Zuku Review FlashNotes™

Acid/Base Disorders

ACID/BASE DISORDERS

- **Simple acidosis/alkalosis**
  - One primary change occurs – same direction as pH
  - Loss or gain of an acid or a base
  - Compensatory response, when present, is:
    - A secondary change in *opposite* direction to pH
    - Usu incomplete; ***Overcompensation*** **does NOT occur**
    - When pH still too low/high, look for another A/B disorder

Simple A/B disorder	pH	[H+]	Primary change	Compensatory response
Respiratory acidosis	↓	↑	pCO_2 ↑	$[HCO_3]$ ↑
Respiratory alkalosis	↑	↓	pCO_2 ↓	$[HCO_3]$ ↓
Metabolic acidosis	↓	↑	$[HCO_3]$ ↓	pCO_2 ↓
Metabolic alkalosis	↑	↓	$[HCO_3]$ ↑	pCO_2 ↑

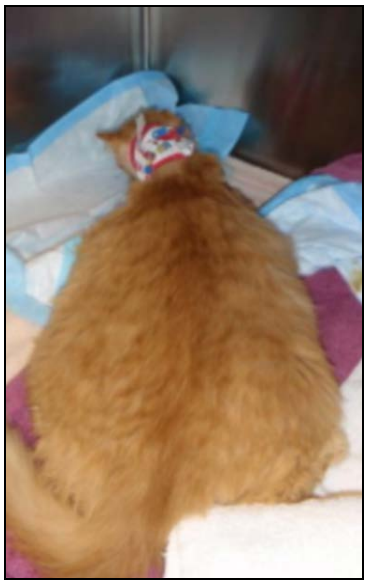
Pharyngeal/laryngeal edema in a dog caused airway obstruction, hypoventilation and respiratory acidosis

Image courtesy Dr. M. Radlinsky

Although the primary and compensatory responses shift in opposite directions ***relative to pH***, the concentration of ions are actually both increasing or decreasing - higher CO_2 is ↑ acid,
higher HCO_3 is ↑ base.

Note: some authors use ***direction*** *to refer to number values as they go up or down; In these notes, direction of change refers to* ***pH***

- **Mixed** – more than one change, usually 2, but more is possible
  - Metabolic and/or respiratory
  - Interpretation more difficult
  - See Blood Gas Evaluation notes



Hypoventilation secondary to obesity - respiratory acidosis, and hypoxemia;

Image courtesy Dr. C Braun

- **Acute vs. Chronic**
  - Compensatory capability differs – greater in chronic diseases
  - Expected compensation can be calculated
  - Compensatory response, when present, is:
    - pH should ↓ or ↑ a specific amount based on change in pCO_2 or HCO_3
    - Varies with species, duration of disease

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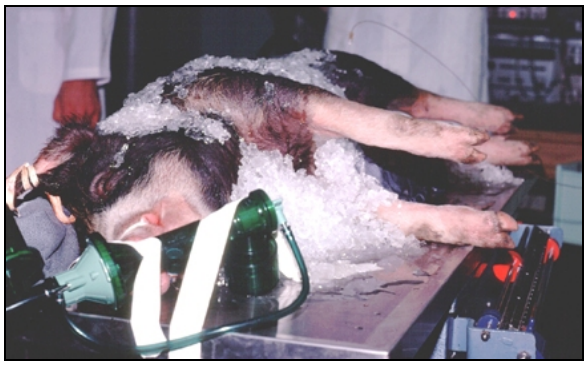
Acid/Base Disorders

CAUSES OF ACID/BASE DISORDERS

- **ACIDOSIS** – loss of base or increased acid
  - **Respiratory acidosis** – **↑ levels of carbon dioxide**
    - Compensation for metabolic alkalosis
    - Hypoventilation – decreased elimination of CO_2
      - ♦ Respiratory tract dysfunction
        - o Upper airway – obstruction
        - o Lower airway – pulmonary or thoracic dz
        - o Muscle weakness – ↓ tidal volume
        - o Atelectasis – recumbency, obesity
      - ♦ Dysfunction of respiratory centers in brain
        - o Anesthesia, sedation – resets threshold at higher pCO_2
        - o Cerebral disease
    - Increased production of CO_2 - overwhelms ventilation
      - ♦ Malignant hyperthermia –abnormal muscle metabolism
      - ♦ Heatstroke
      - ♦ Lactic acidosis also develops



