OXYGEN BASICS

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Disclosure

- UTHSCSA
- No other financial or commercial affiliations

Objectives

- This is a ‘entry’ level lecture about some key points about the clinical use of oxygen
- Appropriate for MS, residents, RTs, and health care personnel who provide oxygen to patients
- At end of this talk, the listener should be able to
  - Define “Respiration”
  - Describe the transport of O2 in the human body
  - List several variables that may affect the amount of oxygen available for respiration
  - To get a general understanding of the variables, not to learn all the formulas and little details (that will happen during the pulmo rotation)

BUT IN REALITY IT WILL SUFFICE IF YOU TAKE HOME 3 KEY MESSAGES

FOCUSING SCENARIOS

FIRST ONE
Normal ABG

pH: 7.40 (7.35-7.45)
pCO2: 40 mmHg (35-45 mmHg)
pO2: 100 mmHg (80-100 mmHg)
HCO3: 24 mEq/L (21-28 mEq/L)
B.E. -2 to +2 mEq/L

Now Imagine

• You arrive to the intensive care unit and have a patient with narcotic overdose recently placed on a ventilator with good breaths and you are giving FiO2 100% O2, sats are at 100%
• ABG is
  pH: 7.40
  CO2: 40 mmHg
  PaO2: 250 mmHg
  HCO3: 26

R these values OK?

SECOND SCENARIO

Make a Wish

• You have a patient with a bad lung condition (CF, fibrosis, cancer, etc) and the patient is on the ward on 4 lpm O2 NC and sats @ 90%. Stable for the last few weeks.
• Final wish is go to Hawaii and bite the dust there. Expected demise in 2-3 months.
• Has plane tickets to Hawaii for next week (SA→Hou→Island).

THIRD SCENARIO

Make a Wish

• Any recommendations for the trip?
  a. Bring a souvenir?
  b. Call the airline to make sure she takes a commercial flight- approved oxygen device?
  c. Galveston not good enough?
  d. Exchange the plane tickets for cruise ship tickets?
JOY RIDE

You and your friends are going for a balloon ride.
You want to go as high as you can.
For this, you prepare with an oxygen tank and a non-rebreather mask (also with good clothes and just in case, a parachute)
Is this enough for your oxygen requirements?

Oxygen Tubing

You have a patient at home with a large oxygen tank.
He is takes 3 lpm per NC
He likes to piggyback the oxygen tubing, so he can walk all around the house without dragging the tank.
He has 300 feet of tubing
Is that bad??

Know this Guy?
Oxygen

- We all seen these hook ups for oxygen.
- When you turn the knob
What comes out:
  a. 100% O2 at the dialed lpm?
  b. 21% O2 that needs to go through a concentrator?
  c. O2 % depends on the device attached at the end of hose
  d. O2 % depends on the number dialed
  e. Compressed air that needs to be brought up to 100% O2

Areas to be Reviewed

Atmosphere

- No definite boundary with outer space
- Most of it (75%) contained on the first 10-11 miles

For practical purposes, all over the world:
  • 21% O2 & 79% N2.
  • So, room air (RA) = 21% O2.
  • If one is breathing RA, then FiO2 = 21%.

The “Hook-ups”
The “Hook-ups”

- What comes out when you turn open the knob of the green hook up (O2)?
- 100% O2 at the number of lpm indicated by the little ball

- And for these devices?
- O2 @ the % dialed & @ the # lpm dialed

Clinical Application

Easy Question:
How much oxygen is being given?

Easy answer:
As many lpm as the valve indicates

Not so easy Question:
What’s the FiO2 for these patients?

The answer requires some math, a table or chart, experience, or amazing guessing. Let’s take a very quick view.

