Fluids & Fluid Resuscitation
Drs. Paul Lysecki, Moin Khan, Valerie Wu Chao Ying
Guest Expert: Dr. Rebecca Kruisselbrink
Objectives

- Review daily fluid needs and considerations in the surgical patient
- Discuss the distribution of fluids in the body with respect to extracellular and intracellular compartments, and transportation of fluids and solutes between those compartments
- Review mechanisms of edema
- Clinical assessment of fluid status
- Oncotic pressure and changes to interstitial volume
Objectives

- Osmotic regulation of ECF – Hormonal,
- ADH, SIADH,
- Autonomic compensatory responses to changes in plasma volume
- Crystalloids and Colloids
- Therapeutic Guidelines
CANMEDS
CANMEDS

- **Communicator**
  - Be able to competently convey information regarding fluids and fluid resuscitation to patients, families, and other health care professionals

- **Collaborator**
  - Work with allied health staff in considering the patient’s needs in terms of fluids and resuscitation

- **Manager**
  - Make educated decisions regarding judicious use of fluids, considering the patient’s individual needs as well as the cost and effectiveness of the products being used

- **Health Advocate**
  - Make use of expertise and knowledge base to promote patient health and wellbeing
Scholar

- Understand the concepts of body fluid compartments; osmotic activity and electrolyte distribution; regulation of fluid volume and maintenance of osmotic homeostasis; understand the composition of and indications for the various types of intravenous fluids
- Be able to educate patients, learners, and other health care professionals in terms of body fluids and fluid replacement

Professional

- Commit to delivering the highest quality care of patients who are in need of fluids and fluid products
The Cellular Environment & Distribution of Body fluids
Paul Lysecki M.D
Objectives

- Review daily fluid needs and considerations in the surgical patient
- Discuss the distribution of fluids in the body with respect to extracellular and intracellular compartments, and transportation of fluids and solutes between those compartments
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- Clinical assessment of fluid status
Daily Ins/Outs

- “Typical” water intake:
  - Drinking/eating (~2100mL)
  - Synthesized during CHO oxidation (200mL)
Daily Ins/Outs

“Typical” water output:
- Insensible losses (700mL)
- Sweat (100mL)
- Feces (100mL)
- Urine (1400mL)
Daily Ins/Outs

- Surgical considerations:
  - NPO status
  - Existing deficits
  - Fever
  - Hypermetabolic state
  - Burns or wounds
  - Vomiting, diarrhea, ostomy/fistula
  - Renal impairment
  - Blood loss
Body Fluid Compartments

- Total Body Water (50-60% body mass)
  - Intracellular Fluid (2/3)
  - Extracellular Fluid (1/3)
    - Intravascular (1/4)
    - Interstitial (3/4)
Body Fluid Compartments

- Total Body Water
  - Influenced by % body fat, age
Body Water Compartments

TOTAL BODY FLUIDS
(40 liters; 60% TBW)

Plasma volume
(3 liters; 5%)

Red cell volume
(2 liters)

Extracellular
(15 liters; 20%)

Blood volume
(5 liters)

Intracellular
(25 liters; 40%)
Body Water Compartments
### DISTRIBUTION OF SOLUTES

<table>
<thead>
<tr>
<th>Extracellular</th>
<th>Intracellular</th>
</tr>
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<tbody>
<tr>
<td><strong>Na</strong>&lt;sup&gt;+&lt;/sup&gt;</td>
<td>142</td>
</tr>
<tr>
<td><strong>K</strong>&lt;sup&gt;+&lt;/sup&gt;</td>
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<tr>
<td><strong>CL</strong>&lt;sup&gt;-&lt;/sup&gt;</td>
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<tr>
<td>**HCO&lt;/sub&gt;₃&lt;sup&gt;-&lt;/sup&gt;</td>
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</tr>
<tr>
<td>Inorganic&lt;sup&gt;-&lt;/sup&gt;</td>
<td>12</td>
</tr>
<tr>
<td>Glucose</td>
<td>3</td>
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<tr>
<td>OSM</td>
<td>300</td>
</tr>
<tr>
<td>UREA</td>
<td>UREA</td>
</tr>
<tr>
<td>(ETOH)</td>
<td>(ETOH)</td>
</tr>
</tbody>
</table>

