Annals of Clinical and Medical Case Reports

Review Article ISSN 2639-8109 | Volume 8

Management of Acid Base Disorders in Pregnant Woman

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Received: 17 Feb 2022
Accepted: 28 Feb 2022
Published: 07 Mar 2022
J Short Name: ACMCR

Keywords:

Acid base disorders; pregnancy; Metabolic acidosis; Metabolic alkalosis; Respiratory acidosis Respiratory alkalosis

Citation:

Marenco MEL, Management of Acid Base Disorders in Pregnant Woman. Ann Clin Med Case Rep. 2022; V8(13): 1-10

1. Abstract

The interpretation of the acid-base status is key in medical practice, being its most frequent use in critically ill pregnant patients with any type of hemodynamic alteration such as hemorrhagic shock or septic shock, which happens in most cases, states of hypoperfusion systemic that produce alteration in the acid base state that generates primary disorders such as acidemia or alkalemia and its metabolic or respiratory components. We make an approach through an arterial or venous blood gas analysis, which has the advantage of an evaluation in a short time to be a diagnosis and thus take medical conduct for a better management of the pregnant patient.

2. Introduction

For more than 100 years we have been investigating acid-base disorders. The pioneer since 1908 Henderson Hasselbalch, first with a traditional approach, then in 1977 Siggaard and Andersen giving an importance to base excess on the interpretation of blood gases, later in the same year Emmet and Narins on the discovery of Anion Gap, already in 1983 Peter Stewart makes the difference of strong ions, and finally 10 years later in 1993 Gilfix on the method of Stewarthan. All of them have provided fundamentals for the understanding of acid-base balance and discussions still continue on what should be the approach in clinical practice; however, the recommended approach to use is the one that is easiest and most practical for the physician with a simple, easily reproducible approach because the clinical approach to the patient finally ends up having diagnostic, prognostic and therapeutic implications, it is imperative to be precise and fast in the process [1, 2] (Table 1, 2).

The first step in the evaluation of a basic acid disorder in an obstetric patient is a careful clinical assessment. Several signs and symptoms often provide clues to the underlying acid-base disorder; these include the patient's vital signs (which may indicate shock or sepsis), neurologic status, signs of infection, pulmonary status (respiratory rate and presence or absence of Kussmaul's respiration, cyanosis, and clubbing fingers), and gastrointestinal symptoms (vomiting and diarrhea). Certain underlying medical conditions, such as pregnancy, diabetes, and heart, lung, liver, and kidney disease, may also indicate the cause. The physician should determine if the patient has taken any medications that affect acid-base balance (e.g., laxatives, diuretics, topiramate, or metformin) and should consider signs of intoxication that may be associated with acid-base disturbances (e.g., acetone factor as a sign of diabetic ketoacidosis or isopropyl alcohol intoxication and visual disturbance as a symptom of methanol intoxication).

As new interpretation measures emerge for a blood gas measurement it becomes a little more complex, however, with this method there appear to be three interrelationships for solving acid-base problems. The skills can be acquired, learned through schematics or when we are taught, as well as by teachers or computer software. The teacher's expertise cannot be transferred to students in ready-to-use templates. The second approach, is the scheme through acid-base curves, also has shortcomings. An acid-base scheme cannot diagnose triple disorders, cannot be used for written exams, and can be lost when you need it most. If an acid-base scheme is used, it should only reinforce conclusions already reached by the same physician [3, 4]. (Algorithm 1; Table 3).

Table 1:

PaO_2 > 65 mmHg	⇓ Hypoxemia	⇑ Hyperoxia
PCO_2 35 – 45 mmHg	⇓ Hypocapnia	⇑ Hypercapnia
HCO_3 22 – 24 mmol/L	-	-
pH 7.35 – 7.45	⇓ Acidosis	⇑Alkalosis

Basic alteration of changes above or below the normal range of PaO2; PaCO2; and pH

Table 2:

