ACID-BASE DISORDERS

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Acid-Base Regulation

- Metabolic processes continually produce acid and, to a lesser degree, base.
- Hydrogen ion (H+) is especially reactive; it can attach to negatively charged proteins and, in high concentrations, alter their overall charge, configuration, and function.
- To maintain cellular function, the body has elaborate mechanisms that maintain blood H+ concentration within a narrow range:

Typically 37 to 43 nmol/L (pH 7.43 to 7.37, where pH =−log [H+]) and ideally 40 nmol/L (pH = 7.40).

Disturbances of these mechanisms can have serious clinical consequences.

- Acid-base equilibrium is closely tied to fluid metabolism and electrolyte balance, and disturbances in one of these systems often affect another.

Acid-Base Physiology

- Most acid comes from "Carbohydrate and fat metabolism"
- Metabolism of carbohydrates and fats generates 15,000 to 20,000 mmol of carbon dioxide (CO2) daily.
- CO_2 is not an acid itself, but in the presence of a member of the carbonic anhydrase family of enzymes, CO_2 combines with water (H2O) in the blood to create carbonic acid (H2CO3), which dissociates into hydrogen ion (H+) and bicarbonate (HCO3−). The H+ binds with hemoglobin in RBCs and is released with oxygenation in the alveoli, at which time the reaction is reversed by another form of carbonic anhydrase, creating water (H2O), which is excreted by the kidneys, and CO2, which is exhaled in each breath.

$$H^+ + HCO_3^- \Leftrightarrow H_2CO_3 \Leftrightarrow CO_2 + H_2O$$

- Lesser amounts of organic acid derive from the following:
  Incomplete metabolism of glucose and fatty acids into lactic acid and ketoacids
  Metabolism of sulfur-containing amino acids (cysteine, methionine) into sulfuric acid
  Metabolism of cationic amino acids (arginine, lysine)
  Hydrolysis of dietary phosphate
- This "fixed" or "metabolic" acid load cannot be exhaled and therefore must be neutralized or excreted by the kidneys.
- Most base comes from metabolism of anionic amino acids (glutamate and aspartate) and from oxidation and consumption of organic anions such as lactate and citrate, which produce HCO3−.

Acid-Base Balance

- Acid-base balance is maintained by chemical buffering and pulmonary and renal activity.
- **Chemical buffering**
- Chemical buffers are solutions that resist changes in pH.
- Intracellular and extracellular buffers provide an immediate response to acid-base disturbances.
- Bone also plays an important buffering role, especially of acid loads.

Acid-Base Balance

- A buffer is made up of a weak acid and its conjugate base.
- The conjugate base can accept H^+ and the weak acid can relinquish it, thereby minimizing changes in free H^+ concentration.
- A buffer system works best to minimize changes in pH near its equilibrium constant (pKa); so, although there are potentially many buffer pairs in the body, only some are physiologically relevant.
- The relationship between the pH of a buffer system and the concentration of its components is described by the Henderson-Hasselbalch equation:
- $$pH = pKa + log(\frac{[anion]}{[weak\ acid]}$$

where pKa is the dissociation constant of the weak acid

- An increase in H^+ drives the equation to the right and generates CO_2.
- This important buffer system is highly regulated; CO_2 concentrations can be finely controlled by alveolar ventilation, and H^+ and HCO_3^- concentrations can be finely regulated by renal excretion.

$$H^+ + HCO_3^- \Leftrightarrow H_2CO_3 \Leftrightarrow CO_2 + H_2O$$

- Other important physiologic buffers include;

- Intracellular organic and inorganic phosphates and proteins, including Hb in RBCs.

- Less important are extracellular phosphate and plasma proteins.

- Bone becomes an important buffer after consumption of an acid load. Bone initially releases sodium bicarbonate ($NaHCO_3$) and calcium bicarbonate ($Ca(HCO_3)_2$) in exchange for H^+.

- With prolonged acid loads, bone releases calcium carbonate ($CaCO_3$) and calcium phosphate ($CaPO_4$). Long-standing acidemia therefore contributes to bone demineralization and osteoporosis.

