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FLUIDS AND ELECTROLYTES

I FLUID COMPARTMENTS

A. Total body water

60% of body weight or 50% of body weight (depending upon who read) 70 kg man + 42 liters or 35 liters

1. Extracellular space = 20% of body weight

   - plasma space = 5% blood plasma
   - interstitial space = 15%

2. Intracellular space = 30-40% of body weight

II COMPOSITION OF FLUID COMPARTMENTS

A. Extracellular

cation (+)	Anion (-)
Na^+ 142meq/l	HCO_3^- 23 meq/l Cl^- 110meq/l
K^+ 4.5 meq/l	$PO_4^=$ $SO_4^=$ 3 meq/l
Ca^+ 8.5 meq/l	Ca^+ 5 meq/l
Mg^+ 2.5 meq/l	Proteinate 10 meq/l

B. Intracellular

cation (+)	Anion (-)
K^+ 157 meq/l	HCO_3^- 10 meq/l
Ca^+ meq/l	SO_4^- meq/l
Na^+ 10 meq/l	
Mg^+ 40 meq/l	Proteinate 76 meq/l

Major Point

1) Na^+ is extracellular ion
2) K^+ is intracellular ion

III FUNCTIONS

A. Na^+

1. One of main determinant of acid-base balance

2. Determines, along with other ions, the osmolality of plasma

a. osmolarity of plasma approximates osmolarity of interstitial space

b. if there are changes you get water shifts

B. K^+

1. All enzymatic functions within cells need K^+

a. phosphorylation of glucose, if glucose not phosphorylated it leaks back out once insulin forces it in.

b. entrance of glucose into the cell requires insulin

c. protein synthesis requires K^+

2. Muscular contraction dependent on K^+

a. low K+ leads to muscle weakness (ie. primary aldosteronism)

b. Cushing disease

C. PO_4 (Phosphate)

1. Major buffer system

2. Also needed for voluntary muscle contraction

a. hypophosphatemia can lead to respiratory failure

IV ABNORMALITIES

A. Hypernatremia

1. Serum sodium in excess of 145 meq/l

2. Causes:

a. pure water loss

1) water loss from extracellular space (ie. plasma)

2) body compensation is via interstitial space but is very slow > 4 hours to start

3) chronic losses

a). mild loss-4% body weight as water

symptoms:

Hct 45-48%
urine specific grav. 1.025-1.028
serum protein 8.0-8.5 gm/dl

b) moderate - 6% body weight as water

symptoms:

thirst
Hct 50% or greater
serum protein 8.5-9.5
urine osmolality 850-1000 mosm
B/P - WNL
pulse increased

c) severe - 8% of body weight loss as water

symptoms

lethargy
muscle weakness
Hct above 55-60%
serum protein > 9.5
urine sp. 1032 or above or may fall if renal failure supervenes
urine osm - 1240 mosm

b. Excess sodium administration (3% or 5% NaCl)

3. Treatment:

a. Give water (ie. D_5W or D_5 1/4N NaCl)

1) amount needed calculated as follows:

a) (example: 70 kg patient with severe dehydration)

0.8 x 70 kg = 2.8 liters needed
(but is above and beyond fluid requirement)
- 1/2 given 1st 24 hours
- 1/2 given next 24 hours

B. Hyponatremia (water excess)
Na deficit = (Na^+ exp. - Na act) x (wt) x (0.6)

1. Causes:

   a. isosmolar water excess

   b. secondary to renal failure

   c. excess hypotonic fluid administration

   d. hyposmolar water excess

   e. trauma

      1) increased cathecholamines which have an anti-diuretic effect

      2) increased ADH

2. Inappropriate ADH

   a. head trauma

   b. sepsis

   c. massive soft tissue injuries

   d. cancer (lung)

   e. shock

   f. CNS infection

   g. patients on ventilators

      1) get marked increase in water reabsorption by kidney with resultant low serum Na

