FOUNDATIONS OF ARTERIAL BLOOD GAS INTERPRETATION

Al Heuer, PhD, MBA, RRT
Professor, Rutgers University
Co-Owner A & T Lectures

Learning Objectives:

- ***Understand*** Indications, Complications and Hazards
- Review ***Normal ABG Values***
- Examine ***Steps in Interpreting*** Results
- Review Common ABG ***Abnormalities***
- Perform and Review Some Actual ABG ***Interpretations***
- Examine Some ***Critical Thinking*** Questions
- Provide Some Additional ***References***

Indications for ABGs (Arterial Blood Gases)

- Determine adequacy of ventilation
  - Disorders: Neuromuscular, COPD, “Code”
- Determine adequacy of oxygenation
  - Disorders: ARDS, Pul. Emboli, Pneumonia
- Determine metabolic status
  - Disorders: Kidney Failure, Sepsis, Keto-acidosis, S/P “Code”
- Assess response to therapy or the severity and progression of disease

Contraindications for Arterial Puncture

- Negative Allen's test
- Should not be performed through a lesion or distal to a surgical shunt
- A coagulopathy or medium- to high-dose anticoagulation therapy
- Opened burns
- ***Relative contraindications***:
  - Minor change in therapy whose impact can be monitored via other means.
  - Serial ABG's in the absence of an arterial line.
  - Lack of a valid indication – overly cautious (resident) physician .

Precautions/Complications of Arterial Punctures

- Arteriospasm
- Air or clotted blood emboli
- Anaphylaxis from local anesthetic
- Patient or sampler contamination
- Hematoma
- Hemorrhage
- Trauma to the vessel
- Arterial occlusion
- Pain
- Nerve damage

Pre-Analytic ABG Errors

Error	Effect(s)	How to Recognize	How to Avoid
Air in Sample	lowers PCO2 raises pH raises low PO2 lowers high PO2	-visible bubbles or froth -low PCO2 inconsistent with patient status	-Discard frothy samples -Fully expel bubbles -Mix only after air expelled - Cap syringe quickly
Venous Admixture	raises PCO2 lowers pH can greatly lower PO2	-failure of syringe to fill by pulsations -patient has no symptoms of hypoxemia	-Avoid brachial/femoral sites -Do not aspirate sample -Use short-bevel needles -Avoid artery 'overshoot' -Cross-check with SpO2
Metabolic Effects	raises PCO2 lowers pH lowers PO2	-Excessive time lag since sample collection -Values inconsistent with patient status	-Analyze quickly -Place sample in ice slush

Normal Values

- Normal Values:
  - pH = 7.35 – 7.45
  - pCO_2 = 35 – 45 torr
  - pO_2 = 80 – 100 torr
  - HCO_3 = 22 – 26 mEq
  - BE = -2 - + 2
  - SO_2 (calculated via PO_2-above) 95-100%
- Typical Representation in Chart (Normal ABG)

  7.40 / 41 / 92 / 23 / 1

How to Interpret ABG

- Evaluate (In this Order):
- Acid-Base Balance
  - 1st - pH: Normal, Acidotic, Alkalotic
  - 2nd - PCO2: Normal, Acidotic, Alkalotic
  - 3rd - HCO3 & BE: Normal, Acidotic, Alkalotic

- Oxygenation
  - PO2, Hb Sat: Normal, Hypoxemic, Hyperoxia

Assessment of pH

- Refers to hydrogen ion (H^+) levels which indicates if the patient is acidotic or alkalotic, indicated by the pH.
- Normal Value: 7.35 – 7.45
- Less than 7.35 = Acidosis
  - Respiratory if $PCO_2 > 45$ torr
  - Metabolic if $HCO_3 < 22$ mEq
- Greater than 7.45 = Alkalosis
  - Respiratory if $PCO_2 < 35$ torr
  - Metabolic if $HCO_3 > 26$ mEq

Assessment of PCO2

- Normal Value: 35 – 45 torr
- Abnormalities
  - PCO2 > 45 torr (CO2 retention/hypoventilation/**acidotic**)
  - PCO2 < 35 torr (hyperventilation/**alkalotic**)
- pH can be normal with high PCO2 if kidneys compensate by retaining HCO3 (> 26 mEq)
  - Example: **pH 7.35; PCO2 58; HCO3=32**
  - Interpretation: fully compensated respiratory acidosis

RESPIRATORY ACIDOSIS--AKA Hypercapnia

Caused by increased CO_2 levels which is then converted to an acid.