Units: mmol/kg of water, except organic<sup>-</sup>
*Units: mEq/kg of water
Body Water Compartments

Plasma Nonelectrolytes
Osmolarity

- Osmolarity = measure of solute concentration per litre of solution
- Example: for 0.9% Saline:
  - 154 mOsm/L Na+
  - 154 mOsm/L Cl-
  
  \[ 154 + 154 = 308 \text{ mOsm/L total osmolarity} \]
Osmolarity also governs osmotic pressure

\[ \pi = CRT \]

Every 1 mOsm/L gradient offers 19.3mmHg osmotic pressure
Osmolarity

<table>
<thead>
<tr>
<th></th>
<th>Plasma (mOsm/L H₂O)</th>
<th>Interstitial (mOsm/L H₂O)</th>
<th>Intracellular (mOsm/L H₂O)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Na⁺</strong></td>
<td>147</td>
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<td><strong>K⁺</strong></td>
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<td><strong>Mg²⁺</strong></td>
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<td><strong>Cl⁻</strong></td>
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<td>2</td>
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<td><strong>SO₄²⁻</strong></td>
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<td>8</td>
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<tr>
<td><strong>Carnosine</strong></td>
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<td></td>
<td>14</td>
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<tr>
<td><strong>Amino acids</strong></td>
<td>2</td>
<td>2</td>
<td>8</td>
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<tr>
<td><strong>Creatine</strong></td>
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<td>0.2</td>
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<td><strong>Lactate</strong></td>
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<td>1.2</td>
<td>1.5</td>
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<td><strong>Adenosine triphosphate</strong></td>
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<td>5</td>
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<td><strong>Hexose monophosphate</strong></td>
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<td>3.7</td>
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<td><strong>Glucose</strong></td>
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<td>5.6</td>
<td>4</td>
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<tr>
<td><strong>Protein</strong></td>
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<td>4</td>
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<tr>
<td><strong>Urea</strong></td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td><strong>Others</strong></td>
<td>4.8</td>
<td>3.9</td>
<td>10</td>
</tr>
<tr>
<td><strong>Total mOsm/L</strong></td>
<td>301.8</td>
<td>300.8</td>
<td>301.2</td>
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<tr>
<td><strong>Corrected osmolar activity (mOsm/L)</strong></td>
<td>282.0</td>
<td>281.0</td>
<td>281.0</td>
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<tr>
<td><strong>Total osmotic pressure at 37°C (mm Hg)</strong></td>
<td>5443</td>
<td>5423</td>
<td>5423</td>
</tr>
</tbody>
</table>
Osmolarity

- Interstitial ECF and Intravascular ECF fluid distribution depends on Starling forces
- Capillary membranes are highly permeable to water and most solutes
Osmolarity
Osmolarity

- Between ICF and interstitial ECF, balance depends upon osmotic effects of small solutes
  - Cell wall is impermeable to most solutes
  - However, it is very permeable to water
Osmolarity

Hypotonic (Swollen cell)

Isotonic (Normal looking cell)

Hypertonic (Shrivelled cell)
Volume Assessment

- **Vital Signs**
  - Postural vitals @ 1-2mins standing

- **General**
  - Well/unwell
  - Confusion, anxiety
  - Mucous membranes - dry/moist
  - Axillary dryness
  - Tongue furrowing
Volume Assessment

- Cardiovascular
  - JVP
  - Heart sounds
  - Peripheral pulses and capillary refill
  - Peripheral edema

- Respiratory
  - Inspiratory crackles
  - Decreased air entry / dullness to percussion

- Abdominal
  - Distention (a)scites
Mechanisms of Edema

- **Intracellular**
  - Impairment of cell membrane function
    - Depression of metabolic systems
    - Lack of nutrition to the cells
  - Inflammation

- **Extracellular**
  - Abnormal leakage of fluid to interstitial spaces
  - Failure of lymphatics to return excess fluid
Mechanisms of Edema

Starling Forces

- Filtration = $K_f \times (P_c - P_{if} - \pi_c + \pi_{if})$
- $K_f =$ filtration coefficient
Mechanisms of Edema

