Fluids & Electrolytes

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Body Water (as % body weight)

	Infant	**Male**	**Female**
Thin	80	65	55
Avg.	70	60	50
Obese	65	55	45

Functional Fluid Compartments

EXAMPLE: 70 Kg man, TBW = 42 L (60% x TBW)

	Body Wt	Compartment	Volume
ECF	5%	Plasma	3500 ml
	15%	ISF	10500 ml
ICF	40%	ICF	28000 ml

Blood Volume = 7-8 % Body wt

$$\text{Hct} = \frac{\text{RBC volume}}{\text{RBC volume + Plasma volume}}$$

Replacement of a 500 ml Plasma Volume Deficit

Solution	Amount
LR	2000 ml
FFP	500 ml
5% albumin	500 ml
25% albumin	100 ml

Osmolarity

- Principal force of fluid movement
- Depends on # of active particles in solution that cannot pass through the semipermeable cell membrane
- Normal serum value = 285-300 mOsm/L
  - **approximation: 2 (Na) + BUN/2.8 + Glucose/18**
- Urine: 70-1200 mOsm/L
  - primarily controlled by ADH

Water Balance

Intake

Oral: 800 - 1500 ml as liquids

500 - 700 ml as solids

Water of oxidation: 200 - 400 ml/day

Water Balance

Output

Urine: 1000 - 2500 ml/day

$\Rightarrow$ need 500 - 800 ml to excrete products of catabolism

Water of stool: 100 - 200 ml/day

Insensible: 600 - 900 ml/day

25% = Respiratory (250 - 750 ml/day)

75% = Skin (400 - 600 ml/day)

Causes of Increased Insensible Water Losses

- Fever: < 250 ml per °F above normal
- Excessive evaporative skin losses (burns)
- Operation: 500 ml/hr
- Respirator or tracheostomy (up to 1.5 L/day)
- Hypermetabolism

Monitoring of Water Balance

- Urine output: 0.5-1.0 ml/kg/hr
  (30-50 ml/hr - adults)
- Daily weights
- Hematocrit, electrolytes, osmolarity
- CVP, PCWP, Cardiac Output

Baseline Fluid Requirements

CHILDREN:

1st 10 Kg	→	100 ml/Kg/day
2nd 10 Kg	→	50 ml/Kg/day
> 20 Kg	→	20 ml/Kg/day

ADULTS: 30 - 35 ml/Kg/day

Baseline Electrolyte Requirements

CHILDREN: < 20 Kg:

- Sodium: 2-3 mEq/Kg/day
- Potassium: 1-2 mEq/Kg/day
- Chloride: 1-1.5 mEq/Kg/day

ADULTS:

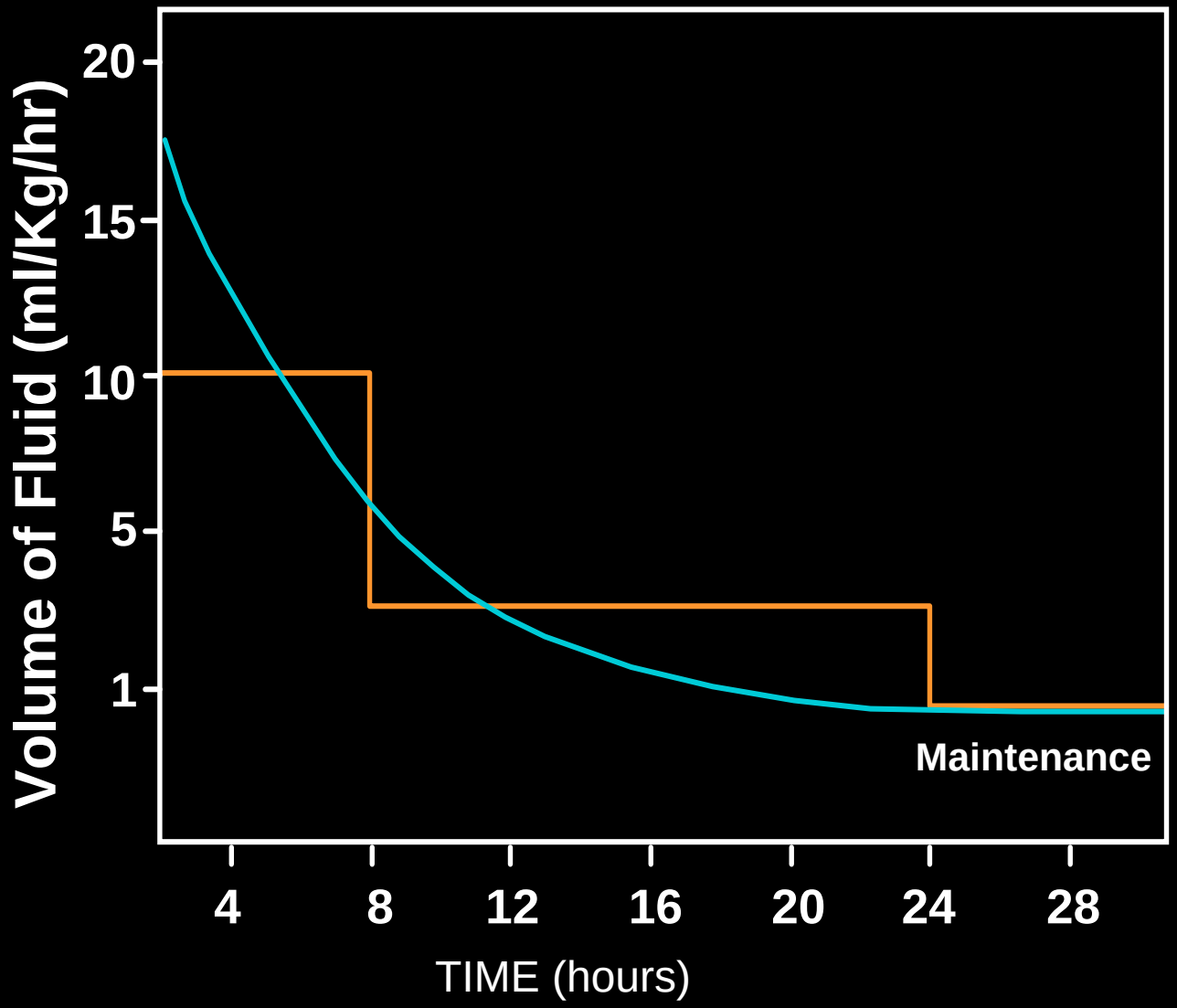
- Sodium: 75 - 120 mEq/day
- Potassium: 65 - 90 mEq/day
- Chloride: 85 - 145 mEq/day