Parameter	Arterial Blood Gasometry 40	Venous Blood Gasometry	Peripheral Blood Gasometry
PaO_2 (mmHg)	65 -100	Use pulse oximeter	Use pulse oximeter
PCO_2 (mmHg)	35 – 45	40 -50	⇓ 7 (GASA)
HCO_3 (mmol/L)	22 – 24	22 - 26	⇓ 5 (GASA)
pH	7.35 – 7.45	7.40 – 7.44	⇑ 0.13 (GASA)
SatO2 %	>94%	60 – 65 %	Use pulse oximeter
EB (mmol/L)	± 2	+ 0.3 a + 0.7	+0.5 a +1.8
Lactate (mmol/L)	<2	+0.2	+0.1

Differences in arterial blood gas, venous blood gas and peripheral blood gas parameters with respect to PaO2; PCO2; HCO3; SatO2 %; BE and Lactate at [40, 42].

Table 3:

Step 1
Determination of pH (acidemia or alkalemia; < 7.35 or > 7.45)

- **Step 2**: Determine if the disorder is primary
- Determine whether the disorder is primary Metabolic or Respiratory or both.

Alkalosis

- - Respiratory Alkalosis: If PCO_2 substantially less than 35 mmHg
- - Metabolic Alkalosis: If HCO_3 is greater than 25 mmol/L

Acidosis

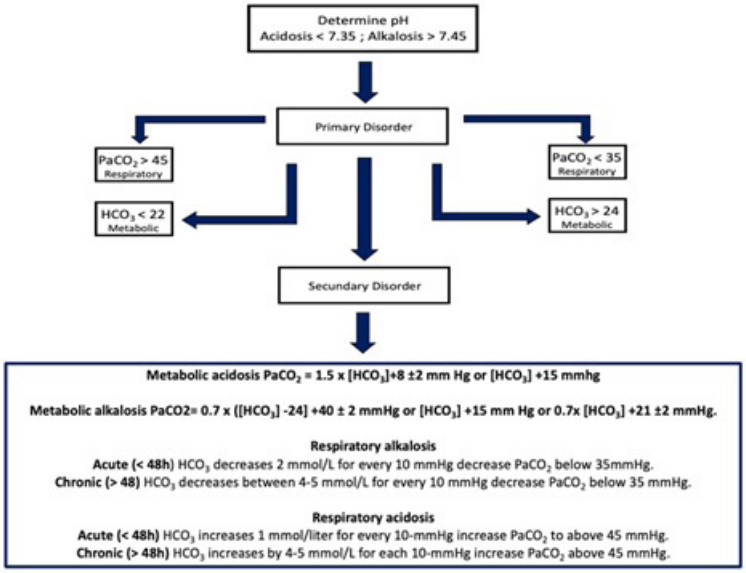
- - Respiratory Acidosis: If PCO_2 is greater than 45 mmHg
- - Metabolic Acidosis: If HCO_3 is less than 22 mmol/L

Step 3 Secondary Response
If the primary disorder is Respiratory Alkalosis
The secondary disorder
Acute (<48 h) HCO_3 decreases 2 mmol/L for each 10 mmHg decrease PCO_2 below 35 mmHg
Chronic (>48 h) HCO_3 decreases by 4 - 5 mmol/L for each 10 mmHg decrease PCO_2 below 35 mmHg
Secondary adaptive response completes in 2 to 5 days
A diagnosis of alkalosis or superimposed metabolic acidosis may be made if the estimated
HCO_3] is greater than or less than predicted

If the primary disorder is Metabolic Alkalosis
Secondary response (respiratory): $PCO_2 = 0.7 \times ([HCO_3] - 24) + 40 \pm 2$ mm Hg or
$[HCO_3] + 15$ mm Hg or $0.7 \times [HCO_3] + 21 \pm 2$ mm Hg
Secondary adaptive response completes in 24-36 h.
Superimposed respiratory acidosis or alkalosis may be diagnosed if the calculated PCO_2 is higher or lower than predicted.

If the primary disorder is Respiratory Acidosis
Secondary response
Acute (<48 h) [HCO_3] increases by 1 mmol/L for each 10 mmHg increase PCO_2 to above 45 mmHg
Chronic (>48 h) [HCO3] increases by 4-5 mmol/L for each 10 mmHg increase PCO_2 above 45 mm Hg
Secondary adaptive response complete in 2 to 5 days
Superimposed alkalosis or metabolic acidosis may be diagnosed if the calculated [HCO3] is higher or lower than predicted.