Examples:

Hypoventilation

Presence of sedatives/sedation/opiates

Central Nervous System (CNS) depression

Pneumonia

Pulmonary edema

Asthma

Iatrogenic causes--

- Setting minute ventilation or tidal volume too low
- Failure to Initiate Appropriate Therapy- NIPPV/BiPAP

Respiratory Alkalosis: AKA Hypocapnia

Definition: a decreased amount of carbon dioxide in the blood.

Potential causes:

- **Patient Hyperventilation** - due to pain, fever, anxiety, brain injury.
- **Iatrogenic Causes: Inappropriate vent settings** e.g. excessive tidal volume (VT) or respiratory rate (f) during mechanical ventilation.

A Word about Capnography

- ***Capnography***- Analysis of waveform (and often numeric value) of exhaled CO_2
  - ***Capnometry***- Measuring the numeric value of exhaled CO_2
- Can be used as a surrogate for PCO_2
- Normal values
  - Normal $EtCO_2$ is 30-43mmHg
  - Normal $PaCO_2$ is 35-45mmHg

Assessment of Metabolic Status (Bicarbonate/HCO3-)

- Normal Value: 22-26 meq
  - Metabolic Acidosis: If HCO3 < 22 mEq and not a compensatory mechanism
  - Metabolic Alkalosis: If HCO3 > 26 mEq and not a compensatory mechanism
- Base Excess (BE) is a function of HCO3
- Normal BE + 2 to -2 if HCO3 normal

Causes of imbalance

METABOLIC ACIDOSIS

Caused by either an increase in acids and or a loss of base (HCO3).

Example:

Diarrhea (loss of base)

Renal failure (unable to excrete acids or H+)

Lactic acidosis (increase in acids)

Ketoacidosis (increase in acids)

Causes of imbalance

METABOLIC ALKOLOSIS

Can be caused by an increase in HCO3 or loss of metabolic acids.

Examples:

Prolonged vomiting (acid loss)

GI suctioning (acid loss)

Hypokalemia (excreted to maintain electrolyte balance)

Compensation

Acid Base Disorder	Initial Change	Compensatory Response
Respiratory Acidosis	**↑ PCO2**	**↑HCO3-**
Respiratory Alkalosis	**↓ PCO2**	**↓ HCO3-**
Metabolic Acidosis	**↓ HCO3-**	**↓ PCO2**
Metabolic Alkalosis	**↑ HCO3-**	**↑ PCO2**

Compensation is Not Absolute

- Can be:
  - Uncompensated
  - Partially Compensated
  - Fully Compensated
- Uncompensated:
  - pH is always ***abnormal*** with:
    - Elevated PCO2 with a normal HCO3 scenario
      - AKA uncompensated respiratory acidosis
    - Decreased HCO3 and a normal PCO2
      - AKA uncompensated metabolic acidosis
    - Similar phenomenon for alkalosis

Partial Compensation

- Partially Compensated
  - ***pH is always abnormal*** with ***either:***
    - ***Primary disturbance is an abnormal PCO2***
      - HCO3 is also abnormal but ***only to compensate*** for the primary abnormality.
      - ***Partially Compensated Respiratory Acidosis***: pH=7.30, PCO2=63, HCO3 31 (e.g., COPD exacerbation, ***early*** permissive hypercapnea)
      - Or, ***Partially Compensated Respiratory Alkalosis***: pH-7.51, PCO2=27, HCO3= 20 (e.g., inadequately treated pain or anxiety)

Or

-
  -
    - ***Primary disturbance is an abnormal HCO3***
      - PCO2 is also abnormal but ***only to compensate*** for the primary abnormality.
      - ***Partially Compensated Metabolic Acidosis***: pH=7.30, HCO3 15, PCO2=25 (e.g., DKA, Renal insuff.)
      - Or, ***Partially Compensated Metabolic Alkalosis***: pH-7.51, HCO3= 30, PCO2=49 (e.g., electrolyte disturbance)

Full Compensation

- Fully Compensated
  - ***pH is always Normal*** with ***either:***
    - Primary disturbance is an abnormal PCO2 where HCO3 is also abnormal but ***only to compensate*** for the primary abnormality.
      - ***Fully compensated Respiratory Acidosis***: pH=7.36, PCO2=53, HCO3 31 (e.g., COPD Steady State, permissive hypercapnea)
      - Or, ***Fully Compensated Respiratory Alkalosis***: pH-7.44, PCO2=30, HCO3= 20