Other Body Fluid Losses

G.I. Tract: secretes 8-10 L/day

Source	Volume	Na	K	Cl	HCO_3
Saliva	1500	10	25	15	30
Stomach	1500	60	10	130	--
Duodenum	100-2000	140	5	80	--
Pancreas	100-800	140	5	75	115
Bile	50-800	145	5	100	35
Ileum	3000	140	5	104	30
Colon	----	60	30	40	--

Graphic Concept of Fluid Resuscitation



Concept of 3rd Space

- Fluid still within ECF (interstitial)
- Sequestered into areas of injury
- Must be replaced
- Losses are mobilized after recovery

Acute Dehydration

Most Common Fluid Disorder in Surgical Patients

Diagnosis:

- **2% body wt**: dry skin, thirst, ↑ **urine osmolarity, oliguria**
- **4% body wt**: dry tongue and axillae, oliguria, **postural hypotension, tachycardia**
- **6% body wt**: LIFE THREATENING, above symptoms with **lethargy, ileus**

Treatment:

- Rapid infusion of balanced salt solution
- Avoid glucose-containing solutions

Chronic Dehydration

- May tolerate losses up to 10% of body wt.
- More even distribution between ECF & ICF
- Less symptomatic than acute
- Treatment: Slowly over a period of days

Hypotonic Dehydration
(DESALTING WATER LOSS)

Most common fluid balance disorder

Etiology:

- Isotonic extrarenal losses
  - G.I. obstruction or fistula, ileus, vomiting, massive diarrhea, trauma
- Renal losses
  - osmotic diuresis, diuretic phase of ATN

Hypotonic Dehydration

Diagnosis: hypotension, tachycardia, atony, obtundation, hypothermia;
low serum Na, urine Na <20 mEq/L

Treatment:

- Prevention:
  - replace GI losses Q 4-6hrs if massive
  - approximate electrolyte content of fluid lost
- Therapeutic:
  - **RAPID** replacement of water and electrolytes

Hypotonic Overhydration
(Water intoxication)

Etiology:

- **Overadministration of water**
- **Postop patients sensitive to hypotonic fluids**
- Chronic visceral disease on low Na diet
- Chronic caloric starvation
  - increased endogenous water production
  - increased ADH
  - defect in Na pump due to energy deficit
- **Inappropriate ADH syndrome**
  - cancer, COPD, porphyria, head injury

Hypotonic Overhydration

Diagnosis: lethargy, stupor, coma, convulsions, weight gain, anasarca, pulmonary edema

Treatment:

- **Water intoxication**: Decrease water intake
  ? Solute diuretic (mannitol)
  ?? 3% NaCl, 1/6 M Na Lactate

- **Inappropriate ADH**: Decrease water intake
  Lithium
  Declomycin

Hypertonic Dehydration
(Desiccation)

Etiology:

- Evaporative water loss: respiratory tract
  fever, burn wound
- Loss of hypotonic fluids: excess sweating (50 mEq Na/L)
  diarrhea (in children)
- Renal abnormalities or abnormal renal stimuli
  (*i.e.,* diabetes insipidus)
- Excess solute loading: hyperalimentation (NKHC, DKA)
  osmotic diuretics, angio. dyes
- Water deprivation

Hypertonic Dehydration

Diagnosis:

- Dry mucus membranes, thirst, oliguria, CNS changes
- Increased BUN, Na, osmolarity

Treatment:

- **Water replacement**
- Monitor body weight, osmolarity, renal function
- Watch for signs of cerebral edema

Parenteral Solutions

Solution	Na	K	Ca	Mg	Cl	HCO_3
ECF	142	4	5	3	103	27
LR	130	4	3	-	109	28
0.9% NaCl	154	-	-	-	154	--
1/2 NS	77	-	-	-	77	--
3% NaCl	513	-	-	-	513	--

Hyperkalemia

Etiology:

- Renal insufficiency, stored blood
- Severe injury, cellular damage
- Metabolic acidosis (in exchange for H^+)
- Iatrogenic

Symptoms: nausea, vomiting, diarrhea, colic
weakness, depressed DTR's

Hyperkalemia

Diagnosis: peaked T waves; prolonged ST, QRS

Complications: arrhythmias, ventricular fibrillation

Treatment:

- Glucose-insulin-bicarbonate: 50 cc D_{50}
  10-25 units regular insulin
  1 amp $NaHCO_3$
- Calcium gluconate (10%): 50-100 cc
- Kayexalate: 5-10 gm po QID or 30 gm enema Q 3-6h
- Dialysis: when $K^+ > 7$ mEq/L

Hypokalemia

Etiology:

- GI tract losses, alkalosis
- Renal excretion (diuretics)
- K into cells (insulin)
- Administration of K-free fluids
- Hyperaldosteronism
- Chronic hypercortisolism

Symptoms:

nausea, vomiting, weakness

ileus, depressed DTR’s

Hypokalemia

Diagnosis: flat T wave, prolonged QT, U wave

Complications: **DIGITALIS TOXICITY**

Treatment: potassium supplements
(< 20 mEq/hr)

Hypercalcemia

Etiology:

- Hyperparathyroidism
- Bony metastases
- Tumors secreting pseudoparathormone

Symptoms: CNS (weakness)
GI (anorexia)

Treatment:

- 0.9% Saline, furosemide
- Mithramycin
- Chelating agents
- Steroids

Hypocalcemia

Etiology:

- Hypoparathyroidism
- Soft tissue infections
- Pancreatitis
- Renal failure

Symptoms: circumoral numbness, tingling
hyperreflexia, tetany, cramps

Treatment: Calcium chloride or gluconate

Metabolic Acidosis

Etiology:

- Increased organic acid
  - diabetic ketoacidosis, lactic acidosis
  - cellular hypoxia (shock, airway obstruction, sepsis)
- Decreased renal excretion of acid
  - oliguric renal failure
  - hyperchloremia
  - obstructive uropathy
- Abnormal loss of bicarbonate
  - diarrhea
  - small bowel or pancreatic fistula

Metabolic Acidosis

Compensation:

- Hyperventilation, early
- Renal, late

Treatment:

- Correct underlying problem
- $NaHCO_3$
- Na lactate
- THAM (alkali w/o Na)

Metabolic Alkalosis

Etiology:

- Loss of HCl
  - NG suction, vomiting
- Loss of KCl
  - vomiting, diarrhea
  - diuretics, steroids, aldosteronism

Metabolic Alkalosis

Compensation:

- generally uncompensated by lungs
- renal excretion of bicarbonate

Treatment:

- Chloride replacement
- Potassium replacement
- 0.1 N HCl or ammonium chloride

Respiratory Acidosis

Etiology:

- Hypoventilation
- A-V shunting

Compensation: renal

Treatment: **mechanical ventilation**

Respiratory Alkalosis

Etiology:

- pain
- sepsis
- fever
- early ARDS

Compensation: renal

Treatment:

- Pain management
- Ventilatory support (CPAP/PEEP)
- Search for possible underlying sepsis

Interpretation of Blood Gases

	pH	pCO_2	HCO_3
Metabolic alkalosis	↑	—	↑
Metabolic acidosis	↓	—	↓
Respiratory acidosis	↓	↑	—
Respiratory alkalosis	↑	↓	—

Analysis of Acid-Base Balance

- $pCO_2 \uparrow$ 10 mm Hg > 40 $\Rightarrow$ pH decreases 0.08
- $HCO_3 \uparrow$ 10 mEq > 25 $\Rightarrow$ pH increases 0.15
- Bicarbonate deficit (mEq):
  - (25 - HCO_3) x (0.2 x Body wt) or B.E. x (0.3 x Body wt)
  - Replace $\leq$ 50% at a time