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Core Messages

› Essentially all pediatric disorders, if severe enough, can lead to acid–base disturbances directly, as a result of therapy, or both.
› Acid–base disorders need to be anticipated in all critically ill patients. Proactive monitoring of the acid–base status will allow the early recognition of derangements and the prevention of what could become a life-threatening state.
› Acidosis is the most common acid–base derangement in the intensive care unit (ICU), with metabolic acidosis potentially indicating a more severe course and worse outcome.
› A pH of <7.2 merely indicates a primary acidosis-inducing disorder. Further assessment of the type of acidosis and the presence of a mixed acid–base disorder requires measurement of pCO₂, serum bicarbonate, albumin, and calculation of the anion gap.
› The most commonly encountered causes of metabolic acidoses in the ICU are renal insufficiency, sepsis, and DKA, while acute respiratory distress syndrome (ARDS) and severe status asthmaticus are the usual suspects in respiratory acidoses.
› Alkalosis, on the other hand, is less common in the ICU. Fluid status derangements and, especially, gastric fluid depletion are the usual underlying causes of metabolic alkalois, whereas rapid respiration secondary to lung diseases, excessive mechanical ventilation, pain, or central nervous system processes are the common causes of respiratory alkaloses.
› In the ICU, identification of acid–base derangements is followed by timely stabilization of the patient irrespective of the underlying cause. Depending on the severity of the derangement and the patient’s response to the stabilizing interventions, the underlying cause might also need to be aggressively sought and emergently reversed.
› Identification of the underlying cause(s) of the acid–base disorder at hand may be the final step in the management of these patients, but plays an important role both in the prevention of worsening of the derangement and other complications as well as in the determination of the patient’s overall prognosis.
Case Vignette 1

An 11-year-old girl with a history of mild bronchial asthma presented with fever and increased work of breathing refractory to repeated albuterol treatments at her pediatrician’s office. Status asthmaticus was diagnosed, and an ABG was obtained upon arrival to the emergency room, showing a pH of 7.22, a pCO₂ of 38 mmHg, and a serum bicarbonate level of 15 meq L⁻¹. Her serum sodium and chloride were 141 and 110 meq L⁻¹, respectively; her serum lactate concentration was 11 mmol L⁻¹, and her serum albumin level was 1 g dL⁻¹. What is your interpretation of her ABG?

The ABG is consistent with acidosis, given the low pH of 7.22. The bicarbonate level is low at 15 meq L⁻¹ whereas pCO₂ is almost normal, rendering the primary disorder a metabolic acidosis. Following the rule of 1:1 compensation, pCO₂ would be expected to be 30–32. Thus, this patient also has an element of pCO₂ retention and thus a mixed acid–base disorder, namely primary metabolic acidosis and acute respiratory acidosis. The metabolic component is secondary to an AG acidosis, with the AG measuring 16 prior to the required adjustment as follows:

Corrected albumin (4 g dL⁻¹ expected – 1 g dL⁻¹ observed) of 3 × 2.5 = 7.5. Hence, adjusted AG 16 measured + 7.5 = 23 with a delta/delta of 1, indicating no other underlying type of metabolic acidosis. Treatment to target lower airway obstruction with bronchodilators and steroids will assist in resolving both the respiratory and the metabolic defect. The latter will also be alleviated with judicious use of hydration. Lastly, the cause of severe hypoalbuminemia needs to be sought.

Case Vignette 2

A 2-year-old child was found unconscious and with increased work of breathing. An ABG showed a pH of 7.38, a pCO₂ of 28 mmHg, and a serum bicarbonate of 16 meq L⁻¹. What is your interpretation?

This is a typical ABG of a patient with salicylate poisoning. Depending on further clinical and laboratory evaluations, this patient might need intubation, gastric lavage, dialysis, or simple hydration and supportive care.

Acid–base disorders are among the most commonly encountered medical problems in critically ill patients. Departure of blood acidity from the normal range can result in a spectrum of adverse consequences and, when severe, can be life-threatening. Identifying acid–base derangements, correcting the pH, and arriving at the correct underlying cause for each derangement are of paramount importance for caring for patients in the intensive care unit. This chapter will address physiology of acid–base status, interpretation of blood gas measurements, common causes of derangements, and approach to reestablishing normalcy.

2.1 Introduction

The human organs and tissues function under a tightly controlled pH in the range of 7.35–7.45. Depending on the degree of the deviation of pH outside this narrow range, several homeostatic responses are activated in an effort to restore normal acid–base status. Initially, reactions by chemical buffers will attempt to neutralize the derangement, followed by ventilatory adjustments by the lungs and, finally, alterations in acid excretion by the kidneys.

Several factors impact the prognosis of patients with acid–base disturbances:

1. Severity of acidemia or alkalemia.
2. Acuity and duration of the derangement.
3. Functional status of the lungs and kidneys.
4. Underlying cause: This factor is what ultimately defines the patient’s outcome.

A plasma pH of 7.10 can be inconsequential when caused by diabetic ketoacidosis, but it portends a poorer outcome if it is secondary to septic shock and poor organ perfusion. Likewise, a plasma pH of 7.60 caused by anxiety-hyperventilation syndrome is inconsequential, whereas it signals a worse prognosis if it is secondary to a brain tumor.

To manage patients with serious acid–base disturbances appropriately, accurate history taking, precise interpretation of blood gas results, and arriving at the correct cause underlying the disorder are critical. Even though our management in the ICU is centered on stabilizing patients’ cardiopulmonary status and correcting derangements, including acid–base disorders, knowing the underlying etiology of these disturbances and addressing it with the proper interventions, if deemed necessary, can expedite a patient’s recovery and reverse the pathologic process.

2.2 Physiology of Acid–Base Balance

Hydrogen ion (H⁺) is much more precisely regulated in the extracellular fluid in order to achieve a concentration