Systematic Acid-Base Interpretation

Many Emergency Departments are equipped with point-of-care analysers that can measure pH, partial pressures of blood gases, and the concentrations of electrolytes and lactate within minutes. These results are valuable adjuncts to the information obtained during the ABCDE in the initial assessment of critically ill patients. This document focuses on the identification and interpretation of acid-base disorders based on the pH, pCO_2, standard base excess (SBE), HCO_3, Na, Cl, and lactate concentrations.

There are several reasons why acid-base interpretation is challenging:

- There are different strategies in use. One strategy is physiological whereas another is physicochemical (Stewart method). One strategy focuses on the SBE whereas another focusses on HCO_3 [1, 2].
- Terminology ("compensation") is sometimes used to mean different things.
- $PaCO_2$ units are in mm Hg in some countries and kPa in others. A normal arterial $PaCO_2$ is 5.3 kPa = 40 mm Hg. The conversion factor is 7.5.
- HCO_3 is sometimes provided as actual HCO_3 or standard HCO_3^- or both. Actual HCO_3 is determined by pH and pCO_2 according to a simple formula (Henderson-Hasselbach equation). The standard HCO_3, on the other hand, is calculated from a complex formula and it indicates what the HCO_3 would be if the pCO_2 were normal. It represents the summative metabolic effect on the pH.
- Sometimes the anion gap is provided on the bedside acid-base print-out or calculated directly; sometimes it is not. Sometimes the potassium is included in the anion gap calculation, other times not.

The method that follows aims to be:

- sufficiently simple that it can be performed at the bedside
- powerful enough to detect the presence of several concomitant acid-base disorders

It consists of an initial "half-step"—converting venous values into arterial ones if a venous gas is provided—followed by four steps summarized in the mnemonic ACID:
1-Alpha disorder?
2-Compensation?
3-Ionic gaps?
4-Differential?

ARTERIAL VALUES?

- **pH** = $-\log_{10}[H^+]$
- A normal arterial pH lies between 7.38 and 7.42 [1].
- **Acidemia** refers to an increased $[H^+]$ in the blood resulting in an arterial pH < 7.38.
- **Alkalemia** refers to a decreased $[H^+]$ in the blood resulting in an arterial pH > 7.42.
- If venous blood is used for the analysis, add 0.03 to estimate what the pH would have been in an arterial sample [3-6].

- **$PaCO_2$** denotes the partial pressure of carbon dioxide in arterial blood.
- A normal arterial $PaCO_2$ is roughly 5.0 - 5.7 kPa.
- **Hypercapnia** and **hypercarbia** refer to a greater-than-normal $PaCO_2$ in blood.
- **Hypocapnia** and **hypocarbia** refer to a lower-than-normal $PaCO_2$ in blood.
- If venous blood is used for the analysis, subtract 0.6 kPa or 5 mm Hg to estimate what the $PaCO_2$ would have been in an arterial sample [3-6]. There is a method of deriving arterial pCO2 from venous pCO2 and SpO2% referred to as "venous to arterial conversion method" (v-TAC) [7]. However, this method is not open-access.

1-ALPHA DISORDER?

- By "alpha" disorder is meant "dominant" disorder, i.e. the disorder that at face value has the most effect on the pH. Patients can suffer from several concurrent acid-base disorders. For example, a patient may suffer from diabetic ketoacidosis and have a metabolic alkalosis due to vomiting, resulting in a normal pH. In other words, an acidosis can be present despite a normal or elevated pH, and an alkalosis can be present despite a normal or low pH. The purpose of this step is to identify whether a dominant acid-base disorder is present.
- **Acidosis** refers to an acid-base disorder that increases [H^+], thereby decreasing the pH.
- **Alkalosis** refers to an acid-base disorder that decreases [H^+], thereby increasing the pH.

Base Excess (BE) refers to "the amount of strong acid (in millimoles per liter) that needs to be added in vitro to 1 liter of fully oxygenated whole blood to return the sample to standard conditions (pH of 7.40, PCO2 of 40 mm Hg, and temperature of 37°C)" [2]. The value printed out on the blood gas is actually the Standard Base Excess (SBE) and it is calculated according to the following formula:

$SBE = HCO_3^- - 24.8 + [16.2 \times (pH - 7.40)]$ [2]

The SBE can be thought of as a summation of the effects of metabolic disturbances on the pH.