Pulmonary regulation

- CO_2 concentration is finely regulated by changes in tidal volume and respiratory rate (minute ventilation).
- A decrease in pH is sensed by arterial chemoreceptors and leads to increases in tidal volume or respiratory rate; CO_2 is exhaled and blood pH increases.
- In contrast to chemical buffering, which is immediate, pulmonary regulation occurs over minutes to hours.
- It is about 50 to 75% effective and does not completely normalize pH.

Renal regulation

- The kidneys control pH by adjusting the amount of HCO_3^- that is excreted or reabsorbed.
- Reabsorption of HCO_3^- is equivalent to excreting free H^+.
- Changes in renal acid-base handling occur hours to days after changes in acid-base status.

Renal regulation

- Acid is actively excreted into the proximal and distal tubules where it combines with urinary buffers.

-primarily freely filtered phosphate ($HPO4^{-2}$),

-creatinine,

-uric acid,

-and ammonia to be transported outside the body.

- The ammonia buffering system is especially important because other buffers are filtered in fixed concentrations and can be depleted by high acid loads; by contrast, tubular cells actively regulate ammonia production in response to changes in acid load.

- Arterial pH is the main determinant of acid secretion, but excretion is also influenced by potassium (K^+), Cl^-, and aldosterone levels.

- Intracellular K^+ concentration and H^+ secretion are reciprocally related; K^+ depletion causes increased H^+ secretion and hence metabolic alkalosis.

Acid-Base Disorders

- Acid-base disorders are pathologic changes in arterial pH and carbon dioxide partial pressure (Pco_2), and in serum bicarbonate (HCO_3^-).
- Acidemia is serum pH < 7.35.
- Alkalemia is serum pH > 7.45.
- Acidosis refers to physiologic processes that cause acid accumulation or alkali loss.
- Alkalosis refers to physiologic processes that cause alkali accumulation or acid loss.
- Actual changes in pH depend on the degree of physiologic compensation and whether multiple processes are present.

Classification

- Primary acid-base disturbances are defined as metabolic or respiratory based on clinical context and whether the primary change in pH is due to an alteration in serum HCO_3^- or in Pco_2.
- **Metabolic acidosis** is serum HCO_3^-< 24 mEq/L.
- Causes:

-Increased acid production

-Acid ingestion

-Decreased renal acid excretion

-GI or renal HCO_3^-loss

Classification

- **Metabolic alkalosis** is serum HCO_3^-> 24 mEq/L.
- Causes:
  - Acid loss
  - HCO_3^- retention
- **Respiratory acidosis** is Pco_2> 40 mm Hg (hypercapnia). Cause is "Decrease in minute ventilation (hypoventilation)"
- **Respiratory alkalosis** is Pco_2< 40 mm Hg (hypocapnia). Cause is "Increase in minute ventilation (hyperventilation)"
- Whenever an acid-base disorder is present, compensatory mechanisms begin to correct the pH Compensation can not return pH completely to normal and never overshoots.

Symptoms and Signs

- Compensated or mild acid-base disorders cause few symptoms or signs.
- Severe, uncompensated disorders have multiple cardiovascular, respiratory, neurologic, and metabolic consequences.

Diagnosis

- ABG
- Serum electrolytes
- The ABG directly measures arterial pH and Pco_2. HCO_3^- levels on ABG are calculated using the Henderson-Hasselbalch equation; HCO_3^- levels on serum chemistry panels are directly measured and are considered more accurate in cases of discrepancy.

Acid-base balance is most accurately assessed with measurement of pH and Pco_2 on arterial blood. In cases of circulatory failure or during cardiopulmonary resuscitation, measurements on venous blood may more accurately reflect conditions at the tissue level and may be a more useful guide to bicarbonate administration and adequacy of ventilation.

