Metabolic acidosis: Causes, Signs and Symptoms, Diagnosis and Treatment

Metabolic acidosis is a decrease in serum bicarbonate concentration below the normal range of between 22-28 mEq/L. It occurs when an acid other than carbonic acid accumulates in the body.

In general, it is associated with a low urine pH but depending on the presence or absence of a respiratory alkalosis, this may also be normal or elevated. Metabolic acidosis usually occurs with compensatory reduction on carbon dioxide partial pressure (Paco2). The pH levels may be low or slightly subnormal.

Basic Overview

For you to understand metabolic acidosis fully, its important that you have a basic understanding of the common terms that are used and the basic physiology of acid base balance.
In a normal person, blood pH is maintained at 7.35-7.45, an increase in pH indicates a decrease in hydrogen ions and vice versa.

Acidemia is an increase in [H+] and a fall in pH while alkalemia is a decrease in [H+] and an increase in pH.

Acidosis and alkalosis are the underlying disorders that cause acidemia and alkalemia respectively.

What is an anion gap?

Plasma is usually neutral; meaning that, the total anions (negatively charged ions) match total cations (positively charged ions). The major plasma cation is sodium ion (Na+), and major plasma anions are chloride and bicarbonate ions (Cl- and HCO3-).

Also there are some extracellular anions that are present in lower concentrations in plasma for example, phosphate, sulfate, and some organic anions. The available cations are potassium ions (K+), Magnesium ions (Mg2+), and Calcium ions (Ca2+).

> The anion gap or an AG is the difference between the concentration of the major measured cation sodium (Na+) and the major measured anions, chloride and bicarbonate ion (Cl- and HCO3-).

What causes and increased anion gap?

An increase in the anion gap results from either a decrease in unmeasured positively charged ions (cations) such as; hypokalemia, hypocalcemia, hypomagnesemia or an increase in unmeasured negatively charged ions (anions) (eg, hyperphosphatemia, high albumin levels).

Therefore the formula for calculation anion gap is;

Serum anion gap = serum Na – serum (Cl +HCO3).

The anion gap is a construct that does not truly exist and represents the difference between the commonly measured anion (Na) and cations (HCO3 and Cl). Thus, the anion gap can change either due to an increase in unmeasured anions or a change in the relative amounts of chloride and bicarbonate.

The measured rather than the corrected serum sodium is used for calculations. The anion gap is comprised primarily of negative charges on serum proteins, primarily albumin.

The normal serum anion gap ranges from 8 to 12 mEq/L.

It is important to note that changes in the serum albumin concentration affect the AG and so the calculated AG should be corrected for the albumin concentration.

The AG typically decreases by 2.5 mEq/L for every 1 g/dl reduction in serum albumin below 4 g/dl.

Classification of metabolic acidosis

Metabolic acidosis can be categorized into two classes based on the presence or absence of serum acidosis.

? A high anion gap metabolic acidosis and
? non anion gap metabolic acidosis (hyperchloremic acidosis)

Metabolic acidosis development mechanism

Metabolic acidosis can be caused by three major mechanisms:

1. An increased acid production;
2. Bicarbonate loss from the kidneys or gastrointestinal tract. When bicarbonate ions are lost, chloride ions are retained so as to maintain electrical neutrality.
3. A decreased renal acid excretion

Causes of metabolic acidosis

For the essence of clarity and application, the causes of metabolic acidosis are classified based on the presence or absence of an anion gap.

Causes of increased anion gap metabolic acidosis.