If the primary disorder is Metabolic Acidosis
Secondary response (respiratory): $PCO_2 = 1.5 \times [HCO_3] + 8 \pm 2$ mm Hg or $[HCO_3] + 15$ mm Hg
Complete secondary adaptive response within 12 to 24 hours.
Superimposed respiratory acidosis or alkalosis may be diagnosed if the calculated PCO_2 is higher or lower than predicted.



Algorithm 1: Interrelation of arterial blood gas with its primary and secondary component during pregnancy, childbirth and puerperium.

3. Assessment of Primary Acid-Base Disorders and their Secondary Response (Algorithm 1)

Empirical observations suggest that the homeostatic response to acid-base disorders is predictable and can be calculated [6, 7].

In response to basic acid metabolic disturbances, changes in respiratory rate develop rapidly and a new steady-state PaCO2 is reached within hours. In cases of persistent respiratory abnormalities, metabolic compensation develops slowly, and 2 to 5 days are required for the plasma bicarbonate concentration to reach a new steady-state level. A respiratory change is termed "acute" or "chronic" depending on whether a secondary change in bicarbonate concentration meets certain criteria. Mixed basic acid disorders are diagnosed when the secondary response differs from that expected [7, 8, 9].

There are several caveats regarding compensatory changes. Blood gas values can always be explained by two or more coexisting basic acid disorders [11].

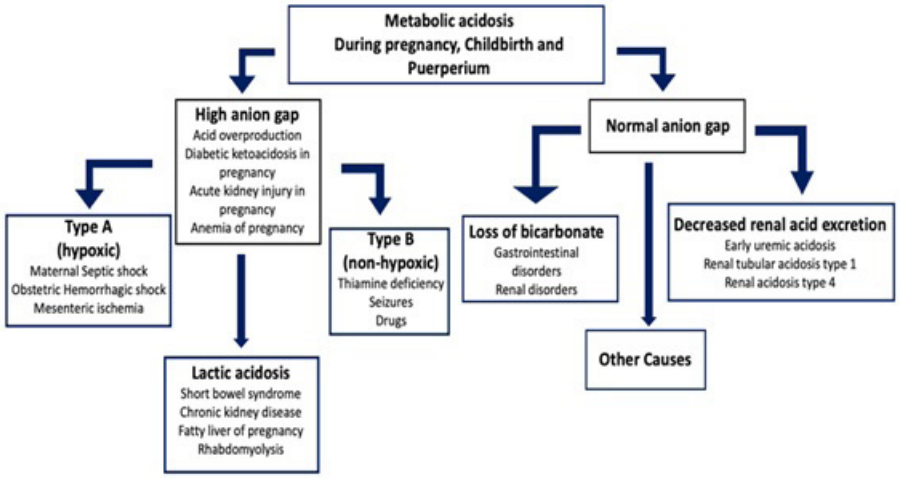
Experimental studies of severe chronic hypocapnia and hypercapnia in humans are not ethically feasible; therefore, the data are insufficient to construct confidence limits for severe chronic respiratory alkalosis and acidosis. It is generally accepted that compensatory processes can normalize pH only in chronic respiratory alkalosis9. In contrast to older data, data from a more recent study indicate that pH in chronic respiratory acidosis may be normal and in individual cases, higher than generally recognized (pH>7.45) [10, 12, 13]. In addition, the usual compensatory changes in PaCO2 may be limited in cases of severe hypoxemia. The instruments used to measure blood gases and electrolytes may differ, affecting the results [14-15].

4. Assessment of the Metabolic Component of an Acid-Base Disorder

Calculating the anion gap is always useful in metabolic derangement32-45. The sum of positive and negative ionic charges in plasma is equal, measurables are: [Na +] + [K +] + [Ca +] + [Mg +] + [H +] + unmeasured cations = [Cl-] + [HCO3] + [CO3] + [OH-] + albumin + phosphate + sulfate + lactate + unmeasured anions (example: inorganic anions) [17,18].

