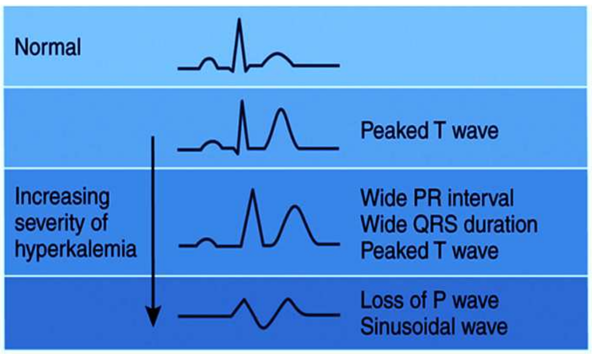
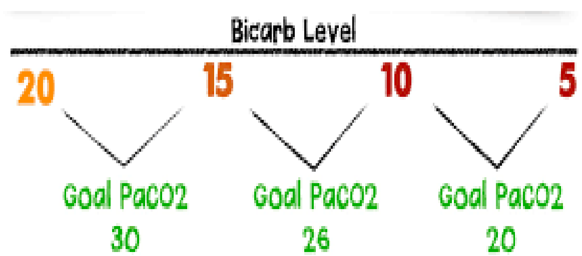
The pH is Metabolic, Now What?

Patrick McDonagh MS. RRT-NPS, ACCS, C-NPT.





1

Disclosures

None To Report

2

Objectives

1.Respiratory Compensation for a Metabolic Acidosis
2.Calculating How much Rate/Volume is Needed

3

What is a RRT's Scope of Practice?

YOU ARE FREE TO KNOW WHATEVER YOU CHOOSE

IT's A SCOPE OF PRACTICE

NOT

A SCOPE OF KNOWLEDGE

4

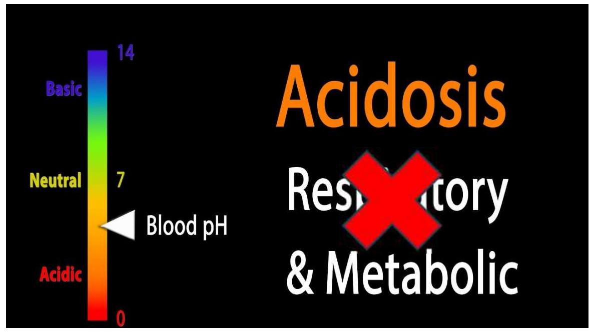
The Negative Effects of an Acidotic pH

Hyperkalemia

Oxygenating the Patient

Hemodynamics

Neurological Patient



Pregnant Patient: Oxygenating Two People

5

Causes of Metabolic Acidosis

G: Glycols, such as ethylene glycol and propylene glycol
O: Oxoproline, a metabolite of paracetamol (acetaminophen)
L: L-lactate, the chemical responsible for lactic acidosis
D: D-lactate
M: Methanol
A: Aspirin
R: Renal failure
K: Ketoacidosis, ketones generated from starvation, alcohol, and diabetic ketoacidosis

- **M**: Methanol
- **U**: Uremia (chronic kidney failure)
- **D**: Diabetic ketoacidosis
- **P**: Propylene glycol, which is used as an inactive stabilizer in many medications
- **I**: Iron overdose, isoniazid (INH), or inborn errors of metabolism
- **L**: Lactic acidosis
- **E**: Ethylene glycol
- **S**: Salicylate

4 Questions to Ask Why?

1. ***Lactic Acidosis***
   Improve oxygenation, Q, Kidney Function
2. ***DKA***
   Control glucose and Insulin levels
3. ***Renal Failure***
   Hydration – Cardiac Output - Failure
4. ***Toxins***
   Stop intake and give antidote – Treat the symptoms

6

Providing Respiratory Compensation: It's Only Temporary

Metabolic Acidosis

MacKenzie Burger; Derek J. Schaller.

Author Information and Affiliations

Authors

MacKenzie Burger; Derek J. Schaller[1].