- Altered $K_f$
  - Inflammation
  - Toxins
  - Infections
  - Ischemia
  - Burns
  - Vitamin deficiency (C in particular)
Mechanisms of Edema

- Altered $P_c$
  - Renal retention of fluids
    - ARF/CRF
    - Mineralocorticoid excess
  - High venous pressure
    - CHF
    - Obstruction
    - Pump failure
  - Decreased arteriolar resistance
    - Hyperthermia
    - Vasodilators
    - Sympathetic insufficiency
Mechanisms of Edema

- Decreased plasma proteins
  - Nephrotic syndrome
  - Burn/wound losses
  - Production failure
    - Liver disease
    - Malnutrition
Mechanisms of Edema

- Lymphatic Blockage ($P_{if}$)
  - Cancer
  - Infections
  - Surgery
  - Congenital
Mechanisms of Edema

- Safety Factors
  - Low interstitial compliance in negative pressure range
  - Adaptability of lymphatic flow
  - Protein washdown

- These factors produce up to ~17mmHg of protection
Regulation of Body Fluids and Fluid Resuscitation

Moin Khan M.D
Objectives

- Oncotic pressure and changes to interstitial volume
- Osmotic regulation of ECF
  - ADH, Aldosterone
  - Abnormal States – DI, SIADH
- Autonomic compensatory responses to changes in plasma volume
- Crystalloids and Colloids – voluven, pentaspan, albumin, blood
Oncotic Pressure

- Plasma oncotic pressure is determined by plasma protein. Albumin generates approx 70% of oncotic pressure.

- Tissue oncotic pressure depends on the interstitial protein concentration and the permeability of the capillary wall. Increases in capillary permeability increase interstitial oncotic pressure.

- Osmotic gradients in general are not allowed to persist in the body. Water will move along the gradient to equalize osmotic pressure.

- Thus osmotic factors exert control over distribution of volume between compartments.
Oncotic Pressure

Osmotic gradient – water moves from cells into ECF until equalization of osmotic pre
Changes in Interstitial volume

- There is a relative osmotic gradient between interstitium and plasma due to higher [protein] in plasma
  - This is opposed by hydrostatic pressure. These 2 forces balance out into steady state.
  - Starling hypothesis
  - Disorder in this balance results in edema
Osmotic regulation of ECF

- Body is equipped with mechanisms that allow precise regulation of ECF
  - H20 and Na play the most important role in ECF volume and osmolality
  - Concentration = solute /solvent

- Regulation via hormonal mechanisms
  - ADH
  - Aldosterone/Angiotensin II
Osmotic regulation of ECF - ADH

- ADH – Anti Diuretic Hormone aka Vasopressin
  - Major hormone regulating water loss
- Produced by neurosecretory cells extending from hypothalamus to posterior pituitary
  - Stimulated by increasing osmolarity of body fluids
- ADH promotes insertion of water-channel proteins (aquaporin-2) into the apical membranes of principle cells in collecting ducts of kidneys
Osmotic regulation of ECF - ADH

- Permeability of principle cells to water increases
- Water molecules move by osmosis from the renal tubular fluid into the cells and then from the cells into the bloodstream
- Results in small volume of concentrated urine
Anti Diuretic Hormone
Osmotic regulation of ECF-ADH

- When the principal cells are not stimulated by ADH, AQ2 molecules are removed by endocytosis.
- ADH secretion is also influenced by decreases in blood volume as detected by baroreceptors in LA and blood vessel walls.
Anti Diuretic Hormone

- Water deficit
  - Extracellular osmolarity
    - Osmoreceptors
      - ADH secretion (posterior pituitary)
        - Plasma ADH
          - \( \text{H}_2\text{O} \) permeability in distal tubules, collecting ducts
            - \( \text{H}_2\text{O} \) reabsorption
              - \( \text{H}_2\text{O} \) excreted
Osmotic regulation of ECF

- Aldosterone/Angiotensin II
- With decreased volume angiotensin II and aldosterone released
- Aldosterone is produced in adrenal cortex of adrenal gland and acts on distal tubules and collecting ducts of nephron
- Effect is to increase reabsorption of Na and Cl from urine
- Water then follows by osmosis thus conserving body fluid and reducing urinary loss
Osmotic regulation of ECF

