Daily Water Requirements

Weight, kg	Water, mL/kg/day
0-10	100 mL/kg/day
11-20	100 mL/kg/day for first 10 kg plus 50 mL/kg/day for each kilogram above 10 kg
21 and up	100 mL/kg/day for first 10 kg plus 50 mL/kg/day for next 10kg plus 20 mL/kg/day for each kilogram above 20 kg

Body Weight Method for Calculating Daily Maintenance Fluid Volume

BODY WEIGHT	FLUID PER DAY
0-10 kg	100 mL/kg
11-20 kg	1,000 mL + 50 mL/kg for each kg>10 kg
>20 kg	1,500 mL + 20 mL/kg for each kg>20 kg*

Hourly Maintenance Water Rate

- For body weight of 0-10 kg: 4 mL/kg/hr
- For body weight of 10-20 kg: 40 mL/hr + 2 mL/kg/hr x (wt – 10 kg)
- For body weight of >20: 60 mL/hr + 1 L/kg/hr x (wt – 20 kg)*

Adjustments in Maintenance Water

SOURCE	CAUSED OF INCREASED WATER NEEDS	CAUSES OF DECREASED WATER NEEDS
Skin	Radiant warmer Phototherapy Fever/Sweat Burns	Incubator (premature infant)
Lungs	Tachypnea Tracheostomy	Humidified ventilator
Gastrointestinal tract	Diarrhea Emesis Nasogastric suction	
Renal	Polyuria	Oliguria/anuria
Miscellaneous	Surgical drain Third spacing	Hypothyroidism

Factors modifying fluid requirements

Factors increasing water requirements

1. Increase in metabolic rate.
   a) Fever (increase fluid in take by 12% per ºC rise above 37.5ºC).
   b) Hypermetabolic states e.g. salicylism, hyperthyoidism (Increase requirements by 25%).
2. Hyperventilation
3. High ambient temperature
4. Extreme activity
5. Any other abnormal fluid losses.

Factors decreasing water requirements

1. Decrease in metabolic rate
2. Hypothermia (decrease fluid intake by 12% per ºC below 37ºC).
3. Hypometabolic states e.g. hypothyroidism (Decrease requirement by 10%)
4. Very high humidity.
5. Extreme inactivity.
6. Presence of cerebral oedema (meningitis, encephalitis)
7. Fluid retention (cardiac failure), oliguria, anuria.

HISTORICAL DATA REQUIRED IN ESTIMATING MAGNITUDE AND TYPES OF DEFICIT AND IN PLANNING DEFICIT THERAPY

- Intake-during period of illness
  - Quantity and how given
    - Kind: water, electrolyte, protein, drugs
- Output – during period of illness
  - Quantity
    - Kind: urine, vomiting, diarrhea, sweat ,drainage
- Balance
  - Weight change
- General medical
  - Age
  - Cardiovascular, respiratory, renal, or central nervous system

$$\text{Percent dehydration} = \frac{\begin{array}{r}\text{(Expected or recent weight)} \\ - \ \text{(Current weight)}\end{array}}{\text{Expected weight}} \times 100$$

CLINICAL ESTIMATION OF DEGREE OF DEHYDRATION

	Mild	Moderate	Severe
Body fluid lost (ml/kg)	<50	50-100	>100
Weight loss (%)	<5	5-10	>10
Stage of stock	Impending	Compensated	Uncompensated
Vital Signs			
Heart rate	Slight ↑	↑ (orthostasis)	↑↑
Respiratory	Normal	Normal	↑(Hyperpnea)
Blood pressure	Normal	Normal (orthostasis)	↓
Skin			
Capillary refill (finger)	<2 sec	2-3 sec	>3 sec
Elasticity (<2 yrs)	Normal	↓	↓↓ (Tenting)
Anterior fontanel	Normal	Depressed	Depressed
Mucous membranes	Normal/dry	Dry	Dry

CLINICAL ESTIMATION OF DEGREE OF DEHYDRATION

CNS	Mild	Moderate	Severe
Mental status	Normal	Altered	Depressed
Eyes			
Tearing	Normal/absent	Absent	Absent
Appearance	Normal	Sunken	Sunken
Laboratory Test			
Urine			
Volume	Small	Oliguria	Oliguria-anuria
Osmolarity	600	800	Maximal
Specific gravity	1.020	1.025	Maximal
Blood			
Blood urea nitrogen	Upper normal	Elevated	High
pH	7.40-7.22	7.30-6.92	7.10-6.80

