Fluid Therapy: The Basics and Beyond

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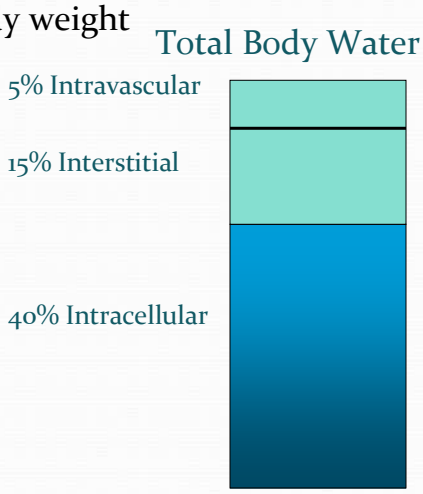
Outline

- Fluid physiology and movement
- Types of fluids: crystalloids and colloids
- Fluid prescription
  - Route
  - Type
  - Rate
- Goals of therapy and treatment strategies
  - Resuscitation
  - Dehydration
  - Maintenance
- Case examples

Fluid Physiology

- Total body water = 60% body weight
  - 40% intracellular
  - 20% extracellular
    - 5% plasma
    - 15% interstitial fluid
- 20kg dog:
  - 12L water
    - 8L intracellular
    - 2L extracellular
      - 1L plasma
      - 3L interstitial fluid



Fluid Composition

- Water = major component of all body fluids
  - Moves freely and equilibrates between most compartments
- Solutes differ across compartments
  - Electrolytes, proteins, minerals, etc
  - Intracellular concentrations controlled by membrane pumps
  - Similar concentrations in extracellular compartments
  - Differences affect water movement
    - Fluid shifts in order to maintain isotonicity

Extracellular Fluid Movement

- Starling's Law:
  - Fluid flux mediated by colloidal and hydrostatic pressure differences between compartments
- Colloid oncotic pressure (COP)
  - Larger molecules that do not cross vascular membrane
    - Albumin*, globulin, fibrinogen
- Hydrostatic pressure
  - Pressure exerted by fluid itself
- Vascular permeability

$$J_V = K_f [(P_c - P_i) - \sigma(\pi_c - \pi_i)]$$

Starling's Law

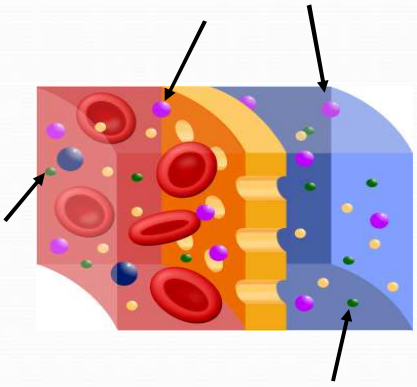
- Factors favoring extravasation of fluid:
  - Decreased plasma COP
  - Increased vascular hydrostatic pressure
  - Increased capillary permeability
  - Decreased lymphatic drainage
- Factors favoring resorption/retention plasma volume:
  - Increased plasma COP
  - Decreased vascular hydrostatic pressure

Types of Fluids

- Crystalloids
  - Contain electrolytes and non-electrolyte solutes capable of entering all body fluid compartments
  - Effects mainly on interstitial and intracellular environment
  - Colloids
  - Large molecular weight substances
  - Effects mainly on intravascular compartment

Crystalloids

- Freely permeable to vascular membrane
- Distribute mainly to interstitial space
- Only 25-30% of infused volume remains intravascular at 1 hour
  - Larger volumes needed to achieve desired effects on blood volume



Crystalloids - Isotonic

- Distribute to vascular and interstitial compartments
- Balanced: composition similar to ECF
  - LRS, Norm R, Plyte 148
- Unbalanced: composition differs from ECF
  - 0.9% NaCl
- Replacement: balanced electrolyte solution with composition similar to ECF
  - LRS, Norm R, Plyte 148
- Maintenance: composition similar to intracellular environment
  - Lower Na and higher K
  - Monitor for hyperchloremia with use
  - Norm M, Plyte M

Crystalloids - Hypertonic

- Increase plasma osmolarity
  - 7-9% NaCl
    - 2400mOsmol/Kg
  - Rapid but temporary fluid shift from interstitium to intravascular space
  - Increase plasma vol by 3.5 times infused volume
  - Must give concurrent isotonic crystalloids with dehydration present
  - Avoid in hypernatremic animals
  - Care with heart disease

Crystalloids - Hypotonic

- Low Na or osmolarity
- Do not give rapidly or as replacement fluids
  - RBC lysis
- Use for treatment hypernatremia, hyperosmolarity, congestive heart failure
  - 0.45% NaCl