- A normal SBE is 0 +/- 3 mmol/L
- A SBE < -3 indicates the presence of a dominant metabolic acidosis
- A SBE > 3 indicates the presence of a dominant metabolic alkalosis

pH < 7.38	SBE < -3 mmol/L	**Metabolic Acidosis**
	pCO_2 > 5.7 kPa (43 mm Hg)	**Respiratory Acidosis**
pH > 7.42	SBE > 3 mmol/L	**Metabolic Alkalosis**
	pCO_2 < 5 kPa (37 mm Hg)	**Respiratory Alkalosis**

- If a patient has both SBE < -3 mmol/L and pCO_2 > 5.7, the patient has both a metabolic acidosis and a respiratory acidosis.
- Conversely, if a patient has both SBE > 3 mmol/L and pCO_2 < 5.0, the patient has both a metabolic alkalosis and a respiratory alkalosis.
- If the pH is between 7.38 and 7.42, then the patient has either no acid-base disturbance or at least two disturbances that balance each other's effect on the pH.

HCO_3 is closely related to SBE. The actual HCO_3 is a function of pH and pCO_2. These three units are linked through the Hendersson-Hasselbach equation. It is the actual HCO_3 that featured in the equation above for the SBE. The standard HCO_3 is calculated using complicated equations and provide the expected HCO_3 in the setting of normal pCO_2, pO_2 and temperature [8]. Most blood gases print out the standard HCO_3, some print out both the standard HCO_3 and the actual HCO_3. A normal HCO_3 is 24 +/- 3 mmol/L.

The bottom lines are as follows:

- SBE and standard HCO_3 are both summative values of the metabolic effect on the pH
- SBE < -3 mmol/L and standard HCO_3 < 21 mmol/L indicate a metabolic acidosis
- SBE > 3 mmol/L and standard HCO_3 > 27 mmol/L indicate a metabolic alkalosis

Examples

Blodgasvärden			
pH	7,221		
pCO_2	9,94	kPa	75 mm Hg
pO_2	7,12	kPa	53 mm Hg
Elektrolytvärden			
cNa^+	137	mmol/L	
cK^+	3,0	mmol/L	
cCrea	55	µmol/l	0.62 mg/dL
cCa^{2+}	1,29	mmol/L	
↓ cCl^-	97	mmol/L	
Metabolitvärden			
↑ cGlu	7,3	mmol/L	131 mg/dL
↑ cLac	4,0	mmol/L	36 mg/dL
Oximetervärden			
ctHb	124	g/L	
*F*COHb	0,5	%	
*F*MetHb	0,7	%	
sO_2	78,5	%	
Beräknade Värden			
$cBase(Ecf)_C$	2,4	mmol/L	
$cHCO_3^-(P,st)_C$	24,3	mmol/L	

Arterial Values?
- Could be

1-Alpha Disorder?
- **Respiratory acidosis**

Blodgasvärden			
pH	7,528		
pCO_2	6,51	kPa	49 mm Hg
pO_2	7,25	kPa	54 mm Hg
Elektrolytvärden			
cNa^+	140	mmol/L	
cK^+	3,0	mmol/L	
cCrea	72	µmol/l	0.81 mg/dL
cCa^{2+}	1,07	mmol/L	
↓ cCl^-	89	mmol/L	
Metabolitvärden			
↑ cGlu	8,5	mmol/L	153 mg/dL
↑ cLac	2,6	mmol/L	23.4 mg/dL
Oximetervärden			
ctHb	163	g/L	
*F*COHb	1,2	%	
*F*MetHb	0,4	%	
sO_2	90,6	%	
Beräknade Värden			
$cBase(Ecf)_C$	16,1	mmol/L	
$cHCO_3^-(P,st)_C$	38,7	mmol/L	