The three ions with the highest plasma concentrations and the largest variations in concentration are used to calculate the excess of "unmeasured anions" in metabolic acidosis that constitutes the "anion imbalance", which is calculated as [Na +] - [Cl-] - [HCO3-].

However, a true ionic gap does not exist in vivo, because the sum of the positive and negative ionic charges in plasma must be equal. Wide reference ranges from 3.0 to 12.0 mmol per liter to 8.5 to 15.0 mmol per liter have been reported for the anion gap 19 because of differences in laboratory methods. 18 Consequently, physicians should know the reference range for their own laboratory (algorithm 2).



Algorithm 2: Interpretation of metabolic acidosis during pregnancy, childbirth and puerperium.

5. Metabolic Acidosis with High Anion Gap

There are many causes of metabolic acidosis with elevated anion imbalance. A useful item for the most common causes is GOLD MARRK (glycol [ethylene and propylene], 5-oxoproline [pyroglutamic acid], l-lactate, d-lactate, methanol, aspirin, renal failure, rhabdomyolysis, and ketoacidosis) [19].

The anion gap increases when bicarbonate concentration decreases relative to sodium and chloride levels due to excessive acid production (e.g., in diabetic ketoacidosis in the pregnant woman, lactic acidosis, and drug- and alcohol-related intoxication), acid underexcretion (in advanced renal failure), cell lysis (in massive rhabdomyolysis), or other circumstances (e.g., use of penicillin-derived antibiotics).

6. Uses and Limitations of Anion Gap

Lactic acidosis accounts for approximately half of the cases of high anion imbalance [19] and is often due to tissue shock or hypoxia [18]. However, anion imbalance is a relatively insensitive reflection of lactic acidosis: approximately half of patients with serum lactate levels between 3.0 and 5.0 mmol per liter have an anion gap within the reference range [39,40]. The anion gap, which has a sensitivity and specificity below 80% for identifying elevated lactate levels, cannot replace a measurement of the serum lactate level [20]. However, lactate levels are not routinely measured or are not always readily available, and a high anion gap may alert.

The anion gap is usually not available for an individual patient. Furthermore, it should always be adjusted for albumin concentration because this weak acid can account for up to 75% of the anion gap [20]. Without correction for hypoalbuminemia, the estimated anion gap does not reveal a clinically significant increase in anions (> 5 mmol per liter) in more than 50% of cases.

For every 1-g per deciliter decrease in serum albumin concentration, the calculated anion gap should increase by approximately 2.3 to 2.5 mmol per liter [20]. However, the albumin-corrected anion gap is merely an approximation, as it does not consider ions such as magnesium, calcium, and phosphate.

Anion gap can help establish the diagnosis of diabetic ketoacidosis. In patients with this condition, the anion gap can be used to track the resolution of ketosis6 and diagnose acidosis with normal anion gap if large volumes of isotonic saline are administered [21].

The pH may also be misleadingly normal or elevated due to concomitant metabolic alkalosis from hyperemesis gravidarum or respiratory alkalosis from fatty liver of pregnancy, high temperature or sepsis [22].

The anion gap can also aid in the diagnosis of lactic acidosis in patients with short bowel syndrome because the standard lactate level remains normal as the anion gap increases [23].

A low or negative anion imbalance is seen when hyperchloremia is caused by high cation levels, as seen in lithium toxicity, monoclonal IgG gammopathy, or disorders characterized by high calcium or magnesium levels. A negative anion gap is caused by pseudo hyperchloremia in bromide or iodide poisoning [24].

7. Acidosis with Normal Anion Gap

Chloride plays a central role in intracellular and extracellular acid-base regulation [25]. A normal anion gap acidosis occurs when the decrease in bicarbonate ions is matched by an increase in chloride ions to retain electroneutrality, also referred to as hyperchloremic metabolic acidosis.