Deficit (mEq) = Body weight (kg) x

[Desired concentration (mEq/L) –

Actual concentration (mEq/L] x Distribution factor

Clinical Evaluation of Dehydration

- Mild dehydration (<5% in an infant;<3% in an older child or adult): normal or increased pulse; decreased urine output; thirsty; normal physical finding.
- Moderate dehydration (5-10% in an infant; 3-6% in an older child or adult): tachycardia; little or no urine output; irritable/lethargic; sunken eyes and fontanel; decreased tears; dry mucous membranes; mild delay in elasticity (skin turgor); delayed capillary refill (>1.5 sec); cool and pale
- Severe dehydration (>10% in an infant; 6% in an older child or adult): rapid and weak or absent peripheral pulses; decreased blood pressure; no urine output; very sunken eyes and fontanel; no tears; parched mucous membranes; delayed elasticity (poor skin turgor); very delayed capillary refill (>3 sec); cold and mottled; limp, depressed consciousness

Fluid Management of Dehydration

- Restore intravascular volume
  Normal saline: 20 mL/kg over 20 min
  Repeat as needed
- Rapid volume repletion: 20 mL/kg normal saline or Ringer Lactate (maximum = 1L) over 2 hr
- Calculate 24-hr fluid needs; maintenance + deficit volume
- Subtract isotonic fluid already administered from 24 hr fluid needs
- Administer remaining volume over 24 hr using D5 ½ normal saline + 20 mEq/L KCl
- Replace ongoing losses as they occur

Composition of Intravenous Solutions

FLUID	[Na^+]	[Cl^-]	[K^+]	[Ca^{2+}]	[Lactate]
Normal saline (0.9% NaCl)	154	154			
½ normal saline (0.45% NaCl)	77	77			
0.2 normal saline (0.2% NaCl)	34	34			
Ringer lactate	130	109	4	3	28

Monitoring Therapy

VITAL SIGNS

- Pulse
- Blood pressure

INTAKE AND OUTPUT

- Fluid balance
- Urine output and specific gravity

PHYSICAL EXAMINATION

- Weight
- Clinical signs of depletion or overload

ORAL ELECTROLYTE SOLUTION COMPOSITION

	Sodium (mEq/L)	Potassium (mEq/L)	Chloride (mEq/L)	Carbohydrate (g/dl)
Rehydration solutions				
World Health Organization formation	90	20	80	2.0 (glucose)
Rehydralyte	75	20	65	2.5 (glucose)
Maintenance solutions				
Pedialyte	45	20	35	2.5 (glucose)
Lytren	50	25	45	2.0 (glucose)
Resol	50	20	50	2.0 (glucose)
Infalyte	50	20	40	2.0 (glucose)
Ricelyte	50	25	45	30 (glucose polymers)

COMPOSITION OF CLEAR LIQUID BEVERAGES

Fluid	Sodium (mmol/L)	Potassium (mmol/L)	Carbohydrates (gm/100 mL)	Osmolarity (mmol/L)
Beef broths	110-248	2.5-17	-	300-390
Chicken broths	140-251	1.5-8.2	-	380-500
Apple juice	0.1–3.5	24-92	12	650-734
Grape juice	0.8-2.8	31-44	15	1170-1190
Colas	1.3-1.7	0.1	10.4-11.3	390-750
Ginger ale	0.8-5.5	0.1-1.5	5.3	520-560
7-Up	5-5.5	1.0-2.0	7.4	520-550
Kool-Aid	0.5-1.2	0.1-1.8	10.6	250-590
Popsicles	4.7-5.6	0.5-2.0	NA	670-720
Jell-O	22-27	1.3-2.0	15.8	570-640
Tea (unsweetened)	0	5	0	-
Gatorade	20	3	4.6	330

Emergency Treatment of Hyperkalemia

Techniques	Agent	Dose	Rate of Administration	Onset/Duration of Action	Comment
Reversal of membrane effects	10% calcium gluconate	0.5 ml/kg	2-5 min IV	Min/30-60 min	ECG monitor; discontinue if pulse rate <100
Movement of K into cells	Na bicarbonate, 7.5% (1 mEq ~	2-3 ml/kg	30-60 min	30 min/1-4 hr	May use in the absence of acidosis
	Glucose 50% plus insulin (regular)	1 unit for every 5-6 g glucose	Same	Same	Monitor blood glucose
Enchanced excretion of K	Kayexalate	1 g/kg	Can be given in 10% glucose (1 g in 4 ml) every 4-6 hr	Hours/variable	Can be given p.o. or by rectum

Complications of Alkali Therapy in Metabolic Acidosis

- Hypokalemia
  - A. K^+ losses as part of the disease process (e.g. renal tubular acidosis, diabetic ketoacidosis)
  - B. K^+ shifts into cells
- Alkalosis
  - A. Overcorrection
  - B. Persistent hyperventilation
  - C. Endogenous manufacture of HCO_3
- CSF Acidosis
  - A. Delay in equilibration of HCO_3 across the blood-brain barrier
- Sodium Overload
- Hypocalcemic Tetany
  - A. Ca^{2+} binding to protein
  - B. Ca^{2+} incorporation into bone