Arterial Values?
- Likely

1-Alpha Disorder?
- **Metabolic alkalosis**

Blodgasvärden			
↑ pH	7,686		
↓ pCO_2	1,74	kPa	13 mm Hg
↑ pO_2	17,1	kPa	128 mm Hg
Elektrolytvärden			
↓ cNa^+	133	mmol/L	
cK^+	3,2	mmol/L	
cCrea	52	µmol/l	0.58 mg/dL
cCa^{2+}	1,10	mmol/L	
cCl^-	107	mmol/L	
Metabolitvärden			
↑ cGlu	6,4	mmol/L	115 mg/dL
↑ cLac	2,1	mmol/L	18.9 mg/dL
Oximetervärden			
ctHb	146	g/L	
FCOHb	1,0	%	
FMetHb	0,3	%	
sO_2	99,9	%	
Beräknade Värden			
$cBase(Ecf)_c$	-4,7	mmol/L	
$cHCO_3^-(P,st)_c$	23,3	mmol/L	

Arterial Values?
- Yes

1-Alpha Disorder?
- **Respiratory alkalosis**

Blodgasvärden			
↓ pH	7,034		
↑ pCO_2	10,8	kPa	81 mm Hg
↓ pO_2	7,57	kPa	57 mm Hg
Elektrolytvärden			
cNa^+	142	mmol/L	
cK^+	3,8	mmol/L	
cCrea	160	µmol/l	1.80 mg/dL
cCa^{2+}	1,15	mmol/L	
cCl^-	107	mmol/L	
Metabolitvärden			
cGlu	4,5	mmol/L	81 mg/dL
↑ cLac	7,1	mmol/L	64 mg/dL
Oximetervärden			
ctHb	108	g/L	
FCOHb	0,4	%	
FMetHb	0,7	%	
sO_2	74,8	%	
Beräknade Värden			
$cBase(Ecf)_c$	-8,9	mmol/L	
$cHCO_3^-(P,st)_c$	15,3	mmol/L	

Arterial Values?
- Possibly

1-Alpha Disorder?
- **Metabolic acidosis**
- **Respiratory acidosis**
- Unclear which is “alpha”

2. COMPENSATION?

The body strives to maintain a normal pH. It has two means of altering $[H^+]$:

- The pCO_2 can be decreased through increased minute ventilation or increased through decreased minute ventilation. pCO_2 combined with H_2O is in equilibrium with HCO_3 and H^+. Reducing pCO_2 results in a consumption of H^+ and a rise in the pH. Increasing pCO_2 results in an increase in H^+ and a decrease in the pH. This compensation occurs within minutes.
- The kidneys can retain or excrete HCO_3. The retention of HCO_3 leads to a consumption of H^+ and a rise in the pH. The excretion of HCO_3^- leads to a rise in the H^+ and a decrease in the pH. It takes the kidneys 3-5 days to compensate of a respiratory disorder. The presence or absence of metabolic compensation can therefore suggest whether the respiratory disturbance is acute (< 2 days) or chronic (> 5 days).

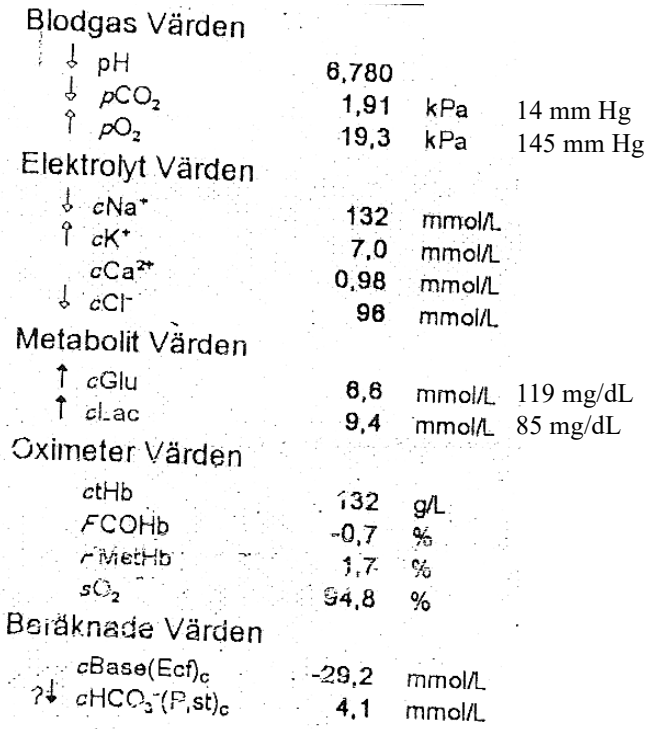
There are several ways of estimating expected compensation to an acid-based disorder. The following table provides a method that can be carried out at the bedside using SBE:

Disorder	Expected Comp	kPa	mm Hg
Metabolic Acidosis	$\Delta pCO_2 = SBE \times$	0.1	1
Metabolic Alkalosis	$\Delta pCO_2 = SBE \times$	0.1	1/2
Respiratory Disorder < 2 days	SBE = 0		
Respiratory Acidosis > 5 days	$SBE = \Delta pCO_2 \times$	3	1/3
Respiratory Alkalosis > 5 days	$SBE = \Delta pCO_2 \times$	3	1/3

These formulae for expected compensation sacrifice precision for ease of use, resulting in broad confidence intervals:

- +/- 1 for pCO2 in kPa
- +/- 5 for pCO2 in mm Hg
- +/- 3 for SBE in mmol/L

Examples



Blodgas Värden			
↓ pH	6,780		
↓ pCO_2	1,91	kPa	14 mm Hg
↑ pO_2	19,3	kPa	145 mm Hg
Elektrolyt Värden			
↓ cNa^+	132	mmol/L	
↑ cK^+	7,0	mmol/L	
cCa^{2+}	0,98	mmol/L	
↓ cCl^-	96	mmol/L	
Metabolit Värden			
↑ cGlu	6,6	mmol/L	119 mg/dL
↑ cLac	9,4	mmol/L	85 mg/dL
Oximeter Värden			
ctHb	132	g/L	
FCOHb	-0,7	%	
FMetHb	1,7	%	
sO_2	94,8	%	
Beräknade Värden			
$cBase(Ecf)_c$	-29,2	mmol/L	
?↓ $cHCO_3^-(P,st)_c$	4,1	mmol/L	

Arterial Values?
- Arterial blood gas

1-Alpha Disorder?
- **Metabolic acidosis**

2-Compensation?

Expected	kPa	mm Hg
ΔpCO_2	-2.9	-29
pCO_2	2.4	11

- No respiratory disturbance

Acid-Base					
pH	7.33				
pCO_2	2.4	kPa	18	mm Hg	
pO_2	4.7	kPa	35	mm Hg	
Base(Ecf)c	-13.6	mmol/L			
$HCO3^-(P,st)c$	10	mmol/L			
Oximetry					
Hb	118	g/L			
Electrolytes					
Na^+	139	mmol/L			
K^+	2.9	mmol/L			
Ca^{2+}	1.22	mmol/L			
Cl^-	105	mmol/L			
Metabolites					
Glucose	9.4	mmol/L	170	mg/dl	
Lactate	1.6	mmol/L	14.4	mg/dl	
Creatinine	37	µmol/L	0.42	mg/dl	
Other					
Anion Gap	24.8	mmol/L			

Arterial Values?
- pH 7.36
- pCO_2 1.8 kPa (13 mm Hg)

1-Alpha Disorder?
- **Metabolic acidosis**

2-Compensation?

Expected	kPa	mm Hg
ΔpCO_2	-1.4	-14
pCO_2	3.9	26

- **Respiratory alkalosis**

3. IONIC GAPS?

The core principle that governs this step is electroneutrality: the sum charge of all ions in the blood must be 0. In other words, the sum charge of all anions must be equal to the sum charge of all cations.

Anion Gap

The following equations refer to electrical charges:

Cations	=	Anions
Na + Other Cations	=	Cl + HCO_3 + Other Anions
Na – (Cl + HCO_3)	=	Other Anions – Other Cations

Na – (Cl + HCO_3) is referred to as the **anion gap (AG).** The AG represents the resulting excess of anions relative to cations in the blood were it possible to remove Na, Cl and HCO_3. These anions are primarily negatively charged proteins such as albumin, which may account for up to 75% of the anion gap [1]. Other unmeasured anions are phosphate, urate and sulphate [9]. K is usually not factored into the AG calculation since it has a relatively low concentration relative to Na, Cl and HCO_3 [10]. Note that it is the actual HCO_3—not the standard HCO_3—that is used to calculate the AG.