This type of acidosis occurs from gastrointestinal loss of bicarbonate (e.g., diarrhea or ureteral shunting), from renal loss of bicarbonate that may occur in defective urinary acidification by the renal tubules (renal tubular acidosis), or in early renal injury when acid excretion is impaired [25, 26]. Hospital-acquired hyperchloremic acidosis is usually caused by infusion of large volumes of "normal" saline (0.9%) [26, 27]. Hyperchloremic acidosis should lead to an increase. Renal ammonium excretion and measurement of urinary ammonium can therefore be used to differentiate between renal and extra renal causes of acidosis with normal anion imbalance. However, since urinary ammonium is rarely measured, urinary anion imbalance and urinary osmolar imbalance are often used as surrogate measures of urinary ammonium excretion [6].

The urinary anion gap ([Na +] + [K +] - [Cl-]) is usually negative in acidosis with normal anion gap, but will become positive when urinary ammonium (NH4 +) excretion (as ammonium chloride [NH4Cl]) is altered, such as in kidney injury, distal renal tubular acidosis, or hypoaldosteronism [6].

In normal anion gap acidosis, a negative urinary anion imbalance occurs due to diarrhea and proximal renal tubular acidosis, in which distal acidification is intact. The urinary anion gap becomes unreliable when polyuria is present, when urine pH exceeds 6.5 or when urinary ammonium is excreted with an anion other than chloride (e.g., ketoacids, acetylsalicylic acid, D-lactic acid, and large amounts of penicillin)6. Furthermore, urine acidification requires an adequate distal supply of sodium; therefore, the usefulness of urinary anion gap is questionable when the urinary sodium level is less than 20 mmol per liter. In such cases, urinary osmolar gap is generally more reliable.

The urinary osmolar gap determines the difference between the measured and calculated urinary osmolarity. Urinary osmolarity is calculated as follows:

(2 × [Na+] + 2 × [K+]) + (blood urea nitrogen [in milligrams per deciliter] ÷ 2.8) + (glucose [in milligrams per deciliter] ÷ 18) or (in millimoles per liter): (2 × [Na +] + 2 × [K +]) + (blood urea nitrogen) + (glucose) (Table 4).

Table 4: Common medical conditions with metabolic acidosis in relation to the anion gap

High anion gap Acid overproduction Ketoacidosis (diabetic ketoacidosis in pregnancy, alcoholic ketoacidosis, starvation) Acute kidney injury in pregnancy Anemia in pregnancy Lactic acidosis **Type A**: Hypoxic (maternal septic shock, obstetric hemorrhagic shock, mesenteric ischemia, hypoxemia, carbon monoxide, poisoning, cyanide). **Type B**: Non-hypoxic (thiamine deficiency, eclampsia, medications [non-nucleoside reverse transcriptase in inhibitors, metformin, propofol, niacin, isoniazid, iron], intoxication [salicylate, ethylene glycol, propylene glycol, methanol, toluene ingestion (early), paraldehyde]) Lactic acidosis in the short bowel syndrome Acid underexcretion Chronic kidney disease Fatty liver of pregnancy Impaired lactate clearance in liver failure (also type B acidosis) Cell lysis (massive rhabdomyolysis) Use of penicillin-derived antibiotics Pyroglutamic acid (5-oxoproline)[30]
Normal anion gap **Loss of bicarbonate** - Gastrointestinal conditions (diarrhea in pregnancy, ureteral shunts, biliary or pancreatic fistulae) - Renal conditions (renal tubular acidosis type 2 [proximal], toluene ingestion [at the end of toluene poisoning], drug-associated conditions [ifosfamide, tenofovir, topiramate, carbonic anhydrase inhibitors such as acetazolamide]);[28,29] **Decreased renal acid excretion**. - Early uremic acidosis - Type 1 renal tubular acidosis (e.g., due to amphotericin, lithium, Sjögren's syndrome);[28] - Renal tubular acidosis type 4 (hypoaldosteronism or pseudohypoaldosteronism) Other causes: fluid resuscitation with saline, hyperalimentation (lysine, histidine or arginine hydrochloride), administration of hydrochloride, ammonium chloride, cholestyramine, hippuric acid, hippuric acid, ammonium chloride, cholestyramine, hippuric acid, ammonium chloride, cholestyramine, hippuric acid, hippuric acid, ammonium chloride.