Appropriate Compensation During Simple Acid-Base Disorders

DISORDER	EXPECTED COMPENSATION
Metabolic acidosis	$PCO_2 = 1.5x\ [HCO_3^-] + 8 \pm 2$
Metabolic alkalosis	PCO_2 increased by 7 mm Hg for each 10 mEq/L increase in serum $[HCO_3^-]$
Respiratory acidosis	
Acute	$[HCO_3^-]$ increased by 1 for each 10-mm Hg increase in PCO_2
Chronic	$[HCO_3^-]$ increased by 3.5 for each 10-mm Hg increase in PCO_2
Respiratory alkalosis	
Acute	$[HCO_3^-]$ falls by 2 each 10-mm Hg decrease in PCO_2
Chronic	$[HCO_3^-]$ falls by 4 each 10-mm Hg decrease in PCO_2

Normal Values of Arterial Blood Gas

pH	7.35-7.45
$[HCO_3^-]$	20-25 mEq/L
PCO_2	35-45 mm Hg

Causes of Metabolic Acidosis

Increased Anion Gap

- Lactic acidosis
  - Tissue hypoxia (shock, hypoxemia, severe anemia)
  - Liver failure
  - Malignancy
  - Intestinal bacterial overgrowth
  - Inborn errors of metabolism
  - Medications (nucleoside analogues, metformin)
- Ketoacidosis
  - Diabetic ketoacidosis
  - Starvation ketoacidosis
  - Alcoholic ketoacidosis
- Kidney failure
- Poisoning
  - Ethylene glycol
  - Methanol
  - Salicylate
  - Toluene
  - Paraldehyde
- Inborn errors or metabolism

Causes of Respiratory Alkalosis

CENTRAL STIMULATION

- Central nervous system disease
  - Subarachnoid hemorrhage
  - Encepphalistic or meningitis
  - Trauma
  - Brain tumor
  - Stroke
- Fever
- Pain
- Anxiety (panic attack)
- Psychogenic hyperventilation or anxiety
- Liver failure
- Sepsis
- Pregnancy
- Medications
  - Salicylate intoxication
  - Theophylline
  - Progesterone
  - Exogenous catecholamines
  - Caffeine
- Mechanical ventilation
- Hyperammonemia
- Extracorporeal membrane oxygenation or hemodialysis

Treatment of Hypernatremic Dehydration

- RESTORE INTRAVASCULAR VOLUME

  Normal saline: 20mL/kg over 20 min

  (Repeat until intravascular volume restored)

- DETERMINE TIME FOR CORRECTION BASED ON INITIAL SODIUM CONCENTRATION

  [Na]: 145-157 mEq/L: 24 hr

  [Na]: 158-170 mEq/L: 48 hr

  [Na]: 171-183 mEq/L: 72 hr

  [Na]: 184-196 mEq/L: 84 hr

Treatment of Hypernatremic Dehydration

- ADMINISTER FLUID AT CONSTANT RATE OVER TIME FOR CORRECTION

  Typical fluid: D5½ normal saline (with 20 mEq/L KCl unless contraindicated)

  Typical rate:1.25-1.5 times maintenance

- FOLLOW SERUM SODIUM CONCENTRATION ADJUST FLUID BASED ON

  CLINICAL STATUS AND SERUM SODIUM CONCENTRATION

  Signs of volume depletion: administer normal saline (20 mL/kg)

  Sodium decrease too rapidly

  Increase sodium concentration of intravenous fluid, or

  Decrease rate of intravenous fluid

  Sodium decreases too slowly

  Decrease sodium concentration of intravenous fluid, or

  Increase rate of intravenous fluid

- REPLACE ONGOING LOSSES AS THEY OCCUR

Emergency Treatment of Hyperkalemia

Techniques	Agent	Dose	Rate of Administration	Onset/Duration of Action	Comment
Reversal of membrane effects	10% calcium gluconate	0.5 ml/kg	2-5 min IV	Min/30-60 min	ECG monitor; discontinue if pulse rate <100
Movement of K into cells	Na bicarbonate, 7.5% (1 mEq ~	2-3 ml/kg	30-60 min	30 min/1-4 hr	May use in the absence of acidosis
	Glucose 50% plus insulin (regular)	1 unit for every 5-6 g glucose	Same	Same	Monitor blood glucose
Enchanced excretion of K	Kayexalate	1 g/kg	Can be given in 10% glucose (1 g in 4 ml) every 4-6 hr	Hours/variable	Can be given p.o. or by rectum