Affiliations

[1] Central Michigan University

Last Update: July 17, 2023.

Annals of Intensive Care

Springer

Ann Intensive Care. 2019 Aug 15;9:92. doi: 10.1186/s13613-019-0563-2

Diagnosis and management of metabolic acidosis: guidelines from a French expert panel

Boris Jung [1,2], Mikaël Martinez [3,4], Yann-Erick Claessens [5], Michaël Darmon [6,7,8], Kada Klouche [2,9], Alexandre Lautrette [10,11], Jacques Levraut [12,13], Eric Maury [14,15,16], Mathieu Oberlin [17], Nicolas Terzi [18,19], Damien Viglino [20,21], Youri Yordanov [22,23,24], Pierre-Géraud Claret [25], Naïke Bigé [14]; for the Société de Réanimation de Langue Française (SRLF); the Société Française de Médecine d'Urgence (SFMU)

Author information Article notes Copyright and License information

PMCID: PMC6695455 PMID: 31418093

Respiratory compensation is the physiologic mechanism to help normalize a metabolic acidosis, however, compensation never completely corrects an acidemia. It is important to determine if there is adequate respiratory compensation or if there is another underlying respiratory acid-base disturbance.

The aim of ventilation to compensating for a metabolic acidosis is by increasing the minute ventilation while to not to normalize pH. A target pH greater than or equal to 7.15 seems reasonable. Medical treatment of metabolic acidosis and of its cause should be applied, as ventilatory compensation can only be symptomatic and temporary.

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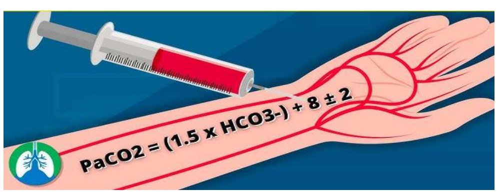
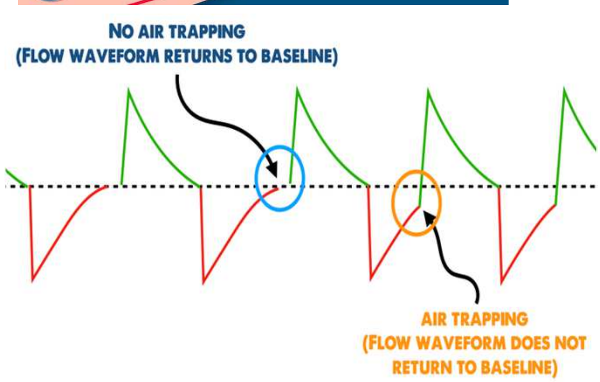
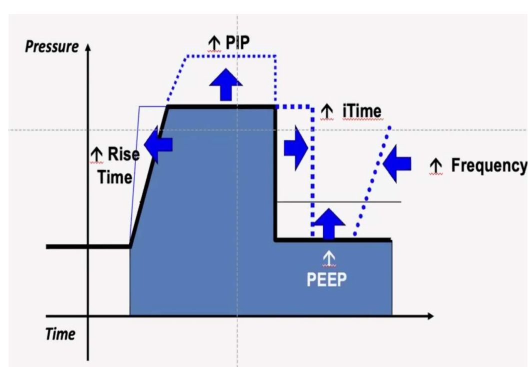
Maximal Respiratory Compensation



Do we Change the RR or VT….
Or Both?





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Should we Target the ETCO2 or the paCO2?