Diagnosis

- Anion gap calculated
- The **anion gap** should always be calculated; elevation almost always indicates a metabolic acidosis.
- A normal anion gap with a low HCO_3^- (eg, < 24 mEq/L) and high serum chloride (Cl^-) indicates a non-anion gap (hyperchloremic) metabolic acidosis.
- If metabolic acidosis is present, a delta gap is calculated to identify concomitant metabolic alkalosis, and Winters formula is applied to determine whether respiratory compensation is appropriate or reflects a 2nd acid-base disorder (predicted $Pco_2 = 1.5\ [HCO_3^-] + 8 \pm 2$; if Pco_2 is higher, there is also a primary respiratory acidosis—if lower, respiratory alkalosis).

THE ANION GAP

- The anion gap is defined as serum sodium (Na) concentration minus the sum of chloride (Cl^-) and bicarbonate (HCO_3^-) concentrations; $Na^+ - (Cl^- + HCO_3^-)$.
- The term "gap" is misleading, because the law of electroneutrality requires the same number of positive and negative charges in an open system; the gap appears on laboratory testing because certain cations (+) and anions (−) are not measured on routine laboratory chemistry panels.
- Na^+ + unmeasured cations (UC) = Cl^- + HCO_3^- + unmeasured anions (UA)
- The anion gap, $Na^+ - (Cl^- + HCO_3^-) = UA - UC$

THE ANION GAP

- The predominant "unmeasured" anions are phosphate (PO_4^{3-}), sulfate (SO_4^{-}), various negatively charged proteins, and some organic acids, accounting for 20 to 24 mEq/L.
- The predominant "unmeasured" extracellular cations are potassium (K^+), calcium (Ca^{++}), and magnesium (Mg^{++}) and account for about 11 mEq/L.
- Thus the typical anion gap is 23 − 11 = 12 mEq/L. The anion gap can be affected by increases or decreases in the UC or UA.

THE ANION GAP

- **Increased anion gap** is most commonly caused by metabolic acidosis in which negatively charged acids—mostly ketones, lactate, sulfates, or metabolites of methanol, ethylene glycol,or salicylate—consume (are buffered by) HCO_3^-. Other causes of increased anion gap include hyperalbuminemia and uremia (increased anions) and hypocalcemia or hypomagnesemia (decreased cations).

- **Decreased anion gap** is unrelated to metabolic acidosis but is caused by hypoalbuminemia (decreased anions); hypercalcemia, hypermagnesemia, lithium intoxication, and hypergammaglobulinemia as occurs in myeloma (increased cations); or hyperviscosity or halide (bromide or iodide) intoxication. The effect of low albumin can be accounted for by adjusting the normal range for the anion gap 2.5 mEq/L downward for every 1-g/dL fall in albumin.

- **Negative anion gap** occurs rarely as a laboratory artifact in severe cases of hypernatremia, hyperlipidemia, and bromide intoxication.

- **The delta gap:** The difference between the patient's anion gap and the normal anion gap is termed the delta gap. This amount is considered an HCO_3^-equivalent, because for every unit rise in the anion gap, the HCO_3^-should lower by 1 (by buffering). Thus, if the delta gap is added to the measured HCO_3^-, the result should be in the normal range for HCO_3^-; elevation indicates the additional presence of a metabolic alkalosis.

Key Points

- Acidosis and alkalosis refer to physiologic *processes* that cause accumulation or loss of acid and/or alkali; blood pH may or may not be abnormal.
- Acidemia and alkalemia refer to an abnormally acidic (pH < 7.35) or alkalotic (pH > 7.45) serum pH.
- Acid-base disorders are classified as *metabolic* if the change in pH is primarily due to an alteration in serum HCO_3^- and *respiratory* if the change is primarily due to a change in Pco_2 (increase or decrease in ventilation).
- The pH establishes the primary process (acidosis or alkalosis), changes in Pco_2 reflect the respiratory component, and changes in HCO_3^- reflect the metabolic component.
- All acid-base disturbances result in *compensation* that tends to normalize the pH. Metabolic acid-base disorders result in respiratory compensation (change in Pco_2); respiratory acid-base disorders result in metabolic compensation (change in HCO_3^-).