8. Assessment of the Metabolic Component of an Acid-Base Disorder

The diagnosis of metabolic alkalosis is based on the demonstration of a simultaneous increase in blood pH > 7.45 and plasma HCO3 > 26mmol/L in an arterial blood sample. An elevated plasma HCO3 alone should not be considered equal to metabolic alkalosis, as it may also be secondary to compensatory respiratory acidosis. As in any acid-base disorder, evaluation of high blood pH is mandatory to identify the secondary disorder and establish the accurate diagnosis.

Once the diagnosis of metabolic alkalosis is made, it is important to evaluate whether respiratory compensation is appropriate (Algorithm 3).

En cualquier caso, la alcalosis metabólica tiene un mal pronóstico

[31] ya que se asocia a variaciones extremas del pH sanguíneo a pesar de los pequeños cambios en el HCO3 plasmático. La orientación diagnóstica adicional viene dada por el análisis del contenido de electrolitos de una muestra de orina.

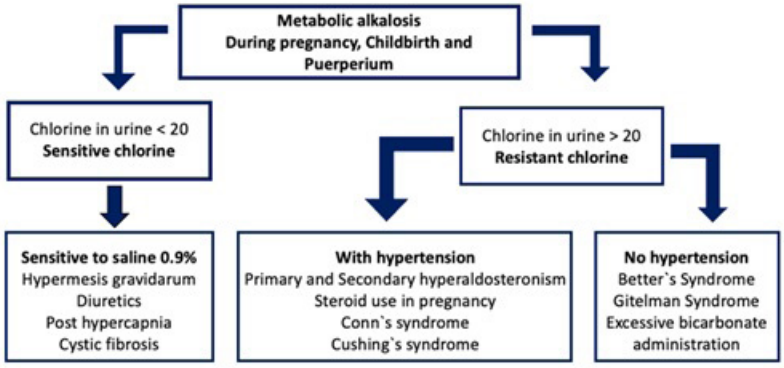
Un Cloro urinario <20 mmol/L establece el diagnóstico de cloro sensible alcalosis por depleción, la mayoría de las veces debido a vómitos, succión nasogástrica o la reciente interrupción de diuréticos [32, 33]. Cabe recordar que en los pacientes que padecen diarrea algunos adenomas vellosos secretan cloro y provocan alcalosis metabólica.

In the absence of an obvious cause, physical examination may give some suspicion of surreptitious vomiting: such as ulcers and calluses on the back of the hand, dental erosions and swollen cheeks [34, 35].

Urinary Chlorine is also low in post-hypercapnic metabolic alkalosis, the diagnosis of which is usually suggested by the clinical context. A urinary chlorine > 20 mmol/L indicates chloride-resistant alkalosis, always due to increased distal cation exchange [32, 33] and requiring assessment of blood pressure and plasma renina inactivity (Table 5).

Table 5: Metabolic Alkalosis: A Differential Diagnosis [16]

Low urine chloride variability (volume or saline sensitive) Loss of gastric volume (hyperemesis gravidarum, nasogastric suction, bulimia nervosa) Diuretics Post hypercapnia Hairy adenoma (rare) Cystic fibrosis, if there has been excessive sweating with the resulting high concentration of chloride in the sweat.
Variety of high urine chloride content (unresponsive to saline) **With hypertension** Primary and secondary hyperaldosteronism Steroid abuse in pregnancy Liddle's syndrome Conn's syndrome (aldosteronoma) Cushing's disease **Without hypertension** Bartter syndrome Gitelman's syndrome Excessive bicarbonate administration



Algorithm 3: Interpretation of metabolic alkalosis during pregnancy, childbirth and puerperium.

9. Key Points for Metabolic Alkalosis [36]

1. Metabolic alkalosis is a common complication in patients with congestive heart failure receiving diuretics.

2. This acid-base disturbance, when severe, can cause adverse effects on cellular function and contribute to increased mortality.

3. Treatment to normalize acid-base abnormalities is indicated.

4. Correction of chloride depletion and normalization of extracellular fluid volume are essential for the correction of metabolic alkalosis.

5. Carbonic anhydrase antagonists such as acetazolamide and aldosterone are useful in correcting metabolic alkalosis in patients with volume overload.

6. In patients with severe metabolic alkalosis, hydrochloric acid or dialysis may be necessary for rapid correction of alkalosis (Table 6).