- Release of Aldosterone is controlled by RAA pathway
  - RAA pathway initiated by dehydration, Na deficiency or hemorrhage
  - Result in decrease in blood volume and subsequent decrease in pressure
  - Juxtaglomerular cells in kidney release renin
    - Converts angiotensinogen to angiotensin 1
    - ACE converts angiotensin 1 → Angiotensin II
    - Angiotensin II stimulates adrenal cortex to secrete aldosterone
RAA pathway and Aldosterone
Autonomic responses to changes in plasma volume

- Changes in volume and flow of plasma volume are matched by equally rapid compensatory responses which minimize the effects of volume reduction or maldistribution.

- 3 major changes occur in response to decreases in arterial pressure:
  - Construction of arterioles of systemic circulation
  - Increases total peripheral resistance and arterial pressure
  - Veins are strongly constricted
    - Displaces blood out of large peripheral blood vessels towards heart, increasing volume of blood in heart chambers and increase contractility and thus arterial pressure
  - Heart itself is directly stimulated by the autonomic nervous system, further enhancing cardiac pumping
Autonomic responses to changes in plasma volume

- Vasomotor Center in brain
  - Located in medulla
  - Transmits parasympathetic impulses through vagus nerves to heart and sympathetic impulses through spinal cord and peripheral nerves to arteries, arterioles and veins of body

- Under normal conditions, the vasoconstrictor area of the vasomotor center transmits signals to cause partial constriction of blood vessels – vasomotor tone

- Pressure is sensed by baroreceptors which transmit signals to CNS
Autonomic responses to changes in plasma volume
Abnormal States of Regulation - DI

- **Diabetes Insipidus**
  - **Central**
    - Decreased secretion of ADH giving rise to polyuria and polydipsia by diminishing patients' ability to concentrate urine
  - **Nephrogenic**
    - Decreased ability to concentrate urine due to resistance to ADH action in the kidney
Abnormal States of Regulation - DI

- **Etiology**
  - **Central**
    - 30% idiopathic, 25% are related to malignant or benign tumors of the brain or pituitary, 20% follow cranial surgery, and 16% are secondary to head trauma.
  - **Nephrogenic**
    - Lithium toxicity, hypercalcemia, hypokalemia, CRD hereditary nephrogenic DI
Abnormal States of Regulation - DI

- Clinical Presentation – polyuria, polydipsia, nocturia are prominent symptoms
- Diagnosis
  - Serum electrolytes, glucose, urinary sodium, simultaneous serum and urine osmolality, and ADH levels. A urine specific gravity of 1.005 or less and a urine osmolality less than 200 mOsm/kg are the hallmark of diabetes insipidus. Random plasma osmolality generally is greater than 287 mOsm/kg.
Abnormal States of Regulation - DI

Treatment
- Replace losses with dextrose and water or another hypo osmolar IV fluid
- Desmopressin - synthetic analogue of antidiuretic hormone (ADH)
- In central DI, the primary problem is a hormone deficiency; therefore, physiologic replacement with desmopressin is usually effective
- Monitor for fluid retention and hyponatremia during initial therapy.
Abnormal States of Regulation - SIADH

- SIADH
  - ADH excess causes excessive amounts of free water resulting in hyponatremia
Abnormal States of Regulation - SIADH

Pathophysiology
- In SIADH, the inappropriately elevated level of vasopressin enhances the reabsorption of water, thus concentrating the urine. It is the excess free water absorption that causes hyponatremia.