Key Points

- More than one primary acid-base disorder may be present simultaneously. It is important to identify and address each primary acid-base disorder.
- Initial laboratory evaluation of acid-base disorders includes ABG and serum electrolytes and calculation of the anion gap.
- Use one of several formulas, rules-of-thumb, or acid-base nomogram to determine if laboratory values are consistent with a single acid-base disorder (and compensation) or if a second primary acid-base disorder is also present.
- Treat each primary acid-base disorder.

Metabolic Acidosis

- **Metabolic acidosis is primary reduction in bicarbonate (HCO_3^-), typically with compensatory reduction in carbon dioxide partial pressure (Pco_2).**

Etiology

- Metabolic acidosis is acid accumulation due to

*Increased acid production or acid ingestion

*Decreased acid excretion

*GI or renal HCO_3^- loss

High anion gap acidosis

- The most common causes of a high anion gap metabolic acidosis are

*Ketoacidosis

*Lactic acidosis

*Renal failure

*Toxic ingestions

- Ketoacidosis is a common complication of type 1 diabetes mellitus, but it also occurs with chronic alcoholism, undernutrition, and, to a lesser degree, fasting. In these conditions, the body converts from glucose to free fatty acid (FFA) metabolism; FFAs are converted by the liver into ketoacids, acetoacetic acid, and beta-hydroxybutyrate (all unmeasured anions). Ketoacidosis is also a rare manifestation of congenital isovaleric and methylmalonic acidemia.

Normal anion gap acidosis

- The most common causes of normal anion gap acidosis are

*GI or renal HCO_3^- loss

*Impaired renal acid excretion

- Normal anion gap metabolic acidosis is also called hyperchloremic acidosis because the kidneys reabsorb chloride (Cl^-) instead of reabsorbing HCO_3^-.

- The renal tubular acidoses either impair H^+ secretion (types 1 and 4) or HCO_3^- absorption (type 2). Impaired acid excretion and a normal anion gap also occur in early renal failure, tubulointerstitial renal disease, and when carbonic anhydrase inhibitors (eg, acetazolamide) are taken.

Symptoms and Signs

- Symptoms and signs are primarily those of the cause.
- Mild acidemia is itself asymptomatic.
- More severe acidemia (pH < 7.10) may cause nausea, vomiting, and malaise.

Symptoms may appear at higher pH if acidosis develops rapidly.

- The most characteristic sign is hyperpnea (long, deep breaths at a normal rate), reflecting a compensatory increase in alveolar ventilation; this hyperpnea is not accompanied by a feeling of dyspnea.
- Severe, acute acidemia predisposes to cardiac dysfunction with hypotension and shock, ventricular arrhythmias, and coma. Chronic acidemia causes bone demineralization disorders (eg, rickets, osteomalacia, osteopenia).

Diagnosis

- ABG and serum electrolytes
- Anion gap and delta gap calculated
- Testing for cause
- Determining the cause of metabolic acidosis begins with the anion gap.
- The cause of an **elevated anion gap** may be clinically obvious (eg, hypovolemic shock, missed hemodialysis), but if not, blood testing should include glucose, BUN, creatinine, lactate, and tests for possible toxins. Salicylate levels can be measured in most laboratories, but methanol and ethylene glycol frequently cannot; their presence may be suggested by presence of an osmolar gap. Calculated serum osmolarity (2 [sodium] + [glucose]/18 +BUN/2.8 + blood alcohol/5) is subtracted from measured osmolarity. A difference > 10 implies the presence of an osmotically active substance, which in the case of a high anion gap acidosis is methanol or ethylene glycol. Although ingestion of ethanol may cause an osmolar gap and a mild acidosis, it should never be considered the cause of a significant metabolic acidosis.

- If the **anion gap is normal** and no cause is obvious (eg, marked diarrhea), urinary electrolytes are measured and the urinary anion gap is calculated as [sodium] + [potassium] – [chloride]. A normal urinary anion gap (including in patients with GI losses) is 30 to 50 mEq/L; an elevation suggests renal HCO_3^- loss.
- In addition, when metabolic acidosis is present, a **delta gap** is calculated to identify concomitant metabolic alkalosis.