Normal AG values depend on the method used to measure Na, Cl and HCO_3. Older methods yield a normal AG of 12 +/- 2 mmol/L, while ion selective electrodes yield a normal AG of 6 +/- 3 mmol/L [10]. For the sake of simplicity, assume that a normal AG is 8 +/- 3 mmol/L.

If the AG is elevated (≥ 14 mmol/L), then excess anions are present in the blood. Excess anions indicate that the patient has a metabolic acidosis. If the Na and Cl are constant, the presence of increased anions will "squeeze" the HCO_3, and a low HCO_3 indicates a metabolic acidosis. A metabolic acidosis brought on by excess anions is termed **HAGMA** = High Anion Gap Metabolic Acidosis. The excess anions are referred to as the delta AG (ΔAG). ΔAG = AG - 10. The conditions that can bring this about (e.g. conditions that result in lactate, ketones) are listed in the next section.

If the AG is low (≤ 6 mmol/L), then the patient has a **Low AG**. One source defines a low AG as ≤ 3 mmol/L [11]. The conditions that can bring this about are listed in the next section.

Na-Cl Gap

A low HCO_3 can also be caused by a drop in the difference between Na and Cl. A narrow Na-Cl difference "squeezes" the HCO_3 leading to a metabolic acidosis. In this case, the anion gap is normal and this type of metabolic acidosis is termed **NAGMA** = Normal Anion Gap Metabolic acidosis. This type of metabolic acidosis is also referred to in the literature as a hyperchloremic metabolic acidosis, because the chloride is usually high. However, it is the difference between Na and Cl which is the key pathophysiologic entity. A low Na and a normal Cl will also result in a **NAGMA**. If the anion gap is normal and the difference between Na and Cl is increased, then the HCO_3 gets "stretched". An increased HCO_3^- indicates a **Metabolic alkalosis**.

According to one study, the median normal Na-Cl gap is 34 mmol/L [12]. The delta (Na-Cl) gap (ΔNa-Cl) can be defined as Na - Cl - 34.

Ionic Gaps

Conceptually, there are two parallel mechanisms by which a metabolic acid-base disturbance occurs:

- Mechanisms that alter the anion gap:
  - If the ΔAG is increased, the patient has a **HAGMA**
  - If the ΔAG is decreased, the patient has a **Low AG**
- Mechanisms that alter the Na - Cl gap
  - If the Δ(Na-Cl) is increased, the patient has a **Metabolic alkalosis** or a compensation for a **chronic respiratory acidosis**
  - If the Δ(Na-Cl) is decreased, the patient has a **NAGMA** or a compensation for a **chronic respiratory alkalosis**

The acid-base interpretation strategy presented here is aligned with the Steward method in so far as the AG corrected for albumin is a good surrogate measure for the SIG and the (Na-Cl) is a good surrogate measure for the SID_{app}, where SIG refers to the Strong Ion Gap and SID to the Strong Ion Difference [12].

Strategies for Calculating the ΔAG

Point-of-care analyzers can calculate the anion gap based on Na, Cl, pH and pCO_2 (the actual HCO_3 is calculated from pH and pCO_2 using the Henderson Hasselbalch equation).

If the AG is not provided, it can be calculated as Na - Cl - actual HCO_3. If the standard HCO_3 is provided but the actual HCO_3 is not, then one can assume that the two are equal as long as the pCO_2 is between 3.3 and 7.3 kPa, i.e. between 25 and 55 mm Hg.

The literature provides another strategy if the anion gap is not automatically calculated and the actual HCO_3 is not provided [13]. The strategy entails solving the following equation:

$$SBE = \Delta(Na\text{-}Cl) - \Delta AG$$

This strategy might lead to inaccurate results when the pCO_2 is significantly abnormal, given that the SBE is corrected for abnormal pCO_2.