Assumptions

- O2 NC @ 2 lpm
- Pt wt = 70 kg
- TV = 500 cc
- RR = 12 l:1:2
- 1 s in, 2 s exh
- 1 l 500 cc inspired
- NC 2lpm-3lpm/lb
- >24/lb @ >35cc/sec
- TV 500 cc
- 21%/O2=105cc
- 79%/N2=395cc

Simple Chart for Adults
when using NC

<table>
<thead>
<tr>
<th>Flow (Lpm)</th>
<th>% O2</th>
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<tbody>
<tr>
<td>1</td>
<td>24%</td>
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<td>2</td>
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</table>

TV 500 cc
21%/O2=105cc
79%/N2=395cc
3.15cc O2TV + 17.5cc O2NC
21 cc of O2
Out of 15 = High %
-94/22 @ ~ High

Common Chart for Adults
when using NC

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Oxygen Devices
Short Summary

- **O2 concentration in the atmosphere is 21%**
- **O2 at “room air” (RA) is 21%**
- **FiO2 is the inspired fraction of O2 in the TV**
- **@ RA, FiO2 = RA = 21%**
- **For adults and as a general rule, NC increases 3% FiO2 for each lpm, but, for the pediatric population this is not the case**
- **There are many oxygen delivery devices; keep in mind the characteristics of the most common ones**

O2 Transport

- **We have reviewed O2, RA, FiO2, and oxygen delivery devices**
- **Now let’s review other terms: atmospheric pressure, PAO2, PaO2, and hemoglobin dissociation curve**

Atmospheric Pressure

**Commercial Plane Traveling**

Do passengers get enough oxygen?

By Robert Davis, USA TODAY

As the number of reported heart attacks, tinnitus, and other medical emergencies aboard airlines continues to soar, the government is considering changing the way cabins are pressurized to provide more oxygen to passengers. The Federal Aviation Administration and scientists across the industry are reevaluating a standard that was set decades ago and based on studies of healthy passengers in altitude chambers. The modern airplane cabin is very different, as aging travelers—many with health problems that can worsen suddenly and sometimes fatally—fly farther and longer than ever before.

Atmospheric Pressure

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How do we use these values clinically?

The alveolar gas equation helps estimate the PAO2 and from there we can estimate the arterial pressure as it should be within 5-10 mmHg at RA (100-150 @ 100% FiO2)?

Formula: (FiO2 * [AltPress – H2O]) – minus PCO2/RQ

Normal: (0.21 * [763 – 50]) minus 40 / 0.8 = 100 mmHg

Then our PaO2 should be 90-100 mmHg at sea level (760 mmHg)

And how is this related to hemoglobin saturation?
Alveolar Pressures

Sea Level = ~ 100 mmHg
(0.21*760-50) ~ (40/0.8)

Denver = ~ 72 mmHg
(0.21*630-50) ~ (40/0.8)

Mt Everest < 30 mmHg
(0.21*253-50) ~ (40/0.8)

On 100% FiO2 here in SA > 550 mmHg
(1.00*760-50) ~ (40/0.8)

Keep in mind
30 mmHg à 50%
60 mmHg à 90%

Worked Case
Make a Wish: Hawaii

• Scenario: Pt on 4 lpm O2 NC with 90% sats
• Assumptions: TV 500 cc in 1 s Insp.
• FiO2?
  – 4 lpm is 4000/60 is ~ 67 cc/sec.
  – 500cc is 105 cc of O2 (21%) + 395 ccN2.
  – 105cc (21%) + 67cc (NC @ 4 lpm)=172
  – 172 cc O2 of 500 is around 35% O2. FiO2=0.35
• Alveolar Equation
  \[ PA = \left[ FiO2(AP-H2O) \right] - \frac{CO2}{RQ} \]
  \[ PA = 0.35(760-50) - 40/0.8 \]
  à ~ 200 mmHg

Assumption from the Alveolar Equation

PA = 0.35(760-50) - 40/0.8
à ~ 200 mmHg
Assumption from the Hbg dissociation curve
At 90% there should be ~60 mmHg PaO2

There seems to be an A-a gradient of 140 mmHg (200-60). Therefore we need to keep the same PA while the atmospheric pressure is reduced in the plane (lets assume 550 to be safe, as 565 mmHg is the minimum by FAA).