Etiology
- CNS – Tumor, trauma, infection
- Pulmonary – Tumor, pneumonia, COPD,
- Carcinoma – Lung, pancreas, ovary, lymphoma
- Drugs – exogenous vasopressin, NSAIDS, nicotine, iuretics, TCA’s SSRI’s
Abnormal States of Regulation - SIADH

- Clinical Presentation
  - Related to CNS dysfunction and correlate to severity and acuity of hyponatremia
  - Anorexia, nausea, and malaise are the earliest findings, followed by headache, irritability, confusion, muscle cramps, weakness, obtundation, seizures, and coma
Abnormal States of Regulation - SIADH

- **Diagnosis**
  - Serum – lytes, bun, cr, glucose, osmolality
    - Hyponatremia
    - Low serum osmolality
  - Urine – lytes and osmolality
    - Elevated urine sodium level
    - Urine osmolality generally >100 mOsm/L
  - Chest radiographs may reveal an underlying cause
  - CT head
Abnormal States of Regulation - SIADH

- Aggressive tx should be weight against risk of central pontine myelinolysis
- Emergent aggressive management is indicated in pts with severe symptoms – seizures or mental status changes and those with [Na] < 110 mEq/L
  - 3% hypertonic saline, correct at rate of 0.5 – 2 mEq/h
  - Furosemide increases excretion of free water and has been used along with isotonic or hypertonic saline in severe cases.
- Chronic hyponatremia secondary to SIADH
  - Fluid restriction
Colloids & Crystalloids

Crystalloids are solutions of varying amounts of mineral salts or other water soluble molecules

- Hypotonic
  - 0.45% NaCl
  - D5W
- Isotonic
  - Normal Saline (0.9%)
  - RL
- Hypertonic
  - Hypertonic Saline (3%)

The predominant effect of volume resuscitation with crystalloid fluids is to expand the interstitial volume rather than the plasma volume. Approx 1/4\textsuperscript{th} of the fluid given will remain in the ECF.
Colloids & Crystalloids

- Colloids are often based on crystalloid solutions, thus containing water and electrolytes, but have the added component of a colloidal substance that does not freely diffuse across a semipermeable membrane.

- Produce large osmotic pressure gradient and thus favors retention of fluid in vascular compartment.
  
  - Voluven, Pentaspan, 5% albumin, 25% albumin, Blood
## Composition of Fluids

<table>
<thead>
<tr>
<th>Solution</th>
<th>pH</th>
<th>Na⁺</th>
<th>Cl⁻</th>
<th>K⁺</th>
<th>Ca²⁺</th>
<th>Lactate</th>
<th>Glucose</th>
<th>Osmolality</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>.9% normal saline</td>
<td>5.0</td>
<td>154</td>
<td>154</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>308</td>
<td>0</td>
</tr>
<tr>
<td>LR</td>
<td>6.5</td>
<td>130</td>
<td>109</td>
<td>4</td>
<td>3</td>
<td>28</td>
<td>0</td>
<td>275</td>
<td>0</td>
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<tr>
<td>5% dextrose in water (D₅W)</td>
<td>4.0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>50 g/L</td>
<td>252</td>
<td>0</td>
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<tr>
<td>.45% normal saline with dextrose (D₅/1/2 NS)</td>
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<td>77</td>
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<td>0</td>
<td>0</td>
<td>50 g/L</td>
<td>406</td>
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<tr>
<td>Albumin (5%)</td>
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<td>130-160</td>
<td>&lt; 1</td>
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<td>0</td>
<td>0</td>
<td>309</td>
<td>50 g/L albumin</td>
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<td>Albumin (25%)</td>
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<td>0</td>
<td>312</td>
<td>250 g/L albumin</td>
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<td>Hetastarch 6%</td>
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<td>0</td>
<td>0</td>
<td>310</td>
<td>60 g/L starch</td>
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<td>Pentastarch 10%</td>
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<td>0</td>
<td>0</td>
<td>326</td>
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<td>Dextran-40 (10% solution)</td>
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<td>100 g/L dextran</td>
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<td>Dextran-70 (6% solution)</td>
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<td>0</td>
<td>310</td>
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<tr>
<td>Haemaccel 3.5%</td>
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<td>145</td>
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<td>Gelofusine</td>
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<td>0</td>
<td>0</td>
<td>308</td>
<td>40 g/L gelatin</td>
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Therapeutic Guidelines
Valerie Wu Chao Ying M.D
Crystalloids

- Crystalloid fluids are electrolyte solutions with small molecules that can diffuse freely throughout the extracellular space.

- The principal component of crystalloid fluids is the inorganic salt sodium chloride (NaCl).

- Sodium is the most abundant solute in the extracellular fluid, where it is distributed uniformly.