Treatment

- Cause treated
- Sodium bicarbonate ($NaHCO_3$) primarily for severe acidemia—give with caution
- Treatment is directed at the underlying cause. Hemodialysis is required for renal failure and sometimes for ethylene glycol, methanol, and salicylate poisoning.

Treatment

- Treatment of acidemia with $NaHCO_3$ is clearly indicated only in certain circumstances and is probably deleterious in others. When metabolic acidosis results from loss of HCO_3^- or accumulation of inorganic acids (ie, normal anion gap acidosis), HCO_3^- therapy is generally safe and appropriate. However, when acidosis results from organic acid accumulation (ie, high anion gap acidosis), HCO_3^-therapy is controversial; it does not clearly decrease mortality in these conditions, and there are several possible risks.

- With treatment of the underlying condition, lactate and ketoacids are metabolized back to HCO_3^-; exogenous HCO_3^- loading may therefore cause an "overshoot" metabolic alkalosis. In any condition, HCO_3^- may also cause sodium and volume overload, hypokalemia, and, by inhibiting respiratory drive, hypercapnia. Furthermore, because HCO_3^- does not diffuse across cell membranes, intracellular acidosis is not corrected and may paradoxically worsen because some of the added HCO_3^- is converted to carbon dioxide (CO_2), which does cross into the cell and is hydrolyzed to $H^+$and HCO_3^-.

- Despite these and other controversies, most experts still recommend HCO_3^- IV for severe metabolic acidosis (pH < 7.10). H .

Key Points

- Metabolic acidosis can be caused by acid accumulation due to increased acid production or acid ingestion; decreased acid excretion; or GI or renal HCO_3^- loss.
- Metabolic acidoses are categorized based on whether the anion gap is high or normal.
- High anion gap acidoses are most often due to ketoacidosis, lactic acidosis, renal failure, or certain toxic ingestions
- Normal anion gap acidoses are most often due to GI or renal HCO_3^- loss
- Calculate delta gap to identify concomitant metabolic alkalosis, and apply Winters formula to see whether respiratory compensation is appropriate or reflects a 2nd acid-base disorder.
- Treat the underlying cause
- $NaHCO_3$ is indicated when acidosis is due to a change in HCO_3^- (normal anion gap acidosis)
- Intravenous NaHCO3 is controversial in high anion gap acidosis (but may be considered when pH < 7.00, with a target pH of ≤ 7.10).

LACTIC ACIDOSIS

- Lactic acidosis is a high anion gap metabolic acidosis due to elevated blood lactate.
- Lactic acidosis results from overproduction of lactate, decreased metabolism of lactate, or both.
- Lactate is a normal byproduct of glucose and amino acid metabolism.

Symptoms and Signs

- Symptoms and signs are dominated by those of the underlying cause (eg, septic shock, toxin ingestion).

Diagnosis

- ABG and serum electrolytes
- Anion gap and delta gap calculated
- Blood lactate level
- Diagnosis requires blood pH < 7.35 and lactate > 5 to 6 mmol/L.
- Less extreme lactate and pH changes are referred to as hyperlactatemia.

Treatment

- Treatment of cause
- Bicarbonate is potentially dangerous in high anion gap acidosis but may be considered when pH < 7.00, with a target pH of ≤ 7.10.
- In d-lactic acidosis, treatment is IV fluids, restriction of carbohydrates, and sometimes oral antibiotics (eg, metronidazole).

Metabolic Alkalosis

- **Metabolic alkalosis is primary increase in bicarbonate (HCO_3^-) with or without compensatory increase in carbon dioxide partial pressure (Pco_2)**

Etiology

- Metabolic alkalosis is bicarbonate HCO_3^- accumulation due to

*Acid loss

*Alkali administration

*Intracellular shift of hydrogen ion (H^+—as occurs in hypokalemia)

*HCO_3^-retention

- Metabolic alkalosis can be
- **Chloride-responsive:** Involves loss or excess secretion of Cl; it typically corrects with IV administration of NaCl-containing fluid.
- **Chloride-unresponsive**: Does not correct with NaCl-containing fluids, and typically involves severe magnesium and/or potassium deficiency or mineralocorticoid excess.
- The 2 forms can coexist, eg, in patients with volume overload made hypokalemic by high-dose diuretics.