      2) treatment

         withhold water (not Na^+)
         lithium bicarbonate (suppresses ADH)
         Declomycin - drug of choice

C. Hyperkalemia

1. Symptoms:

   a. muscle weakness

   b. stops heart in diastole

   c. increased peaked T-waves in EKG

2. Causes:

a. renal failure

1) normally 15-20 meq/liter excreted (minimum)

2) kidney cannot secrete a K^+ free urine

3) in failure, K^+ excreted decreases sharply

b. iatrogenic

1) automatic K^+ given even in normokalemic patients

3. Treatment:

a. avoid fever (increased protein breakdown)

b. avoid protein breakdown

1) each gm of protein liberates 2 meq of K^+ into ECF

c. give carbohydrates

1) at least 150 gm/day

d. withhold protein

e. give ion exchange resin (ie. kayexelate)

f. dialysis

1) peritoneal

2) hemo (more efficient)

g. glucose and insulin - emergency temporary measure

h. discontinue K^+ in I.V. solution

D. Hypokalemia

1. Symptoms:

a. skeletal muscle weakness

b. lethargy

c. paralytic ileus

d. EKG changes

1) increased S-T interval

2) depressed S-T segment

3) inverted T waves or flat

4) U waves

2. Causes:

a. diarrhea - loss of 20 meq K^+/liter

b. vomiting - loss of 30 meq K^+/liter

c. diuretic therapy

d. trauma

1) increased loss from intercellular space

2) increased loss in urine (Na^+ spared) - mediated by aldosterone

e. high output renal failure

f. aldosterone producing tumor

g. Cushing syndrome

3. Treatment:

a. potassium given above & beyond daily requirement

1) 20-40 meq/liter

2) 10 meq-50-100 cc-D_5W over 30 min (with ECG)

3) 15 meq/hour

4) hemodialysis with dialysate of 6.5-7.0 meq/l K^+

b. must know status of kidney function

E. Dehydration

a. Treatment:

1) give 9% NaCl or R.L. - N.B: fluid movement in such a loss is ICS $\longrightarrow$ ISS $\longrightarrow$ ECS correction involves reversal in flow

b. Isosmolar fluid loss

1) increased insensible water loss

a) endotracheal tube, especially with a ventilator

b) increased perspiration

c) surgical procedure

2) treatment:

a) R.L fine in practice

b) .45% or .9 NaCl

c. Osmotic diuresis

1) sodium lossing nephropathy

2) hyperosmolar state (dehydration or non ketotic coma) with increased glucose Insulin exhausted and glucose causes diuresis; mannitol acts in same manner

3. treatment:

a) .45% NaCl + d/c hyperalimentation

d. Osmotic diarrhea

1) hyperalimentation (oral)

2) treatment:

a) D_5W

F. Magnesium

1. Functions:

a. intracellular

1) phosphorylation of glucose

2) needed for gluconeogenesis

b. extracellular

1) required for cholinesterase activity

2) acetylcholine is neurotransmitter-cholinesterase breaks this substance down

2. Turnover:

   a. all body fluids contain 2.0 meq/liter except for intracellular fluid

   b. daily excretion - 4 meq/day

3. Syndromes:

   a. hypomagnesemia

      1) causes

         a) large burns

         b) third space loss

         c) prolonged IV therapy (more than 10 days)

         d) hyperalimentation

         e) diarrhea

         f) acute pancreatitis (parahormone like substance)

         g) intestinal obstruction

         h) post-parathyroidectomy

         i) chronic severe liver disease

      2) symptoms:

         a) increased acetylcholine activity

         b) hallucinations

         c) irrational behavior

         d) fibrillation

         e) increased deep tendon reflexes

         f) purposeless movement of hands

      3) treatment:

         a) magnesium given as 8-32 gm/liter/day or 64-250 meq/liter

b. Hypermagnesemia

1) symptoms:

a) lethargy

b) hyporeflexia

c) muscle flaccidity

d) coagulopathy

-deficit of prothrombin precursor

-liver doesn't generate prothrombin precursor

2) treatment

G. Zinc deficit

1. Syndromes:

a. acrodermatitis enteropathica

1) autosomal recessive Zinc deficiency

a) alopecia

b) diarrhea

c) mental aberrations

d) dermatitis of soles of the feet and fingertips

b. adult type

1) result of parenteral hyperalimentation

a) Zinc required for phosphorylation of ATP & ADP

2) may be increased Zinc loss in urine

3) develops over weeks or month

4) symptoms:

a) central facial dermatitis around eyebrows, nasal-labial folds

b) cheilosis

c) diarrhea

d) dementia

e) questionable deficient wound healing

5) treatment:

a) 1-2 units of plasma per week

b) Zinc Cl_2 or Zinc SO_4 - 60 mg/day

H. Iron deficiency

1. Function:

a. hemoglobin

2. Causes:

a. menorrhagia

b. chronic blood loss

c. microcytic, hypochromic anemia

3. Treatment:

a. give iron

I. Copper deficiency

1. Symptoms:

a. leukopenia

b. anemia

c. bone marrow depression

1) decrease in megakaryocyte maturation

2) decreased white cell release

3) decreased red cell maturation

J. Cobolt deficiency

1. Megaloblastic anemia

ACID BASE ABNORMALITIES

$$pH = pKa + \log \frac{[HCO_3^-]}{[H_2CO_3]} \quad \text{or} \quad pH = \frac{[HCO_3^-]}{[CO_2]} = \frac{20}{1}$$

Primary goal is to maintain 20:1 ratio

RESPIRATORY DERANGEMENTS

A. Respiratory Acidosis

1. pCO_2 increases so 20:1 ratio decreases
2. Compensation is via kidney over a period of days
   a. increase in HCO_3^- (retains) thereby increasing numerator so 20:1 ratio is returned
3. Treatment
   a. increase minute ventilation to blow off CO_2
   b. do not give $NaHCO_3$ unless acidosis is severe (pH below 7.30)

B. Respiratory Alkalosis

1. pCO_2 is decreased because of an increased minute ventilation so 20:1 ratio is increased
2. Compensation via kidney is to dump HCO_3^- (slow process)
3. Treatment
   a. sedate patient to slow respiratory rate or intubate and control

C. Metabolic Acidosis

1. CO_2 increases functionally via $CO_2 + H_2O \rightleftharpoons H2CO_2 \rightleftharpoons H+ + HCO_3^-$
   a. cause is usually shock
   b. HCO_3^- (serum) decreases
   c. decrease in numerator of 20:1 ratio

2. Compensation via lungs to increase alveolar ventilation and decrease pCO_2 (denominator)

   Also: kidneys retain HCO_3^-

3. Treatment

   a. correct cause (usually shock)

   b. drain abscess or remove dead bowel

D. Metabolic Alkalosis

1. Increase in HCO_3^- (numerator)

   a. causes

      1) excessive citrate load (ie. transfusion)

      2) excessive bicarbonate administration

2. Compensate partially by lung to increase pCO_2 but cannot increase pCO_2 to high enough level before central drive forces increase respiration