ABG Changes

pH change of 0.08 will move paCO2 10 in the opposite direction

pH 7.30 – paCO2 50

pH change of 0.10 will move K+ 0.6 in the opposite direction

pH 7.30– K+ 5.6

pH change of 0.15 will move HCO3 10 in the same direction

pH 7.25 – HCO3 14

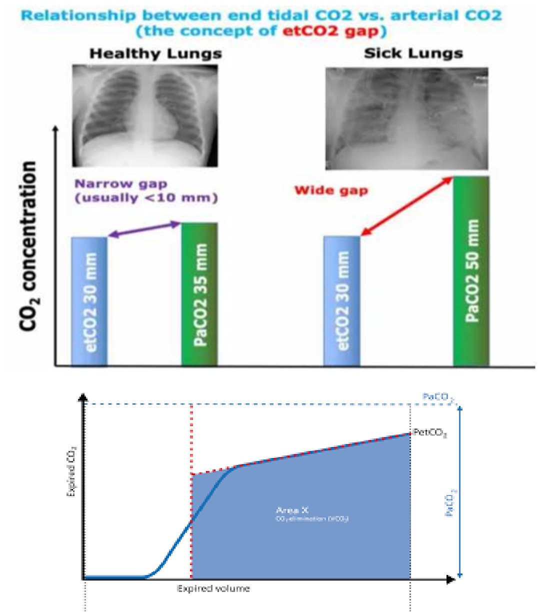
Adjusting The Ventilator

Have-Want Formulas

RR change= (current RR x current paC02) / desired paC02

VT change= (current VT x current paC02) / desired paC02

MV change= (current MV x current paC02) / desired paC02



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The Negative Effects of Acidosis: Hyperkalemia

JASN

J Am Soc Nephrol. 2018 Feb 26;29(5):1411–1425. doi: 10.1681/ASN.2017111163

Mechanism of Hyperkalemia-Induced Metabolic Acidosis

Autumn N Harris[1], P Richard Grimm[2], Hyun-Wook Lee[1], Eric Delpire[3], Lijuan Fang[1], Jill W Verlander[1], Paul A Welling[2], I David Weiner[1,4]

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PMCID: PMC5967781 PMID: 29483157

Hyperkalemia can be the direct cause of metabolic acidosis from its effects on multiple components of renal metabolism.

NIH National Library of Medicine
National Center for Biotechnology Information

Bookshelf   Books   Browse Titles   Advanced

Clinical Methods: The History, Physical, and Laboratory Examinations. 3rd edition.

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Walker HK, Hall WD, Hurst JW, editors.
Boston: Butterworths; 1990.

Contents

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Chapter 195 Serum Potassium

Asghar Rastegar.

A rise in the serum pH (decrease in H^+ concentration) will result in a shift of H^+ out of the cell and potassium into the cell. The reverse occurs during acidemia with a shift of potassium out of the cell

10

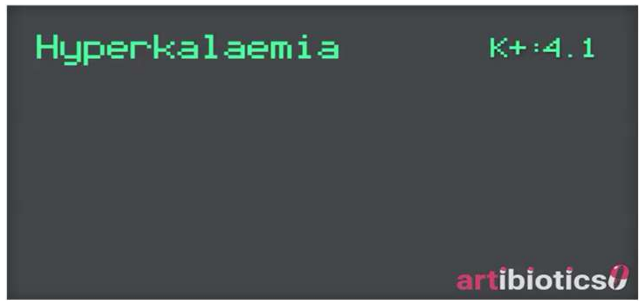
Hyperkalemia Range and Treatment

Normal Range

3.5 to 5 mEq/L

QUESTION
Should We Directly Treat the Hyperkalemia or Fix the Metabolic Acidosis?

- **C**alcium
- **B**eta Agonist and Bicarb
- **I**nsulin
- **G**lucose
- **K**ayexalate
- **D**iuretics/Dialysis



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Albuterol and Hyperkalemia

> Arch Intern Med. 1987 Apr;147(4):713-7.