- 75 to 80% of the extracellular fluid is located in the interstitial space, a similar proportion of the total body sodium is in the interstitial fluids.

- Intravenously administered sodium follows the same distribution:
  - 75 to 80% of the volume of infused sodium chloride (saline) solutions will be distributed in the interstitial space.
This means that the predominant effect of volume resuscitation with crystalloid fluids is to expand the interstitial volume rather than the plasma volume.
# Infusion contents

<table>
<thead>
<tr>
<th>Fluid</th>
<th>Na</th>
<th>Cl</th>
<th>K</th>
<th>Ca</th>
<th>Mg</th>
<th>Buffers</th>
<th>pH</th>
<th>Osmolality (mOsm/L)</th>
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<tr>
<td>Plasma</td>
<td>140</td>
<td>103</td>
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<td>5</td>
<td>2</td>
<td>Bicarb (25)</td>
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<td>0.9% NaCl</td>
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<td>154</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>5.7</td>
<td>308</td>
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<tr>
<td>7.5% NaCl&lt;sup&gt;a&lt;/sup&gt;</td>
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<td>1,283</td>
<td>—</td>
<td>—</td>
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<td></td>
</tr>
<tr>
<td>Plasma-Lyte</td>
<td>140</td>
<td>98</td>
<td>5</td>
<td>—</td>
<td>3</td>
<td>Acetate (27)</td>
<td>7.4</td>
<td>295</td>
</tr>
<tr>
<td>Isolyte&lt;sup&gt;b&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Gluconate (23)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>


<sup>b</sup>Isolyte also contains phosphate (1 mEq/L).
Normal saline

- A comparison of isotonic saline and plasma in shows that isotonic saline has a higher sodium concentration (154 vs. 140 mEq/L), a much higher chloride concentration (154 vs. 103 mEq/L), a much lower pH (5.7 vs. 7.4), and a slightly higher osmolality (308 vs. 290 mOsm/L).

- Infusion of large volumes of isotonic saline can produce a **metabolic acidosis**
Ringer lactate

- Lactated Ringer's solution contains potassium and calcium in concentrations that approximate the free (ionized) concentrations in plasma.
- The addition of lactate (28 mEq/L) similarly requires a reduction in chloride concentration, and the resultant chloride concentration in lactated Ringer's (109 mEq/L) is a close approximation of the plasma chloride concentration (103 mEq/L). This eliminates the risk of hyperchloremic metabolic acidosis with large-volume infusions of lactated Ringer's solution.
Ringer lactate

- The calcium in Ringer's solutions can bind to certain drugs and reduce their effectiveness.

- The calcium in Ringer's can also bind to the citrated anticoagulant in blood products. This can inactivate the anticoagulant and promote the formation of clots in donor blood.

- For this reason, **lactated Ringer's solution is contraindicated as a diluent for red blood cell transfusions.**
Dextrose solution

- In the days before the introduction of enteral and parenteral nutrition, dextrose was added to intravenous fluids to provide calories. However, with the advent of effective enteral and parenteral nutrition regimens, the popularity of $D_5$ infusion fluids is no longer justified.

- Adverse effects include: metabolic acidosis from enhanced lactate production and hyperglycemia.
Colloids

- Colloid fluids are more effective than crystalloid fluids for expanding the plasma volume because they contain large, poorly diffusible, solute molecules that create an osmotic pressure to keep water in the vascular space.
# Colloids comparison table

## TABLE 13.2 Comparative Features of Colloid Fluids

<table>
<thead>
<tr>
<th>Fluid</th>
<th>Average Molecular Wt (kilodaltons)</th>
<th>Oncotic Pressure (mm Hg)</th>
<th>ΔPlasma Volume Infusate Volume</th>
<th>Duration of Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>25% Albumin</td>
<td>69</td>
<td>70</td>
<td>4.0-5.0</td>
<td>16 hr</td>
</tr>
<tr>
<td>10% Dextran-40</td>
<td>26</td>
<td>40</td>
<td>1.0-1.5</td>
<td>6 hr</td>
</tr>
<tr>
<td>6% Hetastarch</td>
<td>450</td>
<td>30</td>
<td>1.0-1.3</td>
<td>10 hr</td>
</tr>
<tr>
<td>5% Albumin</td>
<td>69</td>
<td>20</td>
<td>0.7-1.3</td>
<td>16 hr</td>
</tr>
</tbody>
</table>