3. Treatment

   a. correct K^+, Cl^- deficit

   b. .9% NaCl

   c. 2% NH_4Cl

   d. arginine hydrochloride

   e. 0.1N HCl

      1) give via CVP

      2) slow infusion with constant checking of pH

4. Paradoxical Aciduria

   a. metabolic alkalosis with acid urine

      1. loss of K^+ into ECS

      2. Na^+ moves into cell to replace K^+ in ratio of 2 Na^+ + 1 H^+ per 3 K^+ loss

      3. Renal tubular cell sees an intracellular acidosis so it excretes H^+ into urine

Table 1. Composition, Osmolarity, and pH Range

	Composition					OSMOLARITY* (mOsm/l)	pH Range**
	Dextrose Monohydrate (g/l)	Sodium Chloride (g/l)	Sodium Lactate (g/l)	Potassium Chloride (mg/l)	Calcium Chloride Dihydrate (mg/l)		
5% Dextrose Injection, USP	50	0	0	0	0	252	3.5-6.5
10% Dextrose Injection, USP	100	0	0	0	0	505	3.5-6.5
0.9% Sodium Chloride Injection, USP	0	9.0	0	0	0	308	4.5-7.0
Sodium Lactate Injection, USP (M/6 Sodium Lactate)	0	0	18.7	0	0	334	6.0-7.3
2.5% Dextrose & 0.45% Sodium Chloride Injection, USP	25	4.5	0	0	0	280	3.5-6.0
5% Dextrose & 0.2% Sodium Chloride Injection, USP	50	2.0	0	0	0	321	3.5-6.0
5% Dextrose & 0.33% Sodium Chloride Injection, USP	50	3.3	0	0	0	365	3.5-6.0
5% Dextrose & 0.45% Sodium Chloride Injection, USP	50	4.5	0	0	0	406	3.5-6.0
5% Dextrose & 0.9% Sodium Chloride Injection, USP	50	9.0	0	0	0	560	3.5-6.0
10% Dextrose & 0.9% Sodium Chloride Injection, USP	100	9.0	0	0	0	813	3.5-6.0
Ringer's Injection, USP	0	8.6	0	300	330	309	5.0-7.5
Lactated Ringer's Injection, USP	0	6.0	3.1	300	200	273	6.0-7.5
5% Dextrose in Ringer's Injection	50	8.6	0	300	330	561	3.5-6.5
Lactated Ringer's with 5% Dextrose	50	6.0	3.1	300	200	525	4.0-6.5

*Normal physiologic isotonicity range is approximately 280-310 mOsm/liter. Administration of substantially hypotonic solutions may cause hemolysis and administration of substantially hypertonic solutions may cause vein damage.

**pH ranges are USP for applicable solutions, corporate specification for non-USP solutions.

Table 2. Approximate Ionic Concentrations (mEq/l) and Calories per Liter

	Ionic Concentrations (mEq/l)					Calories per liter
	Sodium	Potassium	Calcium	Chloride	Lactate	
5% Dextrose Injection, USP	0	0	0	0	0	170
10% Dextrose Injection, USP	0	0	0	0	0	340
0.9% Sodium Chloride Injection, USP	154	0	0	154	0	0
Sodium Lactate Injection, USP (M/6 Sodium Lactate)	167	0	0	0	167	54
2.5% Dextrose & 0.45% Sodium Chloride Injection, USP	77	0	0	77	0	86
5% Dextrose & 0.2% Sodium Chloride Injection, USP	34	0	0	34	0	170
5% Dextrose & 0.33% Sodium Chloride Injection, USP	56	0	0	56	0	170
5% Dextrose & 0.45% Sodium Chloride Injection, USP	77	0	0	77	0	170
5% Dextrose & 0.9% Sodium Chloride Injection, USP	154	0	0	154	0	170
10% Dextrose & 0.9% Sodium Chloride Injection, USP	154	0	0	154	0	340
Ringer's Injection, USP	147.5	4	4.5	156	0	0
Lactated Ringer's Injection, USP	130	4	3	109	28	9
5% Dextrose in Ringer's Injection	147.5	4	4.5	156	0	170
Lactated Ringer's with 5% Dextrose	130	4	3	109	28	180

Add 100-150 ml free water/d

$Na^{\oplus}$ — 135-145

$K^{\oplus}$ — 3.5-5.5

$Cl^{\ominus}$ — 85-115

$HCO_3^{\ominus}$ — 22-29

Ca^{++} — 9×10^{-7}

FLUID

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