Malignant hyperthermia in a pig. Severe metabolic acidosis develops from abnormal muscle metabolism;

Image courtesy Dr. CM Trim

Dogs pant to stay cool and usually have respiratory alkalosis; but pH is dependent on balance between O_2 demand of exercise & effectiveness of removal;

Athletic dogs may develop hyperthermia and even heat stroke; Metabolic acidosis, and respiratory acidosis can occur.

Images courtesy Abujoy, and M Kloet

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Acid/Base Disorders

- **ACIDOSIS** – continued
  - **Metabolic acidosis 1**– compensation for respiratory alkalosis
  - **Metabolic acidosis 2**- due to **loss of HCO_3**
    - Hyperchloremic normal anion gap acidosis
      - Kidney resorbs Cl w/ Na to restore volume - see ↑Cl
      - ↑Cl balances AG equation - HCO_3, Cl are measured anions
    - **Vomiting**/reflux of biliary/pancreatic fluids
    - **Diarrhea in large animals** (*E. Coli*, *Salmonella* spp)
    - **Esophageal obstruction** "choke"- cows, horses
    - Renal loss
      - Tubular acidosis
      - Addison's disease
  - **Metabolic acidosis 3**– due to **increased acid** – called 'titration acidosis'
    - High anion gap acidosis, normochloremic
    - Organic acids are buffered by bicarbonate

Holstein heifer recovered from E. Coli diarrhea with severe metabolic acidosis caused by loss of bicarbonate and severe dehydration

Titration acidosis:
Strong acid dissociates:
H^+UA^- → H^+ + UA^-
Buffered by bicarbonate:
$H^+ + HCO_3^- \rightarrow H_2CO_3 \rightarrow H_2O + \uparrow CO_2$
CO_2 is exhaled
UA^- ↑s – AG↑s, pH drops
$[HCO_3^-]$ ↓s - pH drops

Castrated male cat post urethral obstruction; Uremia caused 'titration' metabolic acidosis; resolved with removal of uroliths & diuresis.

- Uremic acids with **renal failure**
- **Ketoacidosis** – diabetes, ketosis in cattle/camelids
- **Antifreeze** poisoning (ethylene glycol)
- Other toxins - salicylates, methanol, metaldehyde, etc.

Ethylene glycol (antifreeze), and its metabolites are toxic organic acids;

Image courtesy dno1967

Metabolic acidosis	Likely cause
↑ Anion Gap w/ Normal Cl	↑ UA
↓ Anion Gap w/ High Cl	Loss of HCO3
Adapted from chart at Cornell Clin Chem Basics website – see refs	

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Acid/Base Disorders

- **ACIDOSIS** – continued
  - **Metabolic acidosis 3** due to **increased acid** – continued

NOTE! Patients with significant fluid deficits will have some lactic acidosis – Rx with FLUIDS, ***not*** HCO_3