ETIOLOGY OF DEHYDRATION

- Reduced intake
  - Anorexia
  - Coma
  - Fluid restriction
- Increased loss
  - Gastrointestinal
    - Vomiting
    - Diarrhea
    - Enterocutaneous fistula or drains
  - Renal
    - Osmotic diuresis
    - Diuretic administration
    - Adrenal insufficiency
    - Chronic renal failure
    - Salt-losing nephropathy
    - Post obstructive diuresis
    - Central or nephrogenic diabetes insipidus
  - Skin and respiratory
    - Heat exposure
    - Cystic fibrosis
    - Inflammatory skin disease
    - Burns

Composition of Oral Rehydration Solutions

Solution	Glucose (mmol/L)	Na (mEq/L)	K (mEq/L)	Cl (mEq/L)	BASE (mEq/L)	OSMOLALILTY (mOsm/kg)
WHO solution	111	90	20	80	30	311
Rehydralyte	140	75	20	65	30	310
Pedialyte	140	45	20	35	30	250
Pediatric Electrolyte	140	45	20	35	55	250
Infalyte	70*	50	25	45	34	200
Naturalyte	140	45	20	35	55	238

SYMPTOMS AND SIGNS OF HYPONATREMIA

Symptoms	Signs
Lethargy, apathy	Abnormal sensorium
Disorientation	Depressed deep tendon reflexes
Muscle cramps	Chyne-Stokes respiration
Anoxeria, nausea	Hypothermia
Agitation	Pathological reflexes
	Pseudobulbar palsy
	Seizures

TREATMENT OF HYPERKALEMIA

- Membrane-reversing effects
  - a. 10% calcium gluconate, 0.5-1.0 mg/kg IV over 2-5 min
    1. May repeat in 5-10 min
    2. Duration of action 30-60 min
    3. EKG monitoring
- Transcellular shifting of potassium
  - a. Sodium bicarbonate, 1-2 mEq/kg IV over 5-10 min
    1. May repeat in 15 min
    2. Duration of action up to 2 hr
    3. EKG monitoring
  - b. Glucose, 0.5 to 1.0 gm/kg IV over 30 min
    1. May repeat as needed
    2. Duration of action 4-6 hr
    3. May administer regular insulin IV (1 unit/3 gm glucose of 1 unit/kg)
    4. Glucose monitoring
- Potassium elimination
  - a. Diuretics
  - b. Ion exchange resin (sodium polystyrene sulfonate) 1 gm/kg
    1. Retention enema, 0.5 to 1.0 gm/kg over 30-45 min
       (a) Sorbitol 20%-25% solution, 3 mL/gm resin
    2. Orally: 0.5 to 1.9 gm/kg
       (a) Water, 3-4ml/gm resin
       (b) Sorbitol 70% solution or dextrose 10% solution
  - c. Dialysis
    1. Preferably hemodialysis
    2. Peritoneal dialysis

Etiologies of Hyponatremia

- Normal Total Body Water and Na (Hyperosmolar Hyponatremia)
  - A. Hyoerglycemia*
  - B. Mannitol, glycerol therapy
- Increased Total Body, Water and Na (Edema-Forming States)
  - A. Congestive heart failure
  - B. Nephrosis
  - C. Cirrhosis
  - D. Acute renal failure

Etiologies of Hyponatremia

- Decreased Total Body Water and Na (Hypovolemic States)
  - A. Gastrointestinal losses (vomiting, diarrhea,fistulas)
  - B. Renal losses (diuretics, renal tubular acidosis, primary intersitial disease)
  - C. Adrenal (mineralocosticoid deficiencies)
  - D. Third-space losses (ascites, burns, pancreatitis, peritonitis)
- Increased Total Body Water but Normal Total Body Na
  - A. Syndrome of inappropriate antidiuretic hormone secretion
  - B. Water intoxication
  - C. Miscellaneous (reset osmostat, hypothyroidism, glucocorticoid deficiency)
- Psedohyponatremia
  - A. Extreme hyperlipidemia or hyperproteinemia

Symptoms and Signs of Hyponatremia

Symptoms

- Anorexia
- Nausea
- Muscle cramps
- Apathy
- Disorientation
- Agitation
- Acute respiratory failure

Signs

- Clouded sensorium
- Decreased tendon reflexes
- Pathologic reflexes
- Hypothermia
- Pseudobulbar palsy
- Seizures

Laboratory Evaluation of Hyponatremia

- Blood
  - A. Electrolytes (Na, K, Cl, $HCO_{3)}$
  - B. BUN, creatinine
  - C. Liver function tests
  - D. Osmolality
- Urine
  - A. Urinalysis, including specific gravity
  - B. Urine Na
  - C. Urine creatinine
  - D. Urine osmolality