Potassium-lowering effect of albuterol for hyperkalemia in renal failure

J Montoliu, X M Lens, L Revert

PMID: 3827459

Use of albuterol has been shown to decrease serum potassium levels by 0.3 to 0.6 mEq/L within 30 minutes; the decrease lasts for at least 2 hours. Doses from 10 to 20 mg utilized in hyperkalemia are much higher than those used in management of acute bronchospasm

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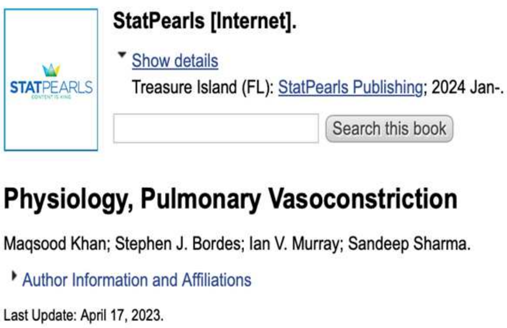
The Negative Effects of Acidosis: Pulmonary Blood Flow


StatPearls [Internet].

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Treasure Island (FL): StatPearls Publishing; 2024 Jan-.

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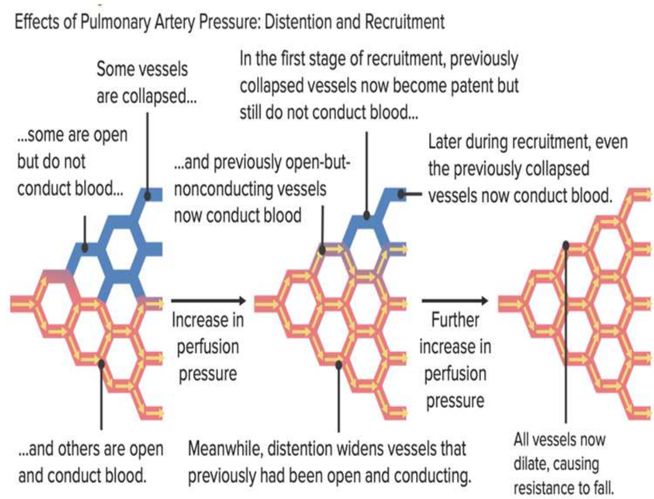
Physiology, Pulmonary Vasoconstriction

Maqsood Khan; Stephen J. Bordes; Ian V. Murray; Sandeep Sharma.

Author Information and Affiliations

Last Update: April 17, 2023.



Acidosis can cause pulmonary vasoconstriction, which is the narrowing of the pulmonary blood vessels.
This is because pH regulates voltage-gated potassium channels in the smooth muscle cells of pulmonary blood vessels.

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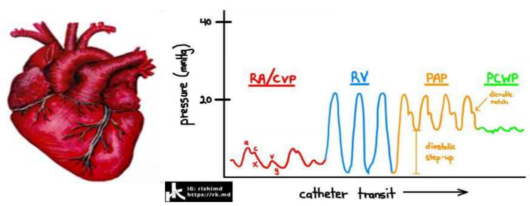
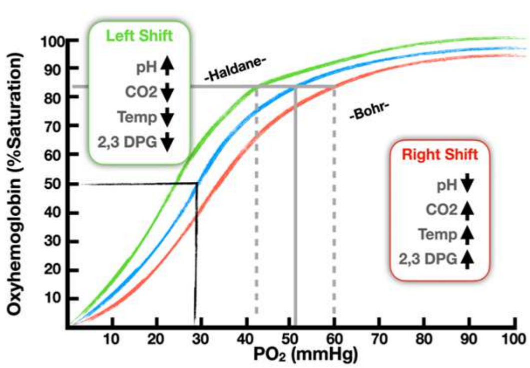
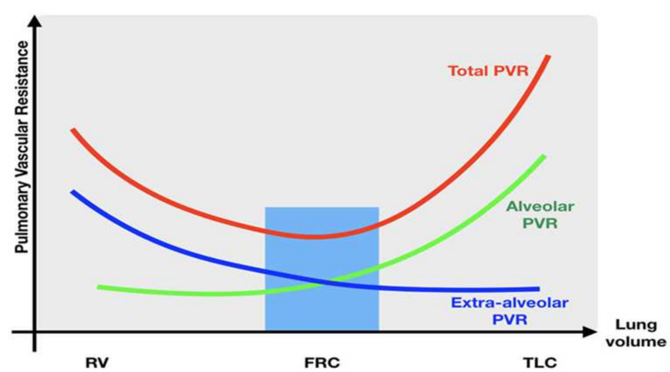
The Negative Effects of Acidosis: Pulmonary Blood Flow



Why would you optimize VT and PEEP for Lung Volumes/Recruitment and allow a metabolic pH decrease pulmonary blood flow by increasing PVR? Then sit and wonder why your Patient is not Oxygenating......