Examples

Syra-Bas Status			
pH	7,418		
pCO_2	4,30	kPa	32 mm Hg
pO_2	3,46	kPa	26 mm Hg
$cBase(Ecf)_c$	-3,3	mmol/L	
$cHCO_3^-(P,st)_c$	21,0	mmol/L	
Oximetervärden			
sO_2	43,2	%	
ctHb	147	g/L	
FMetHb	0,8	%	
FCOHb	0,8	%	
Elektrolytvärden			
cNa^+	137	mmol/L	
cK^+	3,9	mmol/L	
cCa^{2+}	1,18	mmol/L	
cCl^-	95	mmol/L	
Metabolitvärden			
cGlu	28	mmol/L	504 mg/dL
cLac	2,1	mmol/L	18.9 mg/dL
cCrea	170	µmol/l	1.9 mg/dL
Beräknade Värden			
Anion Gap_c	21,3	mmol/L	

Arterial Values?
- pH 7.45
- pCO_2 3.7 kPa = 27 mm Hg

1-Alpha Disorder?
- **Respiratory alkalosis**

2-Compensation?
- Expected SBE if acute = 0
- Expected SBE if chronic:

	kPa	mm Hg
ΔpCO_2	-1.6	-13
SBE	-4.8	-4

3-Ion Gaps?
- Δ (Na-Cl) = 137 – 95 – 34 = 8 mEq/L: **Metabolic alkalosis**
- Δ AG = 21 - 8 = 13 mEq/L: **HAGMA**

Provtyp	Arteriell		
O2	0,0 L/min		
Notera			
Användare			
Blodgasvärden			
pH	7,315		
pCO_2	9,32	kPa	70 mm Hg
pO_2	6,10	kPa	46 mm Hg
Elektrolytvärden			
cNa^+	145	mmol/L	
cK^+	4,5	mmol/L	
cCrea	172	µmol/l	1.93 mg/dL
cCa^{2+}	1,24	mmol/L	
cCl^-	98	mmol/L	
Metabolitvärden			
cGlu	10,8	mmol/L	194 mg/dL
cLac	1,4	mmol/L	12.6 mg/dL
Oximetervärden			
ctHb	143	g/L	
FCOHb	1,0	%	
FMetHb	0,4	%	
sO_2	76,7	%	
Beräknade Värden			
$cBase(Ecf)_c$	8,4	mmol/L	
$cHCO_3^-(P,st)_c$	29,4	mmol/L	

Arterial Values?
- Arterial blood gas

1-Alpha Disorder?
- **Respiratory acidosis**

2-Compensation?
- Expected SBE if acute = 0
- Expected SBE if chronic:

	kPa	mm Hg
ΔpCO_2	4	30
SBE	12	10

- Unclear

3-Ion Gaps?
- Δ (Na-Cl) = (Na-Cl-34) = 13: compensation for **chronic respiratory acidosis**?
- SBE = Δ (Na-Cl) - Δ AG
- 8 = 13 – 5: **HAGMA**

4-DIFFERENTIAL?

The final step consists of integrating all available information—the past medical history, the history pertaining to the current situation, the medications the patient is taking, the physical findings, all available blood test results—to determine the most likely cause(s) for the acid-base disturbance(s) identified.

Respiratory Acidosis

Pathophysiology	Examples
Decreased respiratory drive	• Structural problem: stroke, hemorrhage, tumors • Drugs, e.g. opioids, alcohol, benzodiazepines, barbiturates • Metabolic encephalopathies, e.g. hepatic encephalopathy • Obesity Hypoventilation Syndrome (multifactorial pathophys.)
Decreased negative intrathoracic pressure	• Degenerative conditions, e.g. amyotrophic lateral sclerosis • Neuropathy, e.g. phrenic nerve paralysis, Guillain Barré SD • Neuromuscular junction, e.g. myasthenia gravis, botulism • Muscular conditions, e.g. myopathies, muscular dystrophy • Skeletal: kyphoscoliosis, ankylosing spondylitis • Pleura: pneumothorax, hemothorax
Decreased air flow	• Upper airway obstruction, e.g. angioedema • Lower airway obstruction, e.g. COPD, life-threatening asthma
V/Q mismatch	• Alveoli: pneumonia, pulmonary edema • Blood vessels: massive pulmonary embolism

Noting whether the respiratory disturbance is acute or chronic can help narrow the differential diagnosis.

