na) = ___ mEq (generally not necessary to correct Na to above 135 – set desired at 135 mEq/L)
- Total 24 hour K deficit = fluid deficit (L) x (% fluid deficit from ICF) x 150 mEq/L = ___ mEq
  - (% fluid from ICF is 0.2 if symptoms < 3 days and 0.4 if symptoms > 3 days)
- Correct Na by no more than 12 mEq/L over 24 hours, if < 120 mEq correct over 28-72 hours

INS2018

Rehydration Management: Hyponatremic Dehydration

	Fluid/Water,	Na	K	Rate
1st 8 hours	1/3 maintenance L and 1/2 deficit L	1/3 maintenance mEq and 1/2 total Na deficit mEq	1/3 maintenance and 1/2 deficit mEq	• Combine 1/3 maintenance volume and 1/2 deficit volume, then divide by 8 hours = mL/hr • %Na = mEq Na/water volume (L) – choose closest available mEq • mEq/L KCL = divide mEq by water volume (L)
Next 16 hours	2/3 maintenance L and 1/2 deficit L	1/3 maintenance mEq and 1/2 total Na deficit mEq	2/3 maintenance mEq and 1/2 deficit mEq	• Combine 2/3 maintenance volume and 1/2 deficit volume, then divide by 16 hours = mL/hr • %Na = mEq Na/water volume (L) – choose closest available mEq • mEq/L KCL = divide mEq by water volume (L)

Rehydration Management: Hypernatremic Dehydration

- Hypernatremic dehydration – serum Na >149 mEq/L
- Implies water losses in excess of Na losses
- Calculate 24 hour maintenance water, Na, and K

Rehydration Management: Hypernatremic Dehydration

Replacements

- 1st calculate **free water deficit** = 4 mL/kg (3 mL/kg if Na >170) x weight (kg) x (current Na – desired Na)
    - Note 4 mL/kg water is needed to decrease Na by 1 mEq/L, 3 mL/kg if Na >170
    - Desired Na is usually 145, unless Na is >160 then use (current Na – 15).
    - Only correct by 15 mEq/L per day

- 2nd calculate **solute fluid deficit** = total fluid deficit – free water deficit = ___ L

- Solute Na deficit = solute fluid deficit (L) x (% fluid deficit from ECF) x 145 mEq/L = __ L
    - (% fluid from ECF is 0.8 if symptoms <3 days and 0.6 if > 3 days)

- Solute K deficit = solute fluid deficit (L) x (% fluid deficit from ICF) x 150 mEq/L = ___L
    - (% fluid from ICF is 0.2 if symptoms < 3 days and 0.4 if symptoms > 3 days)

INS2018

Rehydration Management: Hypernatremic Dehydration

	Fluid/Water,	Na	K	Rate
1st 24 hours	24 hour maintenance L and 1/2 free water deficit plus solute fluid deficit	24 hour maintenance mEq and solute Na deficit	24 hour maintenance and solute K deficit	• Combine 24 hour maintenance volume and 1/2 free water deficit volume and plus solute fluid deficit, then divide by 24 hours = mL/hr • %Na = mEq Na/water volume (L) – choose closest available mEq • mEq/L KCL = divide mEq by water volume (L)
Next 24 hours	24 hour maintenance L and 1/2 deficit L	24 hour maintenance mEq	24 hour maintenance mEq	• Combine 24 hour maintenance volume and 1/2 deficit volume, then divide by 24 hours = mL/hr • %Na = mEq Na/water volume (L) – choose closest available mEq • mEq/L KCL = divide mEq by water volume (L)

- Follow serum Na closely, adjust fluid rate and composition appropriately
- Avoid decreasing serum Na by >15 mEq/L per 24 hour period
- Remember to account for Na content in initial NS/LR boluses

Initial serum Na	Time to correct
145-157	24 hours
158-170	48 hours
171-183	72 hours

References

Canada, T., Tajchman, S. K., Tucker, A. M., & Ybarra, J. V. (2015). The ASPEN Fluids, Electrolytes, and Acid-Base Disorders Handbook.

Custer, J. W., & Rau, R. E. (2008). *The Harriet Lane Handbook: Mobile Medicine Series-Expert Consult*. Elsevier Health Sciences.

Dehydration in Children. (2017). Fluid and Electrolyte Therapy. Core Concepts in Pediatrics, 2nd edition. Retrieved from https://www.utmb.edu/Pedi_Ed/CoreV2/Fluids/index.html.

Holliday, M. A., & Segar, W. E. (1957). The maintenance need for water in parenteral fluid therapy. *Pediatrics*, *19*(5), 823-832.

Myburgh, J. A., & Mythen, M. G. (2013). Resuscitation fluids. *New England Journal of Medicine*, *369*(13), 1243-1251.

The Pocket 2012-2013, Cincinnati Children's Hospital Medical Center.

INS2018