Assumption from the Hbg dissociation curve
At 90% there should be ~60 mmHg PaO2

50% O2? How?

• Tough!
• You will need several big tanks.
• NC won’t do it
• A Partial rebreather mask will do
• Try to get that by the FAA and United, American, etc.
• Good Luck!!!!

Length of Tubing

• Remember the Hagen-Poiseuille (pwa-uh-zuh-ee) Law/Equation
  \[ \Delta P = \frac{8nlV}{\pi r^4} \]
  – \( \Delta P \) → Pressure difference
  – n → Viscosity
  – l → length of pipe
  – V → flow rate
  – r → radius of pipe

Hagen-Poiseuille

• \( \Delta P = \frac{8nlV}{\pi r^4} \)
• Then length matters
• But for practical purposes, if the tubing is less than 100 ft, things should be OK
ANOTHER CASE

100% O2?

• You arrive to the intensive care unit and have a patient with narcotic overdose recently placed on a ventilator with good breaths and you are giving FiO2 100% O2, sats are at 100%
• ABG:
  – pH: 7.40
  – CO2: 40
  – PaO2: 250 mmHg
  – HCO3: 26
• Is this OK?

100% O2

• According to the alveolar gas equation, somebody on 100% O2 should have a PaO2 of
  → (1*(763-50)) - (40/0.8) → ~660 mmHg
– Above 550 should be OK
– And the PA should closely match the PaO2
• If your patient’s PaO2 is 250, then there is severe lung disease
• This the main use of the alveolar equation
  – To predict & assess pts in different clinical conditions
  • During illness
    • And during activity, such as climbing or space activities

Predictions

• 1875
  • Gaston Tissandier, Joseph Croce-Spinelli and Théodore Sive.
  • Set to break the altitude record
  • Joe and Theo died
  • Gaston with mental damage
• What was the predicted PaO2 and sats at that altitude?
  • PA= (0.21*(270-50)) - (7/0.8)
  • Sats: ~25%

The Jump

2012 Felix Baumgartner
80 km (50 miles)
– Blast speed of sound
– Alt pressure at 5.1 psi
  – 1.5 psi = 140 mmHg
– World’s highest jump
  → (7*140) - 50 = 80
– Sats on the 30s! Sats: ~30%

Mt Everest

2012 Felix Baumgartner
80 km (50 miles)
– Blast speed of sound
– Alt pressure at 5.1 psi
  – 1.5 psi = 140 mmHg
– World’s highest jump
  → (7*140) - 50 = 80
– Sats on the 30s! Sats: ~30%
8,850 m (29 k ft)
250 mm Hg
Pa\textsuperscript{-}FiO\textsubscript{2}\textsuperscript{-} (Atm - H\textsubscript{2}O) – (CO\textsubscript{2}/RQ)
PA = 0.21 \times (250 - 50) - \frac{40}{0.8}
PA = VERY LOW
Compensation: Hyperventilation with respiratory alkalosis
Pa\textsubscript{O\textsubscript{2}} should be close to PA\textsubscript{O\textsubscript{2}}, if not, there is a problem somewhere (lungs? Heart? Other?)
30 mmHg \rightarrow 50\% and 60 mmHg \rightarrow 90\%
Patients with chronic lung disease who need oxygen (and others) should be assessed before traveling on planes or to high altitude cities
Bear in mind the variables of the alveolar equation: atm pressure, FiO\textsubscript{2}, and CO\textsubscript{2}