Table 6: Treatment Options for Metabolic Alkalosis [36]

Correction of underlying precipitating and maintenance factors (i.e., "general measures"). - Replenish sodium, chloride and potassium deficits - Normalize extracellular fluid volume (isotonic fluids if volume depleted, management of circulatory failure if congestive heart failure is present)
Acetazolamide • Use in euvolemic or hypervolemic patients who do not respond to general measures within 18-24 hours. • Caution with hypokalemia, hypophosphatemia, hypokalemia.
Aldosterone antagonists (spironolactone, eplerenone) • Use in patients with volume overload. • Survival benefit in patients with impaired left ventricular function • Caution with hyperkalemia and over diuresis
Hydrochloric acid • Use if life-threatening alkalemia (pH >7.6) • Rapid effect (8-12h); allows titration • Requires central venous access; caution with hyperkalemia • Lack of immediate availability may limit usefulness
Renal replacement therapy • Alternative for severe alkalosis • Action is rapid (4-12 h depending on modality); precise titration • Standard hemodialysis is limited by the need to maintain dialysate bicarbonate levels approx. 20-24 mEq/L on dialysis machines • Typically restricted in patients with other renal replacement indication.

10. Adverse Clinical Effects of Metabolic Alkalosis that Justify Treatment [37, 38]

-Vasoconstriction (gestational hypertensive syndrome, myocardial ischemia, cerebral ischemia)

- Eclampsia

- Delirium

- Arrhythmias (mainly due to associated hypokalemia)

- Hypoventilation leading to hypercapnia and hypoxia.

- Hypokalemia

- Hypocalcemia

- Hypomagnesemia

- Hypophosphatemia (mainly respiratory alkalosis)

11. Respiratory Alkalosis

- Respiratory alkalosis and hypocapnia occur with alveolar hyperventilation resulting from the following:

- Stimulation of peripheral chemoreceptors by hypoxemia.

- Activation of hypoxemia-independent pulmonary stretch receptors or nonciceptors

- Direct activation of central respiratory centers.

- Overzealous mechanical ventilation

- Fear, excitement, pain, fever, or sepsis.

- After treatment of metabolic acidosis since hyperventilation may still be present for 24 to 48 hours after therapy.

Clinical signs in patients with respiratory alkalosis are primarily attributes of the underlying disease process and are infrequent due to the efficient metabolic compensation that capable of the underlying disease process and are infrequent because of the efficient metabolic compensation that occurs. Tachypnea may be the only clinical sign, especially in patients who have chronic hypocapnia. In some patients who have acute alkalosis, cardiac arrhythmias, confusion, and eclampsia or posterior reversible encephalopathy syndrome (PRES) may be seen. Alkalosis-induced translocation of potassium into cells with additional renal and extrarenal losses may produce signs attributable to hypokalemia (e.g., neuromuscular weakness, arrhythmias, polyuria) in acute respiratory alkalosis (Table 7-9).

Table 7: Causes of Respiratory Alkalosis

Hypoxemia and peripheral chemoreceptor stimulation. - Right-to-left shunt, decreased FiO2, congestive heart failure, severe anemia of pregnancy, hypotension, decreased cardiac output, ventilation-perfusion mismatch (physiological change in pregnant woman, pneumonia, pulmonary thromboembolism, pulmonary fibrosis, pulmonary edema)
Stretch/non-ciceptor activation independent of hypoxemia. Pneumonia, pulmonary thromboembolism, interstitial lung disease, pulmonary edema
Centrally mediated hyperventilation - HELLP syndrome, fatty liver of pregnancy, hyper-adrenocorticism, maternal sepsis, pharmacologic agents (e.g., salicylates, corticosteroids, xanthines), progesterone, recovery from metabolic acidosis, central nervous system disease, exercise, heatstroke
Mechanical ventilation situations caused by pain, fear, anxiety, fever, and sepsis (systemic inflammatory response syndrome in pregnant women).

