Vent II Introduction to Ventilator Management

- Medical Practice Improvement Project
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Disclosures

- None

Learning Objectives

- 1. Learning the difference between time cycle and volume cycled ventilation
- 2. How to adjust the ventilator to compensate for high PCO2
- 3. Management strategies improve oxygenation
- 4. Evaluation of ABG

Modes of Ventilation

- Volume-cycled ventilators:
  - Gas flows to the patient until a preset volume is delivered to the ventilator circuit, even if this entails a very high airway pressure.
  - Individuals require mechanical ventilation for different reasons.
  - Examples:
    - Assist Control (A/C)
    - Synchronized intermittent mandatory ventilation (SIMV)

Modes of Ventilation

- **Pressure Control Ventilation (PCV) is a mode of mechanical ventilation where:**
- The ventilator controls all phases of the breath based on set parameters
- Breath delivery is at a set inspiratory pressure, optimizing oxygenation and reducing barotrauma risk
- The pressure remains constant, but the volume of air delivered can change based on lung compliance and airway resistance
- It is used to regulate pressures applied during mechanical ventilation

How to Correct CO_2 and PaO_2

Oxygenation

- Increased by increasing Fi02
- Mean Airway Pressure
- Peep

Carbon Dioxide Clearance

- Increasing TV
- Increasing Rate
- (increased Minute Ventilation)

Setting the Ventilator Settings

- Volume Cycled Ventilation
  - **Tidal Volume** is set at less than 10 ml/kg for ideal body wt
    - Lung protective strategy is 6-8 ml/kg for ideal body wt
  - **Respiratory rate** : 10-20 BPM
  - **Fio2** starts at 100% and titrates down
  - **Peep** Starts at 5 cm of water and titrated up
  - **Pressure support** starts at 10 cm of water and titrates up for SIMV Ventilation

SIMV VS A/C = Same mode of ventilation at High Rate

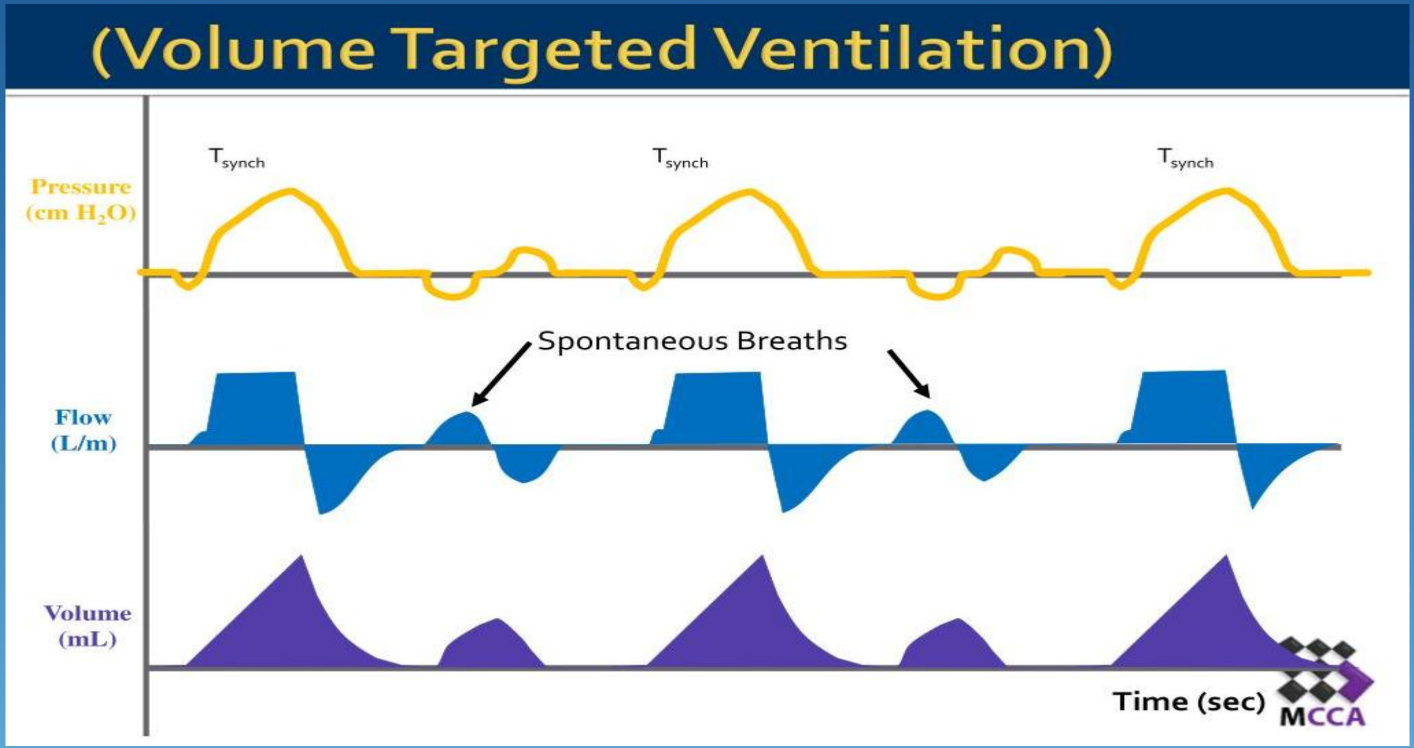
- Example of settings for 75 Kg person: A/C
- R: 14
- Tidal volume 550ml
- Fio2 100%
- PEEP 5 CM H2O