Finally, and very briefly
HEMOGLOBIN

OUTSIDE VIDEO SOURCE

Hemoglobin

\[ \text{Hb} = 2\alpha + 2\beta \text{ subunits} \]
- Haldane:
  - Tissues: CO\textsubscript{2} pickup facilitates O\textsubscript{2} release
  - Lungs: O\textsubscript{2} loading decreases CO\textsubscript{2} release
- Bohr:
  - Tissues: O\textsubscript{2} release facilitates H\textsuperscript{+} pickup
  - Lungs: O\textsubscript{2} pickup facilitates H\textsuperscript{+} release
- 2,3-DPG:
  - high releases O\textsubscript{2} from the 2\beta subunits first
  - The 2,3-DPG at tissue binds the 2\beta
  - DPG binding changes the shape of Hb
  - This allosteric change promotes the release of O\textsubscript{2} to the 2\beta subunits
  - W/o DPG, 45% at 55\% efficiency (low mangnitude)
- “Live high, train low”
  - High: O\textsubscript{2} loading, DPG, etc
  - Low: longer peak levels when training

https://www.youtube.com/watch?v=5LjLFrmKTSA
"Oxygen Transport from Lungs to Cells" 10/2013

OUTSIDE VIDEO SOURCE

http://faculty.etsu.edu/currie/hemoglobin.htm
Hyperbaric Chamber

- 98% of O2 carried by Hgb
- \((\text{Hgb} \times 1.34 \times \text{Hgb}) + (\text{PaO2} \times 0.3)\)
- Arterial (97-100% sats)
  - \(100 \times 1.34 \times \text{Hgb} = 83.5 \text{ ml/dl}\)
- Venous O2 saturation
  - \(90 \times 1.34 \times \text{Hgb} = 51.4 \text{ ml/dl}\)
- Oxygen Content (CaO2)
  - \(15 \times 1.34 \times \text{Hgb} = 20.10 \text{ ml/dl}\)
  - \(\text{PaO2} \times 0.003 = 0.3 \text{ ml/dl}\)

Venous CvO2 (60-80% sats)
- \(80 \times 1.34 \times 15 = 16.08 \text{ ml/dl}\)
- \(45 \times 0.003 = 0.14 \text{ ml/dl}\)

Oxygen Consumption (VO2)
- \(\text{CaO2} - \text{CvO2} \approx 5 \text{ ml/dl} \times \text{Cardiac Output}\)

The amount of oxygen needed could be supported in a hyperbaric chamber (2-6 atm) just with the oxygen that is diluted. No Hgb needed!

At 6 atm \(\times 760 = 4,560 \text{ mmHg}\)
- \(4,560 \times 0.003 = 14.14 \text{ ml/dl}\)
- At 3 atm \(\times 760 = 2,280 \text{ mmHg}\)
- \(2,280 \times 0.003 = 7.07 \text{ ml/dl}\)

Short Summary

- Hgb is the major carried of O2
- Allosteric effects: Haldane, Bohr, and 2,3 DPG
- Hyperbaric chambers can provide a great amount of dissolved O2 due to the increased pressure.

FINALLY

ABG Interpretation Nomogram

AND THAT’S IT!
Now to the final summary

Final Summary

- 21% of O2 in the atmosphere
- But pressure varies and it affects the real amount of oxygen available
- The alveolar equation is an important formula to develop clinical predictions
- There are many oxygen delivery devices, familiarize with them.
- Hemoglobin is affected by allosteric changes: Haldane, Bohr, and 2,3 DPG
- You may use an ABG nomogram while you get used to interpret gases

Acid-Base Nomograms

Use these little graphs to figure out if your patient is in:
Chronic or Acute
Respiratory or Metabolic
Acidosis or Alkalosis

AND THAT’S IT!
Now to the final summary
Take Home Points

- The larger the tidal breath, the lower the FiO2 provided by NC. One lpm is not the same in a neonate, a child or an adult.
- If you have two patients on 100% FiO2 and the saturation of both is 100%, that doesn’t mean that the lungs are OK. Pa of 100 vs Pa of 500 mmHg
- Keep in mind the atmospheric pressure when taking decisions about O2 in planes or going to other cities. Use the alveolar equation \( PAO_2 = (FiO2 * (AtmPress – H20)) - PCO2/RQ \)

Thanks!!

Oxygen Basics
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