Etiologies of Hypernatremia

- Increased Total Body Na or Increased Total Body Na Greater than Increased Total Body Water
  - A. Na poisoning (accidental: Na bicarbonate therapy)
  - B. Hyperaldosteronism (rare in children)
- Normal Total Body Na; “Pure” Water Loss
  - A. Insensible losses – respiratory and skin
  - B. Renal (central and nephrogenic diabetes insipidus)
  - C. Inadequate access to water
-

Etiologies of Hypernatremia

- Decreased Total Body Na Less than Decreased Total Body Water
  - A. Extrarenal (gastrointestinal)[a]
  - B. Renal (osmotic diuretics; glucose, mannitol,urea)
  - C. Obstructive uropathy

- Normal Total Body Na and Water with Abnormal Central Osmotic Regulation of Water Balance
  - A. Essential hypernatremia

Etiologies of Hypokalemia

- Apparent K Deficit (transcellular shifts)
  - A. Alkalosis
  - B. Familial hypokalemic periodic paralysis
  - C. Insulin
  - D. β_2 catecholamine
- Decreased Intake
  - A. Anorexia nervosa
  - B. Unusual diets (rate in pediatrics)
- Extra renal Losses
  - A. Protracted vomiting (e.g., pyloric stenosis or gastric suction)
  - B. Protracted diarrhea
  - C. Ureterosigmoidostomy
  - D. Laxative abuse (rare in pediatrics)
  - E. Increased sweating (cystic fibrosis)

Etiologies of Hypokalemia

- Renal Losses
  - A. Diuretic abuse (naturetic, osmotic agents)
  - B. Renal tubular acidosis
  - C. Diabetic ketoacidosis
  - D. Excessive mineral corticoid effect
    1. Primary/secondary hyperaldosteronism
    2. Bartter's syndrome
    3. Licorice abuse (rare in pediatrics)
    4. Cushing's syndrome (rare in pediatrics)
  - E. Excessive administration of "impermeant anions" (carbenicillin)

Pathophysiologic (Clinical) Consequences of Hypokalemia

- Muscle cell dysfunction (rhabdomyolysis)
- Cardiac cell dysfunction (myocardiopathy, arrhythmias)
- Neuromuscular dysfunction (weakness-paralysis,ileus, tetany,encephalopathy with underlying liver disease)
- Renal (polydipsia, polyuria, concentration defect)

Laboratory Evaluation of Hypokalemia

- Blood
  A. Electrolytes (Na, K, Cl, HCO_3)
  B. BUN, creatinine
  C. Glucose
  D. Arterial blood gas
  E. Creatine phophokinase
- Urine
  A. Urinalysis
  B. Urine Na, K, Cl
  C. Urine pH
  D. Urine osmolality
- Other[a]
  A. ECG
  B. Plain abdominal x-ray
  C. Upper gastrointestinal series or ultrasound

Etiologies of Hyperkalemia

- Pseudohyperkalemia (*Hemolysis, extreme leukocytosis, or thrombocytosis)*
- Apparent K Excess (Transcellular shifts)
  - A. Acidosis
- Increased Intake
  - A. Endogenous (rhabdomyolysis, massive hemolysis)
  - B. Exogenous (suicide attempt with K salts)
- Decreased Excretion
  - A. Acute or chronic renal failure (oliguria)
  - B. Adrenal corticoid deficiency (acute adrenal insuffieciency, hyporeninemic hypoaldosteronism)
  - C. Use of K-sparing diuretics in renal failure or in conjunction with dietary K supplements
  - D. B-Blockers, converting enzyme inhibitors

Laboratory Evaluation of Hyperkalemia

- Blood
  A. Electrolytes (Na, K, Cl, HCO_3)
  B. BUN, creatinine
  C. Glucose
  D. Arterial blood gas
  E. Creatine phophokinase
- Urine
  A. Urinalysis
  B. Urine Na, K, Cl
  C. Urine pH
  D. Urine osmolality
- Other[a]
  A. ECG