Crystalloids – Dextrose

- Osmolarity dependent on concentration of dextrose
  - 2.5% = 125mOsm/Kg (hypotonic)
  - 6% = 300mOsm/Kg (isotonic)
  - 50% = 2500mOsm/Kg (very hypertonic)
- Glucose quickly metabolized
  - Equates to administration of free water
  - All concentrations behave as hypotonic fluid in body
  - Not for rapid administration
- Replacement of free water losses – 5% dextrose
- Supplementation of blood glucose – addition of 50% dextrose to other BES

Crystalloids

Advantages:

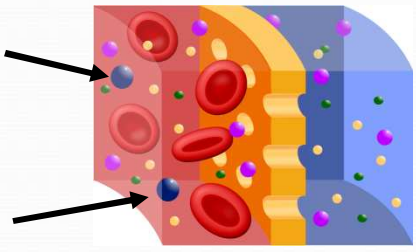
- Easily available
- Inexpensive
- Distribute to intravascular and interstitial spaces
  - Only fluids to replace interstitial fluid
- Minimal side effects

Disadvantages:

- Limited duration of volume expansion
  - 25% remain intravascular space after 1 hour
  - Remaining interstitial
- Risk of hemodilution
  - RBC, proteins
- No oncotic support
  - Increased tendency for tissue edema formation

Colloids

- Molecules larger molecular weight, held within vasculature
- Greater volume expansion over time per volume infused compared to crystalloid
- Typically >85% remains intravascular at 1 hour
- Maintain COP



Natural Colloids

- Plasma
  - Species specific
  - Contains albumin, coagulation factors, antithrombin, proteases, macroglobulins
    - 2.5-3.0g/dL albumin
  - 22ml/kg to raise serum albumin 0.5g/dL
    - 20kg dog needs 440ml
  - COP = 20mmHg (normal = 30mmHg)
  - Not effective colloid, especially larger dogs
- Human albumin
  - Risks of immune reactions
- Canine albumin
  - Newer product, minimal research
  - Efficacy? Safety?

Synthetic Colloids

- Dextrans
  - Dextran 70
- Hydroxyethyl starches
  - 6% hetastarch
  - Suspended in 0.9% NaCl or LRS
- Contain molecules with a wide range of molecular weight
  - Few thousand to several billion Daltons
- Variable effectiveness and pharmacokinetics
  - Individual parameters, MW range, chemical substitutions

Colloids

Advantages:

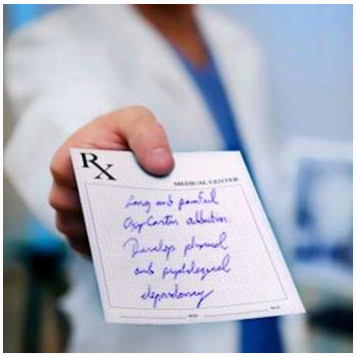
- Prolonged and greater intravascular effect
- Small volume infusions
- Oncotic support
  - Less tendency for tissue edema formation

Disadvantages:

- Side effects
  - Coagulopathies
    - FVIII and vWf
    - Platelets
    - Clot stabilization
  - Allergic reactions
- Cost
  - Leakage with vascular permeability, increased edema risk
  - Negative feedback on liver for albumin synthesis

Fluid Prescription

- Fluids require a prescription plan for administration
- Determine: how, what, how fast and when to change



Route of Fluid Administration

- Subcutaneous
  - Stable, mildly dehydrated patients
- Intravenous
  - Allows rapid dispersion water and electrolytes
  - Resuscitation, rehydration and maintenance
  - Various access points, catheter types
- Intraosseous
  - Especially useful in neonates
  - Resuscitation, rehydration and maintenance

Choosing Fluid Type

- Dependent on:
  - Nature of disease and composition of fluid lost
  - Acid-base and electrolyte disturbances
- If shock present: replacement fluids
- If low COP or low volume resuscitation necessary: colloid or colloid/hypertonic saline combination
- If neither: BES to replace any deficit and provide maintenance therapy

Choosing Fluid Type - Crystalloids

- 0.9% Saline
  - Potassium free
  - Can result in hyperchloremic metabolic acidosis
- LRS
  - Lactate metabolized by liver for mild alkalinizing effect
  - Avoid in DKA, severe liver disease, lymphoma
  - Use for neonates, botulism, neuromuscular disorder
- Normosol R and Plasmalyte 148
  - Acetate metabolized by muscle for more alkalinizing effect than LRS
  - Avoid with diseases of neuromuscular blockade

Choosing Fluid Type - Crystalloids

- Hypertonic saline
  - Good for rapid, transient expansion of plasma volume
  - Avoid multiple boluses
  - Advantages:
    - Increase myocardial contractility
    - Vasodilation, improved blood viscosity
    - Anti-inflammatory effects
    - Decreased intracranial pressure
  - Disadvantages:
    - Avoid with hypernatremia and hyperosmolarity
    - Must use with crystalloids when dehydration present