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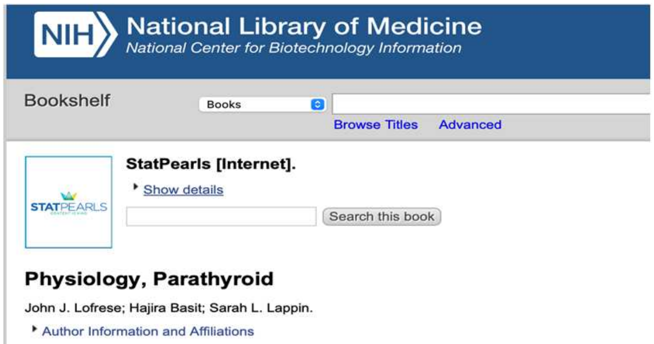
The Negative Effects of Acidosis: Hemodynamics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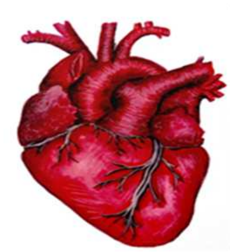
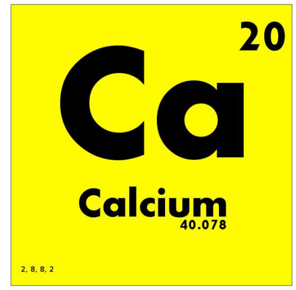
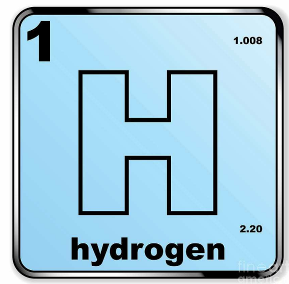
John J. Lofrese; Hajira Basit; Sarah L. Lappin.
Author Information and Affiliations







Ionized calcium, or free calcium, is the biologically active form of calcium necessary for many functions, including cell signaling, neurotransmission***, and muscle contraction*. *At a low pH***, an abundance of hydrogen ions effectively competes with free calcium for binding sites thus increasing free calcium in the serum.

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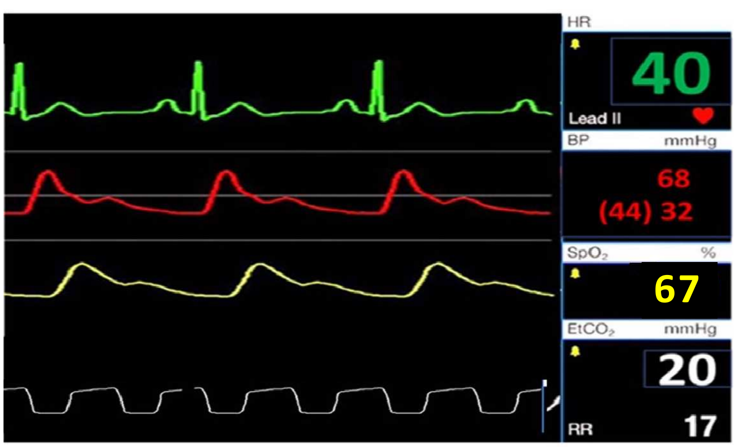
The Negative Effects of Acidosis: Hemodynamics

Patient is not oxygenating and Hypotensive?
Check the pH Level
pH < 7.20 = Decreased Contractility of the Heart




Review > Am J Physiol. 1990 Jun;258(6 Pt 1):C967-81. doi: 10.1152/ajpcell.1990.258.6.C967.