Symptoms and Signs

- Symptoms and signs of mild alkalemia are usually related to the underlying disorder.
- More severe alkalemia increases protein binding of ionized calcium (Ca^{++}), leading to hypocalcemia and subsequent headache, lethargy, and neuromuscular excitability, sometimes with delirium, tetany, and seizures.
- Alkalemia also lowers threshold for anginal symptoms and arrhythmias.
- Concomitant hypokalemia may cause weakness.

Diagnosis

- ABG and serum electrolytes
- Diagnosis of cause usually clinical
- Sometimes measurement of urinary Cl^- and K^+
- Common causes can often be determined by history and physical examination.
- If history is unrevealing and renal function is normal, urinary Cl^- and K^+ concentrations are measured (values are not diagnostic in renal insufficiency).
- Urinary Cl < 20 mEq/L indicates significant renal Cl^-reabsorption and hence a Cl-responsive cause.
  Urinary Cl > 20 mEq/L suggests a Cl-unresponsive form.

Treatment

- Cause treated
- IV 0.9% saline solution for Cl-responsive metabolic alkalosis
- Underlying conditions are treated, with particular attention paid to correction of hypovolemia and hypokalemia.
- Patients with severe metabolic alkalosis (eg, pH > 7.6) sometimes require more urgent correction of blood pH. Hemofiltration or hemodialysis is an option, particularly if volume overload and renal dysfunction are present. Acetazolamide 250 to 375 mg po or IV once/day or bid increases HCO_3^-excretion but may also accelerate urinary losses of $K^+$and phosphate (PO_4^-); volume-overloaded patients with diuretic-induced metabolic alkalosis and those with posthypercapnic metabolic alkalosis may especially benefit.

Key Points

- Metabolic alkalosis is HCO_3^- accumulation due to acid loss, alkali administration, intracellular shift of hydrogen ion, or HCO_3^- retention.
- The most common causes are volume depletion (particularly when involving loss of gastric acid and Cl from recurrent vomiting or nasogastric suction) and diuretic use.
- Metabolic alkalosis involving loss or excess secretion of Cl is termed Cl-responsive
- Treat the cause and give patients with Cl-responsive metabolic alkalosis 0.9% saline IV.
- Cl-resistant metabolic alkalosis is due to increased aldosterone effect.
- Treatment of Cl-resistant metabolic alkalosis involves correction of hyperaldosteronism.

Respiratory Acidosis

- **Respiratory acidosis is primary increase in carbon dioxide partial pressure (Pco_2) with or without compensatory increase in bicarbonate (HCO_3^-).**

- Respiratory acidosis is carbon dioxide (CO_2) accumulation (hypercapnia) due to a decrease in respiratory rate and/or respiratory volume (hypoventilation).
- Conditions that impair CNS respiratory drive
- Conditions that impair neuromuscular transmission and other conditions that cause muscular weakness
- Obstructive, restrictive, and parenchymal pulmonary disorders
- Hypoxia typically accompanies hypoventilation.
- Respiratory acidosis may be acute or chronic. Distinction is based on the degree of metabolic compensation; CO_2 is initially buffered inefficiently, but over 3 to 5 days the kidneys increase HCO_3^- reabsorption significantly.

Symptoms and Signs

- Symptoms and signs depend on the rate and degree of Pco_2 increase.
- CO_2 rapidly diffuses across the blood-brain barrier.
- Symptoms and signs are a result of high CO_2 concentrations (low CNS pH) in the CNS and any accompanying hypoxemia.
- Acute (or acutely worsening chronic) respiratory acidosis causes headache, confusion, anxiety, drowsiness, and stupor (CO_2 narcosis).
- Slowly developing, stable respiratory acidosis (as in COPD) may be well tolerated, but patients may have memory loss, sleep disturbances, excessive daytime sleepiness, and personality changes. Signs include gait disturbance, tremor, blunted deep tendon reflexes, myoclonic jerks, asterixis, and papilledema.