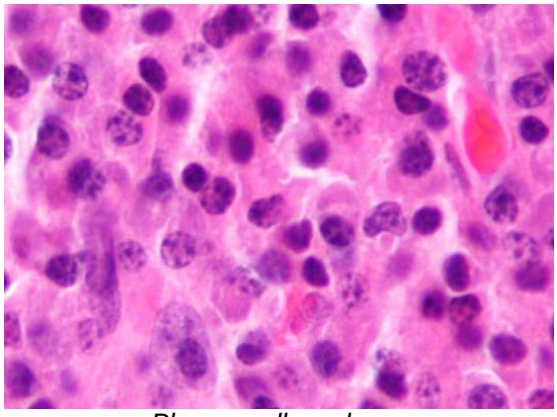
  - **Lactic acid – COMMON – also an organic acid**
    - Tissue hypoxia - anaerobic metabolism - ↑ lactate
      - Decreased perfusion of tissues
        - Hypovolemia – dehydration/hemorrhage
        - Hypotension / vasodilation
        - Sepsis, heart failure, shock, cardiac arrest, etc
      - Hypoxemia -Pneumonia, A/W obstruction, etc
      - Increased demand for O_2 - seizures, exercise
      - Severe anemia
    - Rumen acidosis – grain overload
      - ↑ **production** of L form of lactic acid,
      - Sometimes D-lactate too
      - Often hypovolemic/dehydrated as well
    - Hyperthermia
      - Severe anemia
      - Heat stroke
      - Excessive exercise, especially if unfit – get too hot (Labradors that won't stop)
  - Hyperproteinemia/globulinemia = acids
    - Many proteins are weak acids
      - Presence of histidine in side chains
    - Identified with physiochemical theory of A/B - ↑A_{TOT}
    - Plasma cell myeloma, chronic infection, neoplasia, etc.

Race horses develop short term lactic acidosis due to anaerobic metabolism during high speed exercise. Hypercarbia and hypoxemia also occur due to respiratory limitations.

Image courtesy Softeis

Right torsed abomasum;

Begins with metabolic alkalosis, Can develop metabolic (lactic) acidosis with hypovolemia/dehydration



Plasma cell myeloma

Image courtesy Nephron

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Acid/Base Disorders

- **ALKALOSIS** – increased base or loss of acid

  - **Respiratory alkalosis** – **↑ elimination of CO_2** (volatile acid)
    - Compensatory response to metabolic acidosis
      - ♦ Often incomplete
      - ♦ Limited by hypoxemia
    - Hyperventilation
      - ♦ Excitement, anxiety, fear, warm environments, pain
      - ♦ Hyperthermia-Fever; Exercise; Heat stroke (milder forms)
      - ♦ COMMON in small animals – panting

  - **Metabolic alkalosis**
    - ♦ Compensatory response for respiratory acidosis
      - o Often very good in chronic diseases

    - Loss of H^+ ***and*** Cl^-
      - ♦ Vomiting in SA; gastric reflux in horses
        - o HCl production continues, generates $NaHCO_3$
        - o H^+, Cl^- are lost, but HCO_3 retained

      - ♦ Upper GI obstruction, especially ruminants (“choke”)
        - o Displaced/torsed abomasum – sequestration of H^+ and Cl^-
      - ♦ Kidney saves HCO_3^- , Cl^- not available to resorb w/ Na

    - Increased excretion or loss of Cl^-
      - ♦ Sweating, exertional rhabdomyolysis
        - o Lose lots of Cl; also K, Ca, Na
        - o Sweat volume can be profound
      - ♦ Diuretic therapy
        - o Loop of Henle type - furosemide - lose Na, Cl, K
        - o Thiazide type – lose Na, Cl
    - Increased sodium levels - Na levels > Cl
      - ♦ Hyperaldosteronism
      - ♦ Hyperadrenocorticism

    - Hypoproteinemia
      - ♦ Many proteins are weak acids. (Histidine-containing side groups)
      - ♦ Not apparent with traditional A/B principles
      - ♦ Important component of the ‘strong ion’ theory of A/B
      - ♦ “Hidden” underlying A/B abnormality
        - o Acidosis *appears* less severe in diseases with protein loss

Arabians are well suited to endurance exercise;

Metabolic alkalosis can occur in horses that exercise for long durations

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Acid/Base Disorders

Images and Links worth a look:

Cornell University Clinical Chemistry basics, Acid/base, Mixed acid base, Bicarbonate and Anion Gap

Colorado State University Acid/Base and Blood gas interpretation, with case studies

University of Pennsylvania Clin Path case studies

Tufts University "Strong Ion" theory of Acid Base

References: Unless otherwise noted, images are courtesy of Dr. JG Adams

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