Choosing Fluid Type - Colloids

- Colloid
  - Good for rapid, more lasting expansion of plasma volume
  - Isosmotic – no effect intracellular composition
  - Potential extravasation with worsening of edema when altered vascular integrity
  - Careful use in patients with pre-existing coagulopathy

Goals of Fluid Therapy

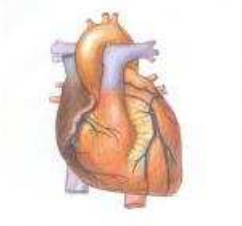
- Restore and maintain adequate systemic hemodynamics and microcirculation to ensure proper nutrient delivery to cells
  - Keep blood flowing!
- Supportive only – underlying disease process must be identified and treated
- 3 Phases:
  - Resuscitation
  - Rehydration
  - Maintenance

Resuscitation

- Circulatory shock:
  - Inadequate perfusion to meet tissue metabolic oxygen demand
    - Not enough oxygen to cells
- Treatment = expansion of intravascular space to correct perfusion deficits
- Goal = improve oxygen delivery to cells
  - IVF therapy paramount

Circulatory Shock

- Types:
  - Hypovolemic: decrease circulating blood volume
  - Distributive: maldistribution of intravascular volume
  - Obstructive: physical obstruction to blood flow
  - Cardiogenic: decrease in forward flow from heart
- All fluid responsive except cardiogenic



Stages of Shock

- Compensatory:
  - Sympathetic response sufficient to stabilize
  - Best time to start treatment
- Early decompensatory:
  - Compensatory mechanism start to fail
  - Still responsive to resuscitation
- Late decompensatory:
  - Prolonged tissue hypoxia produces organ malfunction and cardiovascular collapse
  - Unresponsive to resuscitation

Assessing Perfusion

- Heart rate
- Capillary refill time
- Mucous membrane color
- Pulse quality
- Mentation
- Extremity temperature
- Body temperature
- Blood pressure
- Urine output
- Blood lactate
- Acid-base status
- Central venous pressure
- Mixed venous oxygen

Differentiating Stages

Parameter	Compensatory	Early Decomp	Late Decomp
HR	Inc	Inc	Norm to dec
CRT	<1	>2	>2
MM	Bright pk; red	Pale pink	Gray; white
Pulse quality	strong; bounding	Weak	Absent
Mentation	Alert	Depressed	Depressed; coma
Extremity temp	Norm	Cool	Cold
Body temp	Norm to inc	Norm to dec	Dec
BP	Norm to inc	Norm to dec	Dec
Lactate	Norm to inc	Norm to inc	Inc
UOP	Norm to inc	Dec	Dec
CVP	Norm to inc	Dec	Dec

Shock Fluid Therapy

- Goal: restore effective circulating volume
- Isotonic crystalloids:
  - Dog = 45-90ml/kg; Cat = 30-60ml/kg
  - Standard: start with ¼ to 1/3 shock dose over 20-30 mins, **reassess** and repeat prn
- Hypertonic crystalloids:
  - 4-6ml/kg
- Colloids:
  - Dog = 5-20ml/kg; Cat = 5-10ml/kg
  - Dec crystalloid volume by 25-33% if adding colloids
- Combination: 1/3 hypertonic + 2/3 colloid
  - Total 7-10ml/kg

Key to Shock Treatment

- REASSESS
  - Every 5 to 20 minutes initially
- Adjust treatment as appropriate
- REASSESS again until stable
  - Normalization of monitoring parameters

Hemorrhagic Shock

- Aggressive fluid resuscitation may harm
  - Increase intravascular hydrostatic pressure
  - Dislodgement of blood clots
  - Dilution of oxygen carrying capacity (RBC) and coagulation factors
- Ideal to control hemorrhage first
  - External
- Not always possible prior to stabilization
  - Internal

Hypotensive Resuscitation

- Fluid resuscitation to subnormal but acceptable blood pressure
  - Systolic = 60-90mmHg
- No "right" amount of fluid administration
  - Start slow (5-10ml/kg bolus crystalloids)
  - Close monitoring
  - Repeat as necessary

Low Volume Resuscitation

- Resuscitation with lower volumes more effective fluids
- Use of hypertonic or colloidal solutions
  - Hypertonic saline: 3-5ml/kg
  - Hetastarch: 5-20ml/kg
  - Hypertonic/HES (1:2): 7-10ml/kg
- Avoid excess crystalloid volume administration
  - Minimize tissue edema and hydrostatic pressure

Rehydration

- Dehydration = loss of interstitial fluid
- Isotonic fluid loss
  - Deplete ECF
  - Can lead to hypovolemia
  - No effect ICF
- Hypotonic fluid loss
  - Loss of free water
  - Hypernatremia results
  - Water moves out of ICF
- Hypertonic fluid loss
  - Loss of high solute fluid (Na)
  - Hyponatremia results
  - Water moves into ICF