Diagnosis

- ABG and serum electrolytes
- Diagnosis of cause usually clinical

Treatment

- Adequate ventilation
- Sodium bicarbonate ($NaHCO_3$) almost always contraindicated
- Sodium bicarbonate is almost always contraindicated, because of the potential for paradoxical acidosis within the CNS. One exception may be in cases of severe bronchospasm, in which HCO_3^- may improve responsiveness of bronchial smooth muscle to beta-agonists.

Key Points

- Respiratory acidosis involves a decrease in respiratory rate and/or volume (hypoventilation).
- Common causes include impaired respiratory drive (eg, due to toxins, CNS disease), and airflow obstruction (eg, due to asthma, COPD, sleep apnea, airway edema).
- Recognize chronic hypoventilation by the presence of metabolic compensation (elevated HCO_3^-) and clinical signs of tolerance (less somnolence and confusion than expected for the degree of hypercarbia).
- Treat the cause and provide adequate ventilation, using tracheal intubation or noninvasive positive pressure ventilation as needed.

Respiratory Alkalosis

- **Respiratory alkalosis is a primary decrease in Pco_2 with or without compensatory decrease in bicarbonate (HCO_3^-).**

Etiology

- Respiratory alkalosis is a primary decrease in Pco_2 (hypocapnia) due to an increase in respiratory rate and/or volume (hyperventilation).
- Ventilation increase occurs most often as a physiologic response to hypoxia (eg, at high altitude), metabolic acidosis, and increased metabolic demands (eg, fever) and, as such, is present in many serious conditions.
- In addition, pain and anxiety and some CNS disorders can increase respirations without a physiologic need.

Pathophysiology

- Respiratory alkalosis can be

*Acute

*Chronic

- Distinction is based on the degree of metabolic compensation.
- Excess HCO_3^- is buffered by extracellular hydrogen ion (H^+) within minutes, but more significant compensation occurs over 2 to 3 days as the kidneys decrease H^+ excretion.

Symptoms and Signs

- Symptoms and signs depend on the rate and degree of fall in Pco_2.
- Acute respiratory alkalosis causes light-headedness, confusion, peripheral and circumoral paresthesias, cramps, and syncope.
- Mechanism is thought to be change in cerebral blood flow and pH.
- Tachypnea or hyperpnea is often the only sign; carpopedal spasm may occur in severe cases due to decreased levels of ionized calcium in the blood (driven inside cells in exchange for hydrogen ion [H^+]).
- Chronic respiratory alkalosis is usually asymptomatic and has no distinctive signs.

Diagnosis

- ABG and serum electrolytes
- If hypoxia present, cause vigorously pursued
- Minor hypophosphatemia and hypokalemia due to intracellular shifts and decreased ionized calcium (Ca^{++}) due to an increase in protein binding may be present.
- Presence of hypoxia or an increased alveolar-arterial (A-a) O_2 gradient (inspired Po_2− [arterial Po_2+ $^5/_4$arterial Pco_2]) requires search for a cause. Other causes are often apparent on history and examination. However, because pulmonary embolism often manifests without hypoxia, embolism must be strongly considered in a hyperventilating patient before ascribing the cause to anxiety.

Treatment

- Treatment of underlying disorder
- Respiratory alkalosis is not life threatening, so no interventions to lower pH are necessary.
- Increasing inspired CO_2 through rebreathing (such as from a paper bag) is common practice but may be dangerous in at least some patients with CNS disorders in whom CSF pH may already be below normal.

Key Points

- Respiratory alkalosis involves an increase in respiratory rate and/or volume (hyperventilation).
- Hyperventilation occurs most often as a response to hypoxia, metabolic acidosis, increased metabolic demands (eg, fever), pain, or anxiety.
- Do not presume anxiety is the cause of hyperventilation until more serious disorders are excluded.
- Treat the cause; respiratory alkalosis is not life threatening, so interventions to lower pH are unnecessary.

References

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