An **acute respiratory acidosis** is typically caused by:
- airway obstruction from acute asthma exacerbation or pneumonia
- depression of the central respiratory center from cerebral disease (e.g. trauma) or drugs (e.g. sedatives)

A **chronic respiratory acidosis** is typically caused by:
- chronic obstructive pulmonary disease
- neuromuscular disease (e.g. muscular dystrophy, kyphoscoliosis)

Respiratory Alkalosis

Pathophysiology	Examples
Hypoxia-driven	• Ventilation-perfusion mismatch, e.g. pulmonary edema, pneumonia, pulmonary embolism, aspiration • Intrinsic lung disease • Severe anemia
Non-hypoxia-driven	• Anxiety, pain • Salicylates, methylxanthines (theophyllamine, koffein), nicotine • Pregnancy (progesterone effect on the central nervous system) • Liver cirrhosis (progesterone effect on the central nervous system) • Gram-negative sepsis • Hepatic encephalopathy • Brainstem pathology

Noting whether the respiratory disturbance is acute or chronic can help narrow the differential diagnosis.

An **acute respiratory alkalosis** is typically caused by:
- lung conditions such as pneumonia, pulmonary edema, pulmonary embolism, aspiration
- pain, anxiety, stroke, intoxications (e.g. salicylates)

A **chronic respiratory alkalosis** is typically caused by:
- pregnancy
- hyperthyroidism
- hepatic failure

Metabolic Alkalosis

Pathophysiology		Examples
HCO_3 administration		• Overzealous correction of a metabolic acidosis
H^+ shifts intracellular		• Hypokalemia
H^+ loss	Gastrointestinal	• Vomiting • Chloride wasting enteropathy • Cystic fibrosis • Laxative abuse
	Renal	• Extracellular volume depletion • Diuretic therapy • Renal artery stenosis • Conn's syndrome, Cushing's syndrome • Exogenous mineralocorticoids (e.g. licorice, fludrocortisone)

NAGMA = Normal Anion Gap Metabolic Acidosis

C	Chloride	• Too much chloride "in": NaCl, KCl, CaCl2, NH4Cl, TPN • Falsely elevated chloride (salicylate, bromide, iodide)
R	Renal	• Moderate Renal Failure • RTA type 1, 2, 4
A	Addison's Acetazolamide	• Addison • Acetazolamide
P	Poop	• Diarrhea • Stomy and fistulas

HAGMA = High Anion Gap Metabolic Acidosis

K	Ketones	• Diabetic ketoacidosis • Alcoholic ketoacidosis • Starvation ketoacidosis • Certain toxins (e.g. Salicylate)
U	Uremia	Phosphate and sulphate account for the extra anions
L	Lactate	• L-lactate • D-lactate

T	Toxins	Toxins that do not yield a pure lactic acidosis:
		• Alcohols (toxic):
		  ○ Methanol: formate, L-lactate
		  ○ Ethylene glycol: glycolate, glyoxylate, oxalate, L-lactate
		  ○ Propylene glycol: Pyruvate, L-lactate and D-lactate
		• Aspirin (Salicylates): Pyruvate, L-lactate and ketones
		• Acetamoniphen (chronic): Pyroglutamic acid (5-oxoproline)

L-Lactic Acidosis

L	Liver failure	
A	Accelerated glycolysis	
C	Circulatory failure	Hypovolemic, obstructive, cardiogenic, distributive shock
T	Thiamine deficiency	
A	Anaerobic metabolism	
T	Toxin*	Acute ethanol, CO, CN, iron, Metformin poisoning
E	Ethylene glycol	Falsely elevated lactate by certain point-of-care machines
S	Sepsis	

* "Toxins" that yield a pure L-lactic acidosis: T for Too much ethanol, -ox- for oxidative phosphorylation impairment (carbon monoxide (CO), cyanid (CN), iron), -in for Metformin

Low Anion Gap

Causes		Pathophysiology
L	Lab error	Lab error is the most common cause of low anion gap
	Lithium	Lithium is a cation. Hypercalcemia can also cause decreased AG
	Low albumin	Drop of 10 g/L of albumin leads to an AG drop of 2.5 mmol/L
I	Iodide	Falsely elevated chloride value [10]
M	Myeloma	Positively charged monoclonal IgG
B	Bromide	Falsely elevated chloride value.
S	Salicylates	Falsely elevated chloride value [14-16]

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