Data from References 17, 18, 19, 20 and 28.
Colloids

- Individual colloid fluids differ in their ability to augment the plasma volume, and this difference is a function of the colloid osmotic pressure of each fluid. Fluids with higher colloid osmotic pressures produce greater increments in plasma volume.
Albumin

- Albumin solutions are heat-treated preparations of human serum albumin that are available as a 5% solution (50 g/L) and a 25% solution (250 g/L) in an isotonic saline diluent.

- The 5% albumin solution has an albumin concentration of 5 g/dL and a colloid osmotic pressure of 20 mm Hg, both equivalent to plasma. Infusion of 5% albumin is performed using aliquots of 250 mL.

- About 70% of the infusate volume remains in the plasma for the first few hours post-infusion, but the increment in plasma volume dissipates rapidly thereafter, and the effect can be lost after just 12 hours.
The 25% albumin solution is a non-physiologic, hyperoncotic fluid that is given in aliquots of 50 mL or 100 mL. Following acute infusions of 25% albumin, plasma volume increases by 3 to 4 times the infusate volume. The effect is produced by fluid shifts from the interstitial space, so interstitial fluid volume is expected to decrease by equivalent amounts.
25% Albumin

- Infusion of 25% albumin does not provide replacement of lost volume but merely shifts body fluid from one fluid compartment to another. Therefore, 25% albumin should not be used as volume replacement therapy for patients with acute blood loss or dehydration.

- This fluid should be reserved for the occasional patient with hypovolemia resulting from fluid shift into the interstitial space, which is usually the result of severe hypoalbuminemia.
Hetastarch (Voluven)

• Hydroxyethyl starch (hetastarch) is a chemically modified starch polymer that is available as a 6% solution in isotonic saline.

• Hetastarch elimination is a two-step process. First, circulating starch molecules undergo hydrolysis by amylase enzymes in blood. When the starch molecules are cleaved into small fragments (MW <50,000 daltons), they are cleared by the kidney.

• Clearance of hetastarch can take several weeks, but the oncotic activity is lost after one day.
Hetastarch

- The performance of 6% hetastarch as a plasma volume expander is very similar to 5% albumin. The oncotic pressure (30 mm Hg) is higher than 5% albumin (20 mm Hg), and the increment in plasma volume can be slightly higher as well.

- The effect on plasma volume usually is lost by 24 hours.
Hetastarch

- Overall, **6% hetastarch is equivalent to 5% albumin as a plasma volume expander.** The major difference between these two fluids is cost (hetastarch is less costly) and the risk of altered hemostasis (which is greater with hetastarch).
Adverse effects

• The most popular side effect of hetastarch is a **bleeding tendency** caused by inhibition of factor VII and von Willebrand factor and impaired platelet adhesiveness.

• Troublesome bleeding from hetastarch can be minimized by limiting the infusion volume to less than 1,500 mL in 24 hours and by avoiding the use of hetastarch in patients with an underlying coagulopathy, particularly von Willebrand's disease.

• Macroamylasemia and rare anaphylactic reactions are also possible adverse side effects
Dextrans

- The dextrans are glucose polymers produced by a bacterium (*Leuconostoc*) incubated in a sucrose medium.
- Dextran preparations have a colloid osmotic pressure of 40 mm Hg and cause a greater increase in plasma volume than either 5% albumin or 6% hetastarch.
Adverse effects

- Dextrans produce a dose-related **bleeding tendency** that involves impaired platelet aggregation, decreased levels of factor VIII and von Willebrand factor, and enhanced fibrinolysis. The hemostatic defects are minimized by limiting the daily dextran dose to 20 mL/kg.

- Dextrans have been implicated as a cause of **acute renal failure**. The proposed mechanism is a hyperoncotic state with reduced filtration pressure. However, this mechanism is unproven, and renal failure occurs only rarely in association with dextran infusions.