Table 8: Manifestations of Respiratory Alkalosis [39]

Laboratory Hypokalemia Hypophosphatemia Increased ion gap Decrease in ionized calcium (due to increased binding protein). Increased serum chloride and decreased serum bicarbonate concentration.
● Cardiovascular Coronary vasospasm with potential for precipitating angina Arrhythmias
Central Nervous System Neuromuscular irritability, confusion, lightheadedness. Eclampsia Reversible Posterior Encephalopathy Syndrome (PRES)
● Pulmonary Increased airway resistance Decreased pulmonary compliance Increased pulmonary capillary permeability

Table 9: Management of Respiratory Alkalosis [39] Correcting the Underlying Cause

● Hypoxemia Supplemental oxygen Return to a lower altitude
● Mechanical ventilation Increasing the dead space ventilation circuit Sedation and/or use of muscle relaxant
Psychogenic hyperventilation. Breathe back into closed system (paper bag). Anti-anxiety medications, sedatives
● Salicylate toxicity Urinary alkalinization Hemodialysis with severe clinical toxicity or salicylate levels > 800 mg/L.

Causes Of Acute Respiratory Acidosis [41]	
Problems of the excretory component's perfusion Massive pulmonary embolism Ventilation due to cardiac arrest Severe pulmonary edema Severe pneumonia Adult Respiratory Distress Syndrome Airway Obstruction Bronchospasm (severe) Aspiration (Laryngospasm) Obstructive sleep apnea Pulmonary Restriction, Unstable Chest Pneumothorax, Hemothorax Muscle defects Severe hypokalemia Myasthenic crisis	Central nervous system disorders Sedoanalgesics Trauma Sleep apnea Spinal cord and peripheral nerves Cervical cord injury Guillain-Barré Syndrome Neurotoxins, such as botulism, tetanus, or organophosphates Drugs (succinylcholine, curare, pancuronium or aminoglycosides) Failure of mechanical ventilation

12. Manifestations of Respiratory Acidosis

- Neuromuscular anxiety
- Asterixis
- Lethargy, stupor, coma Delirium
- Convulsions (Eclampsia)
- Headache
- Papilledema
- Focal paresis
- Tremors, myoclonus
- Cardiovascular tachycardia, Vasodilatation Ventricular arrhythmias
- Increased serum total carbon dioxide content
- Hypochloremia
- Acute increase of serum phosphorus (Table 10).

Table 10: Common Medical Conditions Characterized by Acidosis and Respiratory Alkalosis [40]

TYPES OF ACIDOSIS	
RESPIRATORY ACIDOSIS	**COMMON MEDICAL CONDITIONS**
Acute Normal alveolar-arterial O2 difference.	Depression of the central respiratory center due to brain disease (encephalitis or trauma) or drugs (narcotics, barbiturates or benzodiazepines).
Acute High alveolar-arterial O2 difference	Airway obstruction related to acute exacerbations of asthma or pneumonia
Chronic Normal alveolar-arterial O2 difference	Neuromuscular disease (e.g., myasthenia gravis, amyotrophic lateral sclerosis, Guillain-Barré syndrome or muscular dystrophy), kyphoscoliosis, kyphoscoliosis
Chronic High alveolar-arterial O2 difference	Chronic obstructive pulmonary disease
RESPIRATORY ALKALOSIS	
Acute Normal alveolar-arterial O2 difference	Pain, anxiety, fever, stroke, stroke, meningitis, trauma, severe anemia, salicylate toxicity
Acute High alveolar-arterial O2 difference	Pneumonia, pulmonary edema, pulmonary embolism, bronchial embolism, bronchoaspiration, congestive heart failure, maternal sepsis.
Chronic Normal alveolar-arterial O2 difference	Pregnancy, HELLP syndrome, fatty liver of pregnancy, hyperthyroidism
Chronic High alveolar-arterial O2 difference	Pulmonary embolism in pregnancy, HELLP syndrome, fatty liver of pregnancy with aspiration pneumonia

The normal alveolar-arterial O2 difference is < 20. This increases with age. For each decade a person has lived, the alveolar-arterial difference is expected to increase by 2 mmHg; alternatively, age can be compensated for by using the following formula: (alveolar-arterial O2 difference = AGE/4 + 4 Minor defects may result in a normal alveolar-arterial O2 difference.

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