1. Diabetic ketoacidosis due to accumulation of ketones. Ketoacidosis occurs when there is an increased conversion of fatty acids to ketoacids. In diabetic ketoacidosis, a NG metabolic acidosis is often encountered later in the course due to renal excretion of ketoacids.
2. Chronic kidney failure with decreased renal. Patients usually manifest a NG metabolic acidosis due to decreased ammonium excretion. Once renal function declines to a critical level, usually at late stage 4, acids from protein metabolism are retained, resulting in an AG metabolic acidosis.
3. Lactic acidosis due L-Lactate and D-lactate. L-Lactic acidosis is caused by either lactic acid overproduction from tissue hypoxia (Type A lactic acidosis) or lactic acid underutilization from thiamine deficiency/liver diseases or inihibition of oxidate phosphorylation, usually by a drug (type B lactic acidosis).
4. Drugs associated with a Type B lactic acidosis include metformin, phenformin, nucleoside reverse transcriptase inhibitors and propofol. D-lactate is unique, as it is not metabolized by L-lactate dehydrogenase in human. It occurs in patients with short-bowel syndrome.
5. Drug poisoning such as aspirin, methanol or ethylene glycol
6. Salicylate ingestion; the associated anion gap metabolic acidosis occurs secondary to inhibition of the Krebs cycle and subsequent accumulation of organic acids, e.g., lactic acid and ketoacids.
7. Pyroglutamic acidemia (5-oxoprolinemia The associated AG metabolic acidosis results from depletion of gluthathione. This prevents feedback inhibition of the gamma-glutamyl cycle and accumulation of oxoproline. It leads to an anion gap metabolic acidosis but may also cause a NG acidosis
8. Inhalation of toluene can lead to both anion gap and and non gap metabolic acidosis. The AG is caused by the metabolite of toluene, hippuric acid. However, hippuric acid is rapidly excreted in the urine and as the anion is excreted, the anion gap falls with a persistent NG acidosis.
9. Massive rhabdomyolysis causing a release of H+ and organic anions from damaged muscle.

Causes of normal anion gap metabolic acidosis

1. Proximal Renal tubular acidosis causing a urinary loss of bicarbonate. Type 2 RTA results from proximal tubule HCO3 wasting. Because distal acid excretion is normal in these patients, there is a lower limit for the possible bicarbonate concentration – usually 12-20 mEq/L, and alkali therapy results in HCO3 wasting.
2. Gastrointestinal bicarbonate loses through diarrhea
3. Bowel fistula (Enterocutaneous fistula),ie a fistula with drainage from the pancreas
4. Urinary diversion
5. Distal renal tubular acidosis causes impaired tubular acid secretion. RTA-1 results from a defect in distal tubular acid excretion as a result of decreased H+ secretion or back leak of secreted hydrogen. It can be severe and results in progressive HCO3 loss (serum concentration <10 mEq/L). Urine pH in these patients is typically above 5.5 despite the metabolic acidosis. It stimulates bone resorption, and results in hypercalciuria and nephrocalcinosis.
6. Acid infusion with ammonium chloride, hyperalimentation
7. Therapeutic excessive saline infusion

Signs and symptoms

Patients with metabolic acidosis usually present with non specific signs and symptoms.

These patients may present with varying degree of dyspnea because their respiratory center in the brainstem is stimulated causing hyperventilation in an effort to compensate for the acidosis.

They may also complain of;

- Chest pain,
- Palpitations,
- Headache,
- Confusion,
- Lethargy,
- Generalized weakness, and bone pain.

Patients, especially children, also may present with nausea and vomiting, and decreased appetite.

Some patients with metabolic acidosis present with symptoms of an underlying disorder such as;

Diarrhea that is the main mechanism causing GI losses of HCO3-

Hyperglycemia, alcoholism, or prolonged starvation that explains the cause of accumulated ketoacids.

Features of diabetic ketoacidosis such as Polyuria, increased thirst, epigastric pain and vomiting.

Features of chronic renal failure such as nocturia, polyuria, pruritus, and anorexia.

These patients may have a history of ingestion of drugs or toxins like salicylates, acetazolamide, ethylene glycol, methanol or metformin.

In patients who have a history of methanol ingestion, they may present with visual symptoms, including dimming, photophobia and scotomata.

Renal stones ; features of renal tubular acidosis or chronic diarrhea

Tinnitus, blurred vision, and vertigo in the cases of salicylate overdose

Diagnosis of metabolic acidosis

Diagnosis of metabolic acidosis is reached at by;

Performing **Arterial blood gas analysis**

Start by measuring the arterial pH, PCO2, and serum bicarbonate concentration.

If there is a low bicarbonate, then the anion gap should be chec