Quick Review: Acid Base Disorders
T Fujii, B Phillips

Citation

Abstract
Normal blood pH is 7.40 (7.36 - 7.44), which corresponds to a [H+] of 40 nEq/L (44-36). Systemic arterial pH is maintained by complex buffering mechanisms as well as renal and respiratory compensatory responses. This brief article reviews the basics of acid-base disorders.

GENERAL CONCEPTS
The kidneys regulate HCO$_3^-$ by the following mechanisms:

- Reabsorption of filtered HCO$_3^-$
- Formation of titrable acid
- Excretion of NH$_4^+$ in the urine

Acidemia: serum pH < 7.36
Alkalemia: serum pH > 7.44

Acidosis: pathophysiologic processes, which favor development of acidemia
Alkalosis: pathophysiologic processes, which favor development of alkalosis

Buffer: A substance, which can absorb or donate H$^+$ ions in order to mitigate changes pH.

H$_2$CO$_3$ H$^+$ + HCO$_3^-$

* Remember: [H+] ion concentration and pH are inversely related.

HENDERSON-HASSELBALCH EQUATION:
\[ \text{pH} = \text{pK} + \log \left( \text{HCO}_3^- \right) \]
\[ \text{pK} = 6.1 \ (\text{PaCO}_2) \]

KASSIRER-BLEICH EQUATION:
\[ H^+ = 24 \times \text{PCO}_2/\text{HCO}_3^- \]

Reflects how the acidity of blood is determined by the relative availability of acid and alkali, i.e. HCO$_3^-$, PaCO$_2$. Stresses how H$^+$ ion concentration is determined by the ratio of PCO$_2$/HCO$_3^-$, rather than the absolute value of either value alone.

Remember: Metabolic Acidosis/Alkalosis = disturbances of blood bicarbonate
Respiratory Acidosis/Alkalosis = disturbances of PaCO$_2$

METABOLIC ACIDOSIS
Anion Gap: Na$^+$ - (Cl$^-$ + HCO$_3^-$) (represents unmeasured anions in plasma, normally 10-12 mmol/L)

Figure 1

COMPENSATION:
Winter’s formula: PaCO$_2$ = 1.5 x HCO$_3^-$ + 8 (+/-2) (PaCO$_2$ = last 2 digits of pH - chronic metabolic acidosis)

TREATMENT:
Should be directed at the underlying cause Bicarbonate therapy can be considered with severe acidosis with physiologic compromise:

Bicarbonate deficit (mEq) = LBW x 0.5 x (Desired HCO$_3^-$ – actual HCO$_3^-$)

OSMOLAL GAP:
Measured OSM – Calculated OSM

CALCULATED OSMOLALITY:
\[ 2 \times \text{Na} + \text{Glc}/18 + \text{BUN}/2.8 + \text{ETOH}/4.6 \]
Quick Review: Acid Base Disorders

Elevated OG (> 10 mOsm/L):
Methanol
Ethylene glycol
Paraldehyde
ETOH ketoacidosis
Isopropyl alcohol
Mannitol

METABOLIC ALKALOSIS

**Figure 2**

<table>
<thead>
<tr>
<th>CT resistant (Ucl &gt; 30)</th>
<th>CT responsive (Ucl &lt; 20)</th>
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<tbody>
<tr>
<td>01: AG:&lt;10</td>
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<tr>
<td>Vomiting/diarrhea</td>
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<td>Liver failure</td>
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<td>Primary aldosteronism</td>
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<td>Primary mineraloportal excess</td>
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<td>Renal: Diuretics</td>
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<tr>
<td>Post hypercapnia</td>
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<td>Refeeding alkalosis</td>
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<tr>
<td>Cystic fibrosis</td>
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<tr>
<td>Severe hypokalemia/magnesemia</td>
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</tbody>
</table>

**COMPENSATION:**
PaCO2 = 0.9 x HCO3¯ + 9

**TREATMENT:**
Acetazolamide (Diamox): 250-375 mg po qd-bid
HCl infusion: 0.1-0.2 N @ < 0.2 mEq/hour via central line (=100-200 mEq H+/L)
HCL (mmol) = (LBW x 0.5) x Actual HCO3- desired
HCO3)
Hemodialysis: severe alkalosis with cardiac/renal dysfunction

**RESPIRATORY ACIDOSIS**

**CNS:**
Sedatives, morphine, anesthetics
Trauma, Stroke
Infection

**NM DISORDERS:**
Myopathies (MD, K+ depletion)
Neuropathies (GB, polio)

**ACUTE-CHRONIC LUNG DISEASE**
COPD
PNA, pulmonary edema

ARDS
Acute obstruction (aspiration, tumor, spasm)
Obesity
Pneumothorax
Pleural effusion
Kyphoscoliosis
Scleroderma
Crush injury
Mechanical ventilation
Cardiopulmonary arrest

**COMPENSATION:**
Acute: HCO3¯ increases by 1 mmol/L for each 10 mm Hg increase in PaCO2
Chronic: HCO3¯ increases by 4 mmol/L for each 10 mm Hg increase in PaCO2

**RESPIRATORY ALKALOSIS**

- Anxiety, Pain
- CNS Disorders (CVA, tumor, infection)
- Lung Disease:
  - Restrictive disorders
  - Pulmonary embolus
  - Sepsis, fever
  - Hyperthyroidism
  - Hypoxia
  - Hepatic insufficiency
  - Pregnancy
  - Salicylates, Catecholamines
  - Mechanical ventilation

**COMPENSATION:**
Acute: HCO3¯ decreases by 2 mmol/L for each 10 mm Hg decrease in PaCO2
Chronic: HCO3¯ decreases by 5-7 mmol/L for each 10 mm Hg decrease in PaCO2

**DELTA GAP:**
Identifies triple acid base disorders
Figure 3

Δ gap = Δ AG = Δ HCO3

ΔAG/ΔHCO3:  
≤ 1  
> 1  
Non AG acidosis  Metabolic alkalosis + AG acidosis  DKA  Lactic acidosis  Chronic renal failure

SUMMARY OF ACID BASE COMPENSATORY RESPONSES

<table>
<thead>
<tr>
<th>Primary disorder</th>
<th>Primary</th>
<th>Expected</th>
<th>Response</th>
</tr>
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<tbody>
<tr>
<td>Metabolic Acidosis</td>
<td>↓ HCO3</td>
<td>↓ PaCO2</td>
<td>PaCO2 = 1.5 × HCO3 + 8 (±1.2)</td>
</tr>
<tr>
<td>Metabolic Alkalosis</td>
<td>↑ HCO3</td>
<td>↑ PaCO2</td>
<td>PaCO2 = 0.9 × HCO3 + 9</td>
</tr>
</tbody>
</table>
| Respiratory Acidosis | ↑ PaCO2 | ↓ HCO3  | Arterial: HCO3 ↑ 1 mmol/L - 10 mm Hg ↑ PaCO2  
| | | | Chronic: HCO3 ↑ 4 mmol/L - 10 mm Hg ↑ PaCO2 |
| Respiratory Alkalosis | ↓ PaCO2 | ↑ HCO3  | Arterial: HCO3 ↓ 2 mmol/L - 10 mm Hg ↓ PaCO2  
| | | | Chronic: HCO3 ↓ 5 mmol/L - 10 mm Hg ↓ PaCO2 |

References
Author Information

Tisha K. Fujii, DO
Dept. of Trauma & Critical Care, Boston University School of Medicine, Boston Medical Center

Bradley J. Phillips, MD
Dept. of Trauma & Critical Care, Boston University School of Medicine, Boston Medical Center