Or

    - Primary disturbance is an abnormal HCO3 where PCO2 is also abnormal but ***only to compensate*** for the primary abnormality.
      - ***Fully Compensated Metabolic Acidosis***: pH=7.36, HCO3 18, PCO2=30
      - Or, ***Fully Compensated Metabolic Alkalosis***: pH-7.45, HCO3= 30, PCO2=49

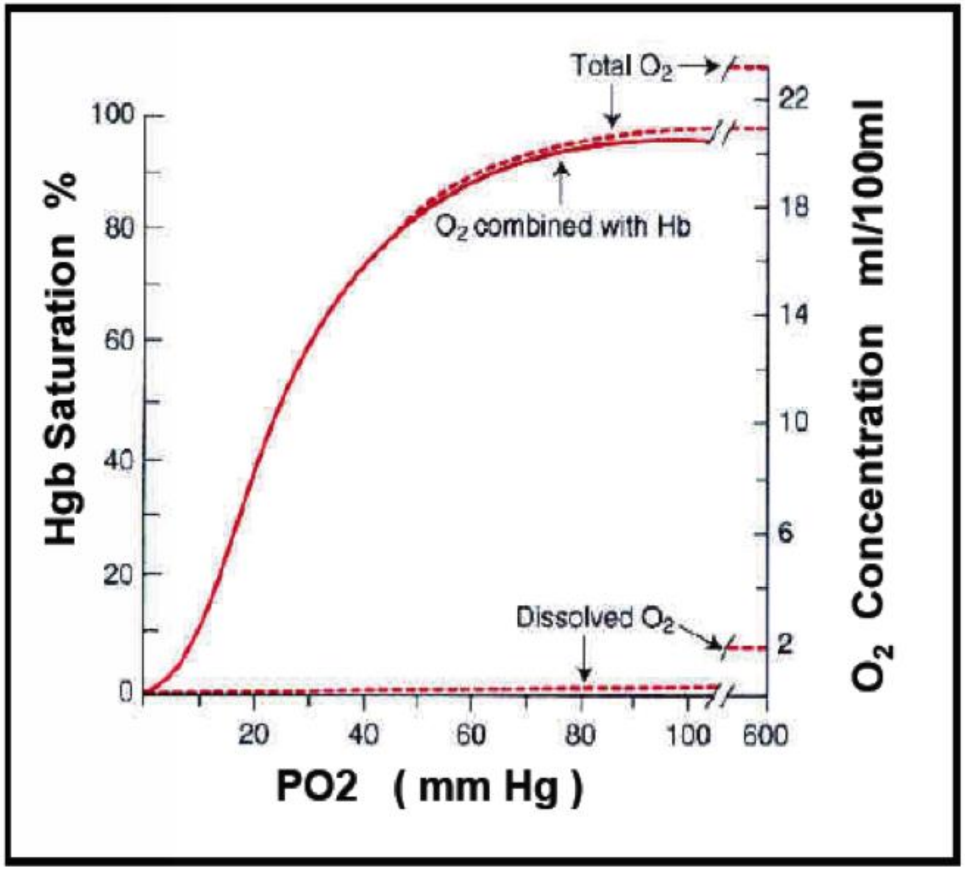
Assessment of Oxygenation: PaO_2 AKA PO_2

- Normal Value PO_2 = 80-100 torr
- Hypoxemia: If PO_2 < 75-80 torr –
  - Mild: PO_2 65-79 torr on room air
  - Moderate: PO_2 50-64 torr
  - Severe: PO_2 < 50 torr
- Hyperoxia: If PO_2 > 100-120 torr
- Example:
  - pH 7.30; PCO_2 55; HCO_3 24; BE +1; PO_2 58
  - Interpretation: uncompensated respiratory acidosis with moderate hypoxemia

What is PaO_2?

- The amount of oxygen dissolved in the plasma, not what is bound to HgB.
- The majority of oxygen is bound to HgB and expressed as SaO2
  - Approximated via SPO2 (pulse oximetry).
- ***So what's the big deal about PaO2?!***
- Because, there is a nicely defined relationship between PaO2 (dissolved in Plasma) and SaO2 (bound to HgB)
  - Oxyhemoglobin Disassociation

Oxygen Dissociation Curve



O_2 binding with hemoglobin

Amount of O_2 in blood

Dissolved O_2 negligible

Most O_2 on hemoglobin

PO_2 > 100 mmHg saturated

Pulse Oximet

Note: O_2 concentration = ml O_2 / 100 ml blood **C_aO_2**

O_2 saturation = % of maximum **S_aO_2**

Putting it Together
Example 1: Assessment of Oxygenation

- pH 7.30; PCO2 55; HCO3 24; BE +1; PO2 58
- Interpretation: uncompensated respiratory acidosis with moderate hypoxemia
- Why?