- **Anaphylactic reactions**, once common with dextrans, are now reported rarely
Hypertonic solutions

• Volume resuscitation with hypertonic saline (7.5% NaCl) has received much attention as a method of small-volume resuscitation. A 7.5% sodium chloride solution has an osmolality that is about 8.5 times greater than plasma. Infusion of 250 mL of 7.5% NaCl will increase plasma volume by about twice the infused volume, indicating that hypertonic saline allows for volume resuscitation with relatively small volumes.
Hypertonic solutions

- This has been proposed as a possible benefit in the resuscitation of trauma victims with head injuries (to limit the severity of cerebral edema). However, the effective resuscitation volumes with hypertonic saline are similar to colloid resuscitation.

- At the present time, hypertonic saline is a resuscitation fluid without a clear indication.
Crystalloids vs colloids

- The biggest disadvantage of colloid resuscitation is the higher cost of colloid fluids.
- Using equivalent volumes of 250 mL for colloid fluids and 1,000 mL for crystalloid fluids, the cost of colloid resuscitation is nine times higher (if hetastarch is used) to twenty-one times higher (if albumin is used) than volume resuscitation with crystalloid fluids.
Colloids vs crystalloids in 2011
Colloids vs crystalloids

• There is no evidence from RCTs that resuscitation with colloids, instead of crystalloids, reduces the risk of death in patients with trauma, burns or following surgery.

• As colloids are not associated with an improvement in survival, and further, colloids are considerably more expensive than crystalloids, it is hard to see how their continued use outside the context of RCTs in subsets of patients of particular concern, can be justified.

• There was a trend towards a favourable effect on mortality for colloids in hypertonic crystalloid, compared to isotonic crystalloids. Nevertheless, the results are compatible with the play of chance.
Colloids in 2011
Colloids comparison

- From this review, there is no evidence that one colloid solution is more effective or safe than any other, although the confidence intervals are wide and do not exclude clinically significant differences between colloids.

- Larger trials of fluid therapy are needed if clinically significant differences in mortality are to be detected or excluded.
Trauma

Bloody vicious cycle
A diagram showing some of the mechanisms leading to coagulopathy in the injured.

Sihler K C, Napolitano L M Chest 2010;137:209-220
Timing and volume of fluid administration for patients with bleeding (Review)

Kwan I, Bunn F, Roberts I
Trauma

• No evidence from trials to support or not to support the use of early or larger volume intravenous fluid in uncontrolled bleeding

• About one third of injury deaths are due to shock from blood loss. Preventing shock in people with uncontrolled bleeding is, therefore, very important and is generally done by giving fluids intravenously. The aim is to maintain blood pressure and reduce tissue damage.

• The review of trials found that there is uncertainty about the best time to give fluid and what volume of fluid should be given.

• While increasing fluids will maintain blood pressure, it may also worsen bleeding by diluting clotting factors in the blood.

• More research is needed.
EARLY GOAL-DIRECTED THERAPY IN THE TREATMENT OF SEVERE SEPSIS AND SEPTIC SHOCK

EMANUEL RIVERS, M.D., M.P.H., BRYANT NGUYEN, M.D., SUZANNE HAVSTAD, M.A., JULIE RESSLER, B.S., ALEXANDRIA MUZZIN, B.S., BERNHARD KNOBLICH, M.D., EDWARD PETERSON, PH.D., AND MICHAEL TOMLANOVICH, M.D., FOR THE EARLY GOAL-DIRECTED THERAPY COLLABORATIVE GROUP*
Early goal-directed therapy
Early goal-directed therapy

- A 500-ml bolus of crystalloid was given every 30 minutes to achieve a central venous pressure of 8 to 12 mm Hg. If the mean arterial pressure was less than 65 mm Hg, vasopressors were given to maintain a mean arterial pressure of at least 65 mm Hg.
- If the central venous oxygen saturation was less than 70 percent, red cells were transfused to achieve a hematocrit of at least 30 percent.
Conclusion

- It is unlikely that one type of fluid is best for all patients. A more logical approach is to select the type of fluid that is best designed to correct a specific problem with fluid balance.

- Tailoring fluid therapy to specific problems of fluid imbalance is the best approach to volume resuscitation.
References


