

Chapter 10 / Capítulo 10

*Electrolyte and Internal Environment Imbalances in
Emergencies (English Edition)*

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Metabolic Acidosis in Emergency Care

Acidosis metabólica en emergencias

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Objectives:

- Understand the renal response to acid load.
- Use of the anion gap for differential diagnosis.
- Recognize differences between arterial and venous pH in hypoperfusion.
- Understand principles of treatment, including the risks of bicarbonate therapy.

INTRODUCTION

Metabolic acidosis is a clinical condition characterized by a decrease in hydrogen ion potential ($\text{pH} < 7.35$), a decrease in bicarbonate ($\text{HCO}_3^- < 22 \text{ mEq/L}$) or base ($\text{B} < -2 \text{ mEq/L}$), which will cause a decrease in carbon dioxide pressure (PCO_2). That is: $\downarrow$ plasma HCO_3^- , $\downarrow$ extracellular pH, and compensatory hyperventilation $\rightarrow \downarrow \text{PCO}_2$.

Classification of metabolic acidosis

Metabolic acidosis, according to its evolution time, can be classified as:

- Acute (lasting minutes to days): acute metabolic acidosis is most often caused by overproduction of acids or impaired elimination of them.
- Chronic (lasting weeks to years): often reflects bicarbonate loss and/or impaired renal acidification.

Main causes

- Toxin ingestion: salicylates, methanol, ethylene glycol.
- Endogenous acid production: lactic acidosis, ketoacidosis.
- Bicarbonate loss: diarrhea, fistulas, type 2 renal tubular acidosis (RTA).
- Decreased acid excretion: renal failure, type 1 and type 4 RTA.

Renal response and alterations

Renal insufficiency

- $\downarrow$ Nephrons $\rightarrow \downarrow \text{NH}_4^+$ excretion.
- As $\text{GFR} < 40 \text{ mL/min}$, H^+ accumulates $\rightarrow$ acidosis.
- Buffers: bone, intracellular proteins.
- Treatment: oral bicarbonate to maintain HCO_3^- between 12-20 mEq/L.

Renal tubular acidosis (RTA)

Type 1 (Distal) is characterized by a failure to acidify urine ($\text{pH} < 5.5$). The underlying mechanisms include a deficiency in H^+ -ATPase, H^+ leakage, and impaired Na^+ reabsorption. Clinical presentation is characterized by hypokalemia or hyperkalemia and high urinary pH. Treatment consists of administering bicarbonate.

In type 2 (proximal), there is a failure to reabsorb HCO_3^- , resulting in urinary loss. It

stabilizes when plasma HCO_3^- decreases to the new threshold (~ 17 mEq/L). Treatment is based on administering high doses of bicarbonate (10-15 mEq/kg/day).

Anion gap

The anion gap is determined by the equation: $\text{BG} = \text{Na}^+ - (\text{Cl}^- + \text{HCO}_3^-)$. The normal value of the BG is between 6 and 10 mEq/L.

Table 10.1. Classification		
Type of acidosis	Anion gap	Examples
Increased (non-hyperchloremic)	↑	DKA, lactic acidosis, intoxications
Normal (hyperchloremic)	Normal	Diarrhea, type 1 and type 2 RTA

The gap correlates with albumin. Each $\downarrow 1$ g/dL decrease in albumin $\rightarrow \downarrow$ anion gap of 2,5 mEq/L. This is supported by the equation: $\text{BAC} = (\text{Na}^+) - (\text{Cl}^- + \text{HCO}_3^-) + 2,5(4,5 - \text{albumin g/dL})$

Since diarrhea is the most common non-renal cause of hyperchloremic metabolic acidosis, it requires classification to determine its origin by calculating the fecal anion gap, which is not routinely measured.

$$(\text{mOsm/kg} = \text{fecal osmolality} - 2 \times (\text{fecal Na}^+ + \text{fecal K}^+))$$

- ≥ 100 mOsm/kg: suggests osmotic diarrhea
- ≤ 50 mOsm/kg: suggests secretory diarrhea

Clinical types of metabolic acidosis

Lactic acidosis

- $\uparrow$ Lactate > 4 -5 mEq/L.
- Causes: tissue hypoxia, shock, seizures.
- Venous pH may be very low despite nearly normal arterial pH
- Bicarbonate: may worsen intracellular acidosis ($\uparrow \text{CO}_2$)

Diabetic ketoacidosis (DKA)

- $\uparrow$ Ketone bodies: β -hydroxybutyrate and acetoacetate.
- Cause: insulin deficiency + glucagon excess.
- Treatment: insulin $\rightarrow \downarrow$ ketone body production and regeneration of HCO_3^- .

Intoxications

- Salicylates:

- Respiratory alkalosis + metabolic acidosis.
- Treatment: alkalinization to promote renal elimination

- Methanol / Ethylene glycol:

- Metabolized to toxic acids.
- Diagnosis: $\uparrow$ anion gap and $\uparrow$ osmolar gap.
- Treatment: fomepizole or ethanol + hemodialysis.

Clinical manifestations

The adverse effects of metabolic acidosis occur across different organs and systems:

- Cardiovascular: $\downarrow$ Contractility, $\downarrow$ Stroke volumen, $\downarrow$ Cardiac output, $\uparrow$ Ventricular arrhythmias
- Neurological: Confusion, lethargy.

- Infectious: increased susceptibility to infections.
- Metabolic: decreased insulin sensitivity, alteration of thyroid hormones function.
- Renal: progression to kidney disease.
- Skeletal muscle: degradation of muscle mass.

General treatment

Indications for bicarbonate use:

- Moderate to severe acidosis ($\text{HCO}_3^- < 12 \text{ mEq/L}$).
- Calculation: Deficit = $(\text{desired } \text{HCO}_3^- - \text{actual } \text{HCO}_3^-) \times 0,5 \times \text{body weight (kg)}$
- In severe diabetic ketoacidosis cases, the following scheme is suggested:⁽¹¹⁾
 - If $\text{pH} \geq 7,0$: sodium bicarbonate is not indicated
 - If $\text{pH } 6,9-7,0$: consider 50 mmol NaHCO_3 in 200 ml of 0,9 % normal saline solution at 200 ml/h
 - If $\text{pH} < 6,9$: administer 100 mmol NaHCO_3 in 400 ml of 0,9 % normal saline solution at 200 ml/h

However, the use of bicarbonate carries certain risks, such as the generation of CO_2 , which leads to intracellular acidosis. It can also worsen cardiac perfusion and function if hypoperfusion is not corrected.

Diagnostic tools

Urinary anion gap (Na^+ , $+$ K^+ and $- \text{Cl}^-$ values)

- Useful in acidosis with normal anion gap.
- Negative values (< -20): indicate adequate NH_4^+ excretion $\rightarrow$ extrarenal cause
- Positive values: type 1 or type 4 RTA.

Conclusions

- Metabolic acidosis correlates with severity and prognosis.
- Metabolic acidosis may arise from HCO_3^- loss, acid production, or acid retention.
- The anion gap is essential for its classification.
- Acidosis with elevated anion gap is usually more severe (DKA, lactic acidosis, toxins).
- Treatment of metabolic acidosis is based on correcting the underlying cause, not only on administering bicarbonate.

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