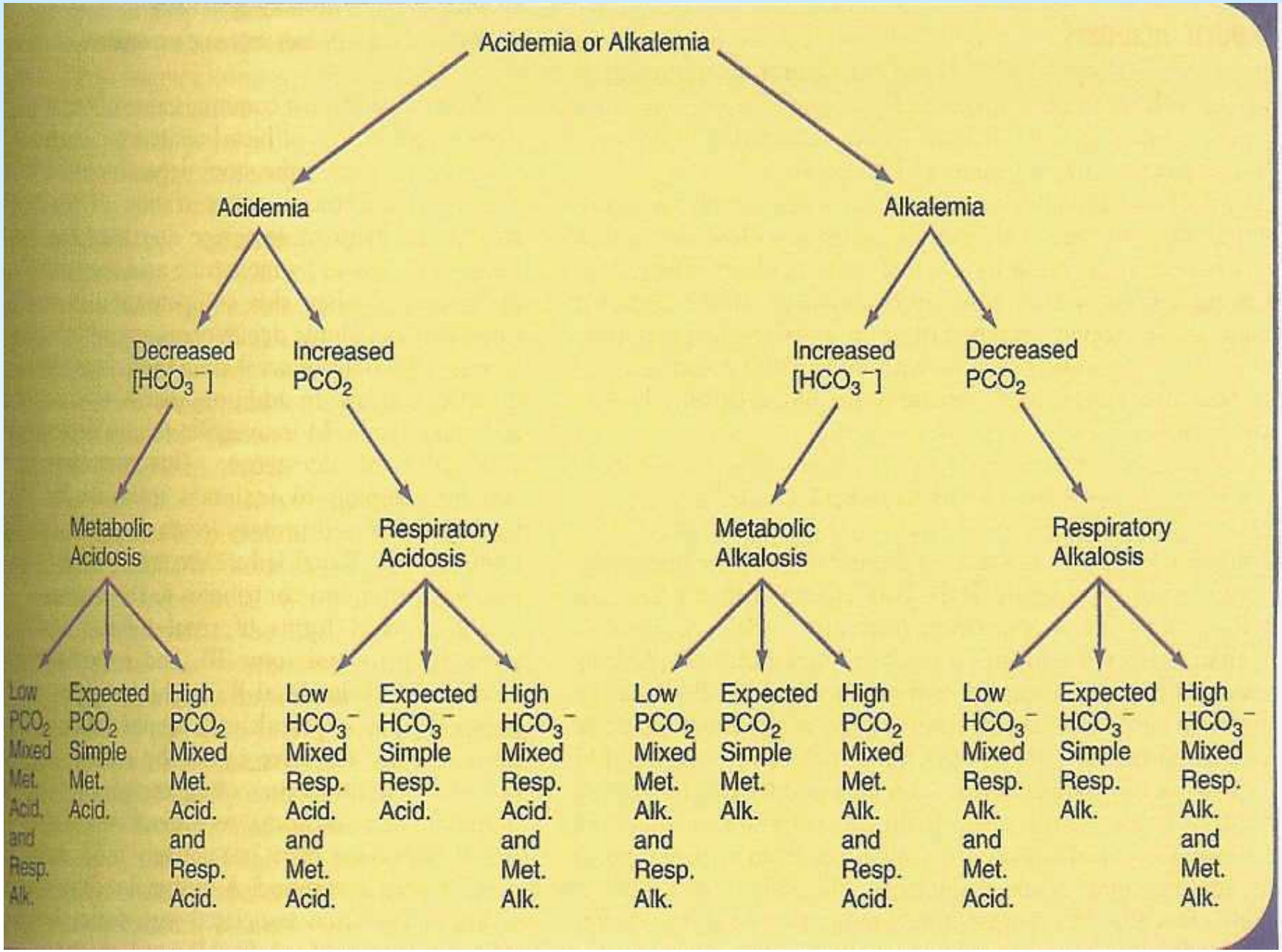
Etiologies of Metabolic Acidosis

- Elevated Anion Gap Acidosis
  - A. Diarrhea dehydration
  - B. Diabetic ketoacidosis
  - C. Renal failure (acute or chronic)
  - D. Inborn errors of metabolism
  - E. Poisons (e.g. salicylates, ethanol, ethylene glycol)
  - F. Kactic acidosis (e.g. hypoxia, sepsis, idiopathic)

- Normal Anion Gap Acidosis
  - A. Hypernatremic dehydration (older children)
  - B. Renal tubular acidosis
  - C. Hyper alimentation
  - D. Enteric fistulas (e.g. pancreatic) or enterostomies
  - F. Drugs (e.g., Sulfamylon, ammonium chloride, amphotericin, acetazolamide)
  - G. Early renal failure (chronic interstitial nephritis)
  - H. Dilution (rapid volume expansion)

Laboratory Evaluation of Metabolic Acidosis

- Blood
  - A. Electrolytes (Na, K, Cl, HCO_3)[a]
  - B. Arterial blood gases
  - C. BUN, creatinine
  - D. Glucose
  - E. Toxic screen[b]
  - F. Lactate, pyruvate[c]
- Urine
  - A. Dipstick (pH, glucose, protein)