Assessing Dehydration

- Physical exam:
  - Skin turgor, mm moistness, CRT, ocular position, heart rate, pulse pressure, body weight
    - Confounding factors that can affect: age, obesity, recent weight loss, panting, nausea, stress, pain, etc
- Laboratory:
  - PCV/TS, urine specific gravity

Estimating Dehydration

% Dehydration	Clinical signs
<5	No abnormalities
5-6	Mild dec skin turgor, dry mm
6-8	Dec skin turgor, tacky mm, inc CRT
8-10	Skin stays tented, sunken eyes
10-12	Early signs of shock
12-15	Definite shock, death imminent

Replacing Deficits

- Estimate degree of dehydration
  - % dehydration x body weight (kg) = L deficit
- Determine time to replace
  - Acute losses: faster replacement
    - 4-8 hours
  - Chronic losses: slower replacement
    - 8-24 hours
  - Caution with heart and kidney disease
- Monitor effect
  - Repeat PE, body weight, laboratory values
  - REASSESS and adjust prn

Maintenance

- Daily fluid needed to maintain zero fluid balance
- Sustain intracellular compartment
- Difficult to estimate, especially sick animals
- Standard = 40-60ml/kg/day
  - Based on lean body mass
- Decreased needs older, larger animals
- Can be affected by diet
  - Water needed to excrete solutes in urine
  - Anorexia = less solutes to excrete , decreased fluid needs

Important Points

- Determine what you are treating
  - Shock, dehydration or maintenance needs
- Choose a route
  - IV appropriate for most ill patients, necessary for any patient with shock
- Choose a fluid type
  - BES generally safe and appropriate
  - Hypertonic saline for resuscitation
  - Colloid for resuscitation and COP support
- Choose a rate
- REASSESS!!

Case 1: Maggie

- 2yr FS Lab
- HBC 20 mins prior
- Walks in, tail wagging
- HR=160bpm; systolic BP=180mmHg; strong femoral pulses
- MM dark pink, CRT <1sec, mm moist

Case 1: Maggie

- Assessment:
  - Circulatory shock, compensatory stage
- Treatment:
  - IVC with bolus Norm R 20-30ml/kg over 30 mins
  - Analgesia
- Reassess:
  - HR=120bpm, systolic BP=120mmHg, mm pink, CRT=2
    - Continue IVF at lower rate (100-120ml/kg/day) with continued close monitoring parameters q30-60 mins initially
  - HR=160bpm, systolic BP=172mmHg, mm pink, CRT=1
    - Additional 10-20ml/kg fluid bolus over 30 mins
    - Reassess after bolus

Case 2: Reno

- 10 yr MI Rottie
- Acute collapse
- Weak, depressed
- HR=200; RR=60/min; T=98.9F; systolic BP=45mmHg
- MM=pale; CRT=3sec; mm tacky; weak femoral pulses
- Distended abdomen, fluid wave present
- Abdominocentesis = non-clotting blood

Case 2: Reno

- Assessment:
  - Circulatory shock, hypovolemia, early decompensatory stage
  - Uncontrolled hemorrhage
- Treatment:
  - IVC with 5ml/kg Norm R bolus over 20 mins and 5ml/kg hypertonic NaCl over 10 mins
  - Hold on colloids initially – monitor initial effect on BP
  - Avoid all 3 at same time; avoid high volumes crystalloids
- Reassess:
  - No change
    - Repeat Norm R bolus OR colloid 5ml/kg IV over 10-15 mins
  - HR=160bpm, systolic BP=60mmHg, mm pale pink, CRT=2
    - Continue Norm R at lower rate (100-120ml/kg/day), close monitoring q15-20 mins while further diagnostics, plans for more definitive treatment for intra-abdominal bleeding

Case 3: Riley

- 3yr MN Heeler, 20kg
- Kicked in head by horse
- Laterally recumbent, obtunded, epistaxis
- Fractured frontal sinus, anisocoria
- HR=180bpm, systolic BP=165mmHg, fair femoral pulses
- MM pale pink, CRT=2sec

Case 3: Riley

- Assessment:
  - Circulatory shock, compensatory stage
  - Head trauma
- Treatment:
  - IVC with 7ml/kg of 1:2 combination hypertonic saline and Hetastarch (50ml HTS and 100ml Hetastarch) over 20 mins
  - Analgesia
- Reassess:
  - Sternal, depressed, improved anisocoria; HR=120bpm, systolic BP=140mmHg, mm light pink, CRT=1.5sec
    - Continue IVF Norm R at 90-120ml/kg/day; continued monitoring; possible mannitol once shock stabilized

Questions?