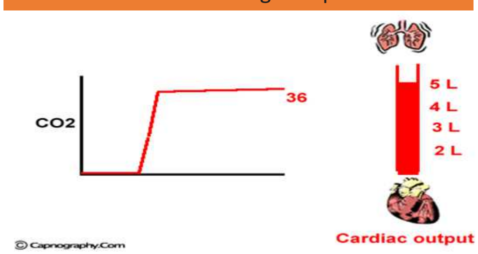
Effects of changes of pH on the contractile function of cardiac muscle

C H Orchard [1], J C Kentish

Affiliations + expand

PMID: 2193525 DOI: 10.1152/ajpcell.1990.258.6.C967

It has been known for over 100 years that acidosis decreases the contractility of cardiac muscle due to small changes of pH levels.



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The Negative Effects of Acidosis: Neurological Patients

> Neurocrit Care. 2024 May 13. doi: 10.1007/s12028-024-01982-8. Online ahead of print.

PaCO$_2$ Association with Outcomes of Patients with Traumatic Brain Injury at High Altitude: A Prospective Single-Center Cohort Study

Eder Cáceres [1 2 3], Afshin A Divani [# 4], Clio A Rubinos [5], Juan Olivella-Gómez [6],
André Emilio Viñan Garcés [6], Ang
Uzma Samadani [8], Luis F Reyes

Affiliations + expand
PMID: 38740704 DOI: 10.1007/s

Acidosis leads to neurological disorders through overexciting cortical pyramidal neurons

ndan He [a], Baozhong Shen [c]

A Metabolic Acidosis can have either a hidden Respiratory Acidosis or Alkalosis

Guidelines recommend maintaining a target paCO2 range between 35–45 mm Hg to prevent cerebral ischemia in the case of low PaCO2 or hyperemia that could lead to **elevated intracranial pressure if PaCO2 is high**

Acidosis in severe disorders of metabolism, kidney and respiration impairs brain function which make the nervous system to be unable to regulate these organs well. **Protecting the brain** function is one of key strategies to block this negative loop.

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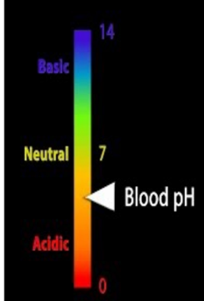
The Negative Effects of Acidosis: Neurological Patients

Hypotension

Oxygenation

pH *(Metabolic Acidosis)*



HOp
KILLERS

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Oxygenating Two People

amhsr Annals of Medical & Health Sciences Research

Ann Med Health Sci Res. 2014 Jan-Feb;4(1):8–17. doi: 10.4103/2141-9248.126602

Maternal and Fetal Acid-Base Chemistry: A Major Determinant of Perinatal Outcome

L Omo-Aghoja [1,✉]

Author information Copyright and License information
PMCID: PMC3952302 PMID: 24669324

When adequate fetal oxygenation does not occur, metabolisms proceed along with an anaerobic pathway with production of organic acids, such as lactic acid. Accumulation of lactic acid can deplete the buffer system and result in metabolic acidosis with associated low fetal pH, fetal distress and poor Apgar score.

Provided to the PMC COVID-19 Collection by Elsevier

EDITORIAL Chest. 2023 Mar 7;163(3):473–474. doi: 10.1016/j.chest.2022.10.025

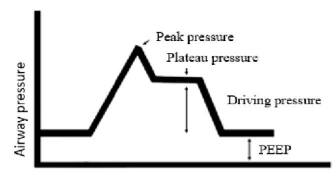
Mechanical Ventilation and Delivery During Pregnancy

Stephen E Lapinsky [a,*], Julien Viau-Lapointe [b]

Author information Article notes Copyright and License information
PMCID: PMC9989325 PMID: 36894256

Goals of MV in obstetric patients

Alveolar protection goals



High Airway Pressures from Increased Pleural Pressure

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ABG Interpretation

pH	**7.28**
$paCO_2$	**24**
HCO_3	**12**

What's your interpretation?
Should we adjust the Rate?
Should we adjust the Tidal Volume?
Should we adjust Both?

Metabolic Acidosis with a **Secondary Respiratory Alkalosis**

Normal HCO3 = 24
Current HCO = 12

Normal paCO2 = 40
Current paCO2 = 24

The paCO2 should decrease approx. the same amount as the HCO3

HCO3
24 (Normal)
<u>- 12</u> (Current)
= 12 (Difference)

RR change= (current RR x current C02) / desired C02

VT change= (current VT x current C02) / desired C02

MV change= (current MV x current C02) / desired C02

Target paCO2
40 (Normal)
<u>-12</u> (HCO3 Difference)
28 is the new paCO2

Adjust Settings to obtain RR of

RR 24 x Current paC02 24
Desired pacO2 28
= New RR 20

20

ABG Interpretation

pH 7.15
$paCO_2$ 34
HCO_3 10

What's your interpretation?
Should we adjust the Rate?
Should we adjust the Tidal Volume?
Should we adjust Both?

Metabolic Acidosis with a **Secondary Respiratory Acidosis**

Normal HCO3 = 24
Current HCO = 20

Normal paCO2 = 40
Current paCO2 = 24

The paCO2 should decrease approx. the same amount as the HCO3

HCO3
24 (Normal)
- 10 (Current)
= 14 (Difference)

RR change= (current RR x current C02) / desired C02

VT change= (current VT x current C02) / desired C02

MV change= (current MV x current C02) / desired C02

Target paCO2
40 (Normal)
- 14 (HCO3 Difference)
26 is the new paCO2

Adjust Settings to obtain VT of

VT 300 x Current paC02 34
Desired paCO2 26
= New VT 392

21

ABG Interpretation

pH 7.15
$paCO_2$ 40
HCO_3 8

What's your interpretation?
Should we adjust the Rate?
Should we adjust the Tidal Volume?
Should we adjust Both?

Metabolic Acidosis with a **Secondary Respiratory Acidosis**

Normal HCO3 = 24
Current HCO = 8

Normal paCO2 = 40
Current paCO2 = 40

The paCO2 should decrease approx. the same amount as the HCO3

HCO3
24 (Normal)
- 8 (Current)
= 16 (Difference)

RR change= (current RR x current C02) / desired C02

VT change= (current VT x current C02) / desired C02

MV change= (current MV x current C02) / desired C02

Target paCO2
40 (Normal)
-16 (HCO3 Difference)
24 is the new paCO2

Adjust Settings to obtain Ve of

Ve 6.3 x Current paC02 40
Desired 24
= New Ve 10.5

22

ABG Interpretation

pH 7.10

paCO2 42

HCO3 16

What's your interpretation?
Should we adjust the Rate?
Should we adjust the Tidal Volume?
Should we adjust Both?

Metabolic Acidosis with a **Secondary Respiratory Acidosis**

Normal HCO3 = 24
Current HCO = 16

Normal paCO2 = 40
Current paCO2 = 40

The paCO2 should decrease approx. the same amount as the HCO3

HCO3
24 (Normal)
<u>- 16 </u>(Current)
= 8 (Difference)

Target paCO2
40 (Normal)
<u>- 8 </u>(HCO3 Difference)
32 is the new paCO2

RR change= (current RR x current C02) / desired C02

VT change= (current VT x current C02) / desired C02

MV change= (current MV x current C02) / desired C02

Ve 6.7 x paC02 42 / 32 = New Ve 8.8

RR 16 x paC02 42 / 32 = New RR 21

VT 420 x paC02 42 / 32 = New VT 550

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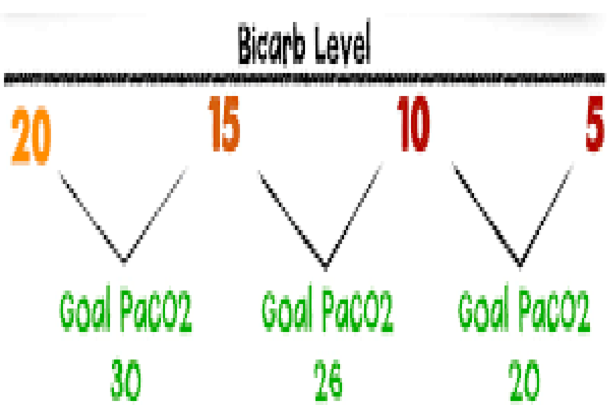
A Visual Reference for Estimation of the paCO2 Goal



Adjusting The Ventilator

Have-want formulas

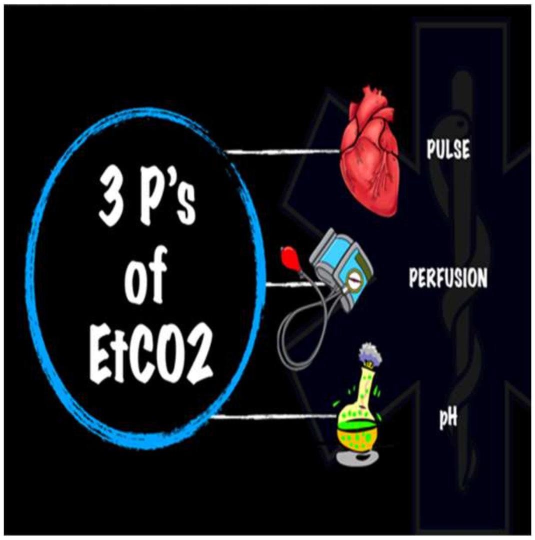
RR change= (current RR x current C02) / desired C02

VT change= (current VT x current C02) / desired C02

MV change= (current MV x current C02) / desired C02

24

3 P's of a Low ETCO2



Decreased ETCO2 – Not Always Respiratory
Patient Dependent

1.Does the Patient have a Perfusing Pulse?

2. Is the Patient's MAP below 65 mmHg?

3. Does the Patient have a Metabolic Acidosis?

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Summary

The Negative Effects of an Acidotic pH

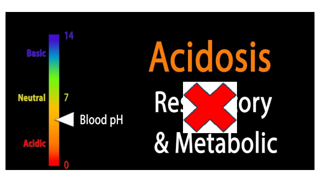
Hyperkalemia

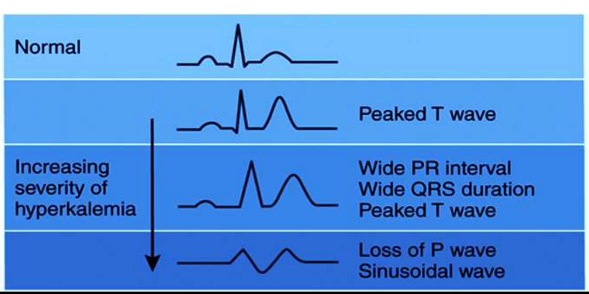
Oxygenating the Patient

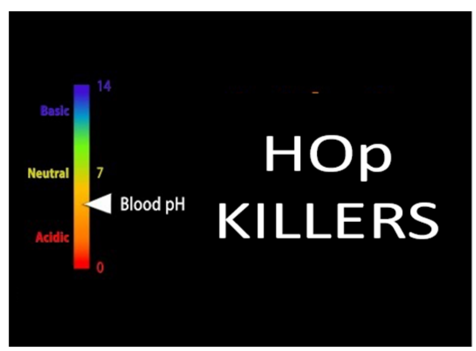
Hemodynamics

Neurological Patient

Pregnant Patient: Oxygenating Two People







Adjusting The Ventilator

Have-want formulas

RR change= (current RR x current C02) / desired C02

VT change= (current VT x current C02) / desired C02

MV change= (current MV x current C02) / desired C02

26