Acidemia or Alkalemia
Acidemia
Alkalemia
Decreased [HCO_3^-]
Increased PCO_2
Increased [HCO_3^-]
Decreased PCO_2
Metabolic Acidosis
Respiratory Acidosis
Metabolic Alkalosis
Respiratory Alkalosis
Low PCO_2 Mixed Met. Acid. and Resp. Alk.
Expected PCO_2 Simple Met. Acid.
High PCO_2 Mixed Met. Acid. and Resp. Acid.
Low HCO_3^- Mixed Resp. Acid. and Met. Acid.
Expected HCO_3^- Simple Resp. Acid.
High HCO_3^- Mixed Resp. Acid. and Met. Alk.
Low PCO_2 Mixed Met. Alk. and Resp. Alk.
Expected PCO_2 Simple Met. Alk.
High PCO_2 Mixed Met. Alk. and Resp. Acid.
Low HCO_3^- Mixed Resp. Alk. and Met. Acid.
Expected HCO_3^- Simple Resp. Alk.
High HCO_3^- Mixed Resp. Alk. and Met. Alk.

Causes of Metabolic Acidosis

Normal Anion Gap

- Diarrhea
- Renal tubular acidosis (RTA)
  - Distal (type 1) RTA (MIM 179800/602722/267300)*
  - Proximal (type 11) RTA (MIM 604278)†
  - Hyperkalemix (type IV) RTA (MIM 201910/264350/177735/145260) †
- Urinary tract diversion
- Posthypocapnia
- Ammonium chloride intake

Causes of Metabolic Alkalosis

CHLORIDE RESPONSIVE (URINARY CHLORIDE< 15 mEq/L)

- Gastric losses (emesis or nasogastric suction)
- Diuretics (loop or thiazide)
- Chloride-losing diarrhea (MIM 214700)
- Chloride-deficient formula
- Cystic fibrosis (MIM 219700)
- Post-hypercapnia

Causes of Metabolic Alkalosis

CHLORIDE RESISTANT (URINARY CHLORIDE>20 mEq/L)

- High blood pressure
  - Adrenal adenoma or hyperplasia
  - Glucocorticoid-remedial aldosteronism (MIM 103900)
  - Renovascular disease
  - Renin-secreting tumor
  - 17α-hydroxylase deficiency (MIM 202110)
  - 11β--hydroxylase deficiency (MIM 202010)
  - Cushing syndrome
  - 11β—hydroxysteroid dehydrogenase deficiency (MIM 218030)
  - Licorice ingestion
  - Liddle syndrome (MIM 177200)

Causes of Metabolic Alkalosis

- Normal blood pressure
  - Gitelman syndrome (MIM 263800)
  - Bartter syndrome (MIM 602023/607364/602522/241200/601678)
  - Autosomal dominant hypoparathyroidism (MIM 146200)
  - Base administration

Causes of Respiratory Acidosis

CENTRAL NERVOUS SYSTEM DEPRESSION

- Encephalitis
- Head trauma
- Brain tumor
- Central sleep apnea
- Primary pulmonary hypoventilation (Ondine curse)
- Stroke
- Hypoxic brain damage
- Obesity-hypoventilation (Pickwickian syndrome)
- Increased intracranial pressure
- Medications
  - Narcotics
  - Barbiturates
  - Anesthesia
  - Benzodiazepines
  - Propofol
  - Alcohols

Causes of Respiratory Acidosis

DISORDERS OF THE SPINAL CORD, PERIPHERAL NERVES, OR NEUROMUXCULAR JUNCTION

- Diaphragmatic paralysis
- Guillain-Barré syndrome
- Poliomyelitis
- Spinal muscular atrophies
- Tick paralysis
- Botulism
- Myasthenia
- Multiple sclerosis
- Spinal cord injury
- Medications
  - Vecuronium
  - Aminoglycosides
  - Organophosphates (pesticides)

Causes of Respiratory Acidosis

RESPIRATORY MUSCLE WEAKNESS

- Muscular dystrophy
- Hypothyroidism
- Malnutrition
- Hypokalemia
- Hypophosphatemia
- Medications
  - Succinycholine
  - Corticosteroids

Causes of Respiratory Acidosis

PULMONARY DISEASE

- Pneumonia
- Pneumothorax
- Asthma
- Bronchiolitis
- Pulmonary edema
- Pulmonary hemorrhage
- Adult respiratory distress syndrome
- Respiratory distress syndrome, neonatal
- Cystic fibrosis
- Bronchopulmonary dysphasia
- Hypo plastic lungs
- Meconium aspiration
- Pulmonary thromboembolus
- Interstitial fibrosis

Causes of Respiratory Acidosis

UPPER AIRWAY DISEASE

- Aspiration
- Laryngospasm
- Angiodema
- Obstructive sleep apnea
- Tonsillar hypertrophy
- Vocal cord paralysis
- Extrinsic tumor
- Extrinsic or intrinsic hemangioma

Causes of Respiratory Acidosis

MISCELLANEOUS

- Flail chest
- Cardiac arrest
- Kyphoscoliosis
- Decreased diaphragmatic movement due to ascites or peritoneal disease.