Example 2: Assessment of PCO2

- pH 7.35; PCO2 58; HCO3=32

- Interpretation: fully compensated respiratory acidosis

- Why?

Example 3: Metabolic Status ($Bicarbonate/HCO_3^-$)

- pH 7.25;PCO2 40;HCO3 16; BE -8
- Interpretation: uncompensated metabolic acidosis
- Why?

Add'l ABG Interpretation Examples

- pH 7.45; PCO2 39; HCO3 24; BE 0; PO2 88
  - Interpretation: normal ventilation and oxygenation
- pH 7.28; PCO2 58; HCO3 26; BE +2; PO2 65
  - Interpret: uncomp. resp. acidosis w/ mild hypoxemia
- pH 7.52; PCO2 28; HCO3 24; BE 1; PO2 53
  - Interpret: uncomp. respiratory alkalosis w/ moderate hypoxemia
- pH 7.22; PCO2 36; HCO3 17; BE -6; PO2 98
  - Interpret: uncomp. metabolic acidosis w/ normal oxygenation

Case 1

- A 70 Kg (PBW), 35 YO male was intubated and placed on a ventilator one hour ago with the following settings:
  - AC-VT=480, RR=16, FIO2=60% and +5 PEEP.
- An ABG results are:
  - pH=7.32-PCO2=52-PO2=62,HCO3=26, BE=+1.
- What is the ABG interpretation?
- What vent setting changes would you recommend and why?

Case 2

- A 50 Kg female admitted for a COPD exacerbation was intubated and placed on a ventilator one hour ago with the following settings:
  - AC-VT=550, RR=16, FIO2=50% and +5 PEEP.
- An ABG results are:
  - pH=7.50 - PCO2=43 - PO2=70 - HCO3=32 - BE=+7.
- What is the ABG interpretation?
- What vent setting changes would you recommend and why?

Case 3

- The COPD patient from Case 2 now has a resolving pneumonia is weaning well on +6 PSV with a RSBI of 72. The morning ABG shows the following:
  - pH 7.41, Pa_{CO_2} 51, Pa_{O_2} 70, HCO_3 30, BE 0, on F_{IO_2} of 0.35.
- What is the ABG interpretation?
- What would you recommend regarding weaning and extubation and why?

Case 4

- A 45 YO male neuromuscular patient is receiving continuous BiPAP with settings of 10/5 and 60% FIO_2.
- The ABG on these settings is: pH 7.30- PCO_2 55- PO_2 55- HCO_3 30 – BE +5.
- What is the ABG interpretation?
- What would you recommend regarding BiPAP settings changes and why?

Case 5

- A nurse, respiratory therapist and PA respond to an RRT call in step-down. You immediately note that the patient appears obtunded, diaphoretic, cyanotic, RR = 40, HR = 155, pulse is thready and BP=80/42. The resident physician orders a NRB and a stat ABG.
- What is additional or alternative recommendations do you have?

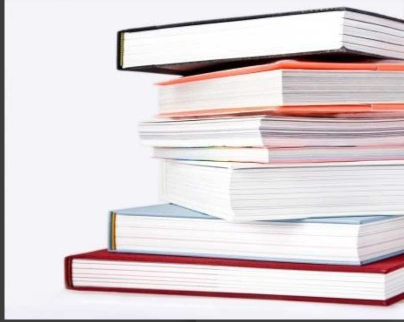
Case 6

- It is the winter and a female patient is admitted to the ICU with suspected CO poisoning due to a furnace malfunction. Her cheeks are flushed and she has difficulty focusing and answering your questions. She is on a high-flow system with an F_IO_2 of 100%. The pulse oximeter, reads 99%. No ABG have been drawn as yet, and the resident asks if you think one is needed.
- What should be your response, and why?

Take Home Messages

- When indicated, ABG’s can be an extremely useful diagnostic tool.
- However, they should be done judiciously
  - They are invasive and have potential hazards.
  - They are resource intensive.
  - They can be supplemented with less/non-invasive modalities (ETCO2, SPO2).
- Becoming proficient in interpreting ABG’s takes time and effort.
- There are many resources available, (including your local RT), so use them!!!

Selected Resources



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