Causes of Respiratory Alkalosis

HYPOXEMIA OR TISSUE HYPOXIA

- Pneumonia
- Pulmonary edema
- Cyanotic heart disease
- Congestive heart failure
- Asthma
- Severe anemia
- High altitude
- Laryngospasm
- Aspiration
- Carbon monoxide poisoning
- Pulmonary embolism
- Interstitial lung disease
- Hypotension

Causes of Respiratory Alkalosis

LUNG RECEPTOR STIMULATION

- Pneumonia
- Pulmonary edema
- Asthma
- Pulmonary embolism
- Hemothorax
- Pneumothorax
- Respiratory distress syndrome (adult of infant)

Causes of Respiratory Alkalosis

Goals of Maintenance Fluids

- Prevent dehydration
- Prevent electrolyte disorders
- Prevent ketoacidosis
- Prevent protein degradation

Sources of Water Loss

Urine: 60%

Insensible losses: ~ 35% (skin and lungs)

Stool: 5%

Replacement Fluid for Diarrhea

AVERAGE COMPOSITION OF DIARRHEA

Sodium: 55 mEq/L

Potassium: 25 mEq/L

Bicarbonate: 15 mEq/L

APPROACH TO REPLACEMENT OF ONGOING LOSSES

Solution: D5 0.2 normal saline + 20 mEq/L sodium bicarbonate + 20 mEq/L KCl

Replace stool mL/mL every 1-6 hr

Replacement Fluid for Emesis or Nasogastric Losses

AVERAGE COMPOSITION OF GASTRIC FLUID

Sodium: 60 mEq/L

Potassium: 10 mEq/L

Chloride: 90 mEq/L

APPROACH TO REPLACEMENT OF ONGOING LOSSES

Solution: normal saline + 10 mEq/L KCl

Replace output mL/mL every 1-6 hr

Adjusting Fluid Therapy for Altered Renal Output

OLIGURIA/ANURIA

Place patient on insensible fluids (25-40% of maintenance)

Replace urine output mL/mL with ½ normal saline

POLYURIA

Place patient on insensible fluids (25-40% of maintenance)

Measure urine electrolytes

Replace urine output mL/mL with solution based on measured urine electrolytes

Conversions and Estimates

Temperature

- To convert centigrade to Fahrenheit:

  (9/5 x temperature) + 32

- To convert Fahrenheit to centigrade:

  (temperature – 32) x 9/5

Conversions and Estimates

Weight

To change pounds to grams, multiply by 454

To change kilograms to pounds, multiply by 2.2

- Growth Patterns

Birth weight (average): 3.3 kg (7 lb 5 oz)

A new born loses up to 10% of birth weight but should be up to birth weight again by 10 days.

An infant gains 30 g (1 oz) day for the first 1-2 month

5 month: birth weight should be doubled

12 month: birth weight should be tripled

2 yr: birth weight should be quadrupled

- Estimates of Weight

4 to 8-year-old: 6 x age + 12 = Weight (lb)

8 to 12-year-old: 7 x age + 5 = Weight (lb)

Conversions and Estimates

Length

To convert inches to centimeters, multiply by 2.54

To convert centimeters to inches, multiply by 0.394

- Growth Patterns

  Birth length (average): 50 cm (20 in)

  12 month: birth length should be doubled

Conversions and Estimates

Head Circumference

- Growth Patterns

  Birth head circumference (average): 35 cm (14 in)

  12 month head circumference (average): 47 cm (19 in)

  Head circumference grows 1 cm/month during first 9 month

Conversions and Estimates

Blood Pressure (estimate)

Systolic BP (mm Hg) = 2 x Age (yr) + 80

Diastolic BP (mm Hg) = 2/3 systolic

Conversions and Estimates

To convert	To	Multiply by
1 mm Hg	PSI	0.0193
1 cm H_20	Mm Hg	0.735
1 mm Hg	Cm H_20	1.259
1 cm	Inch	0.3937
1 inch	Cm	2.54
1 kg	Pound	2.204
1 pound	Kg	0.4536
1 Fr size	mm	0.33

Composition of Oral Rehydration Salts Solution for Severely Malnourished Children (ReSoMal)

COMPONENT	CONCENTRATION (mmol/L)
Glucose	125
Sodium	45
Potassium	40
Chloride	70
Citrate	7
Magnesium	3
Zinc	0.3
Copper	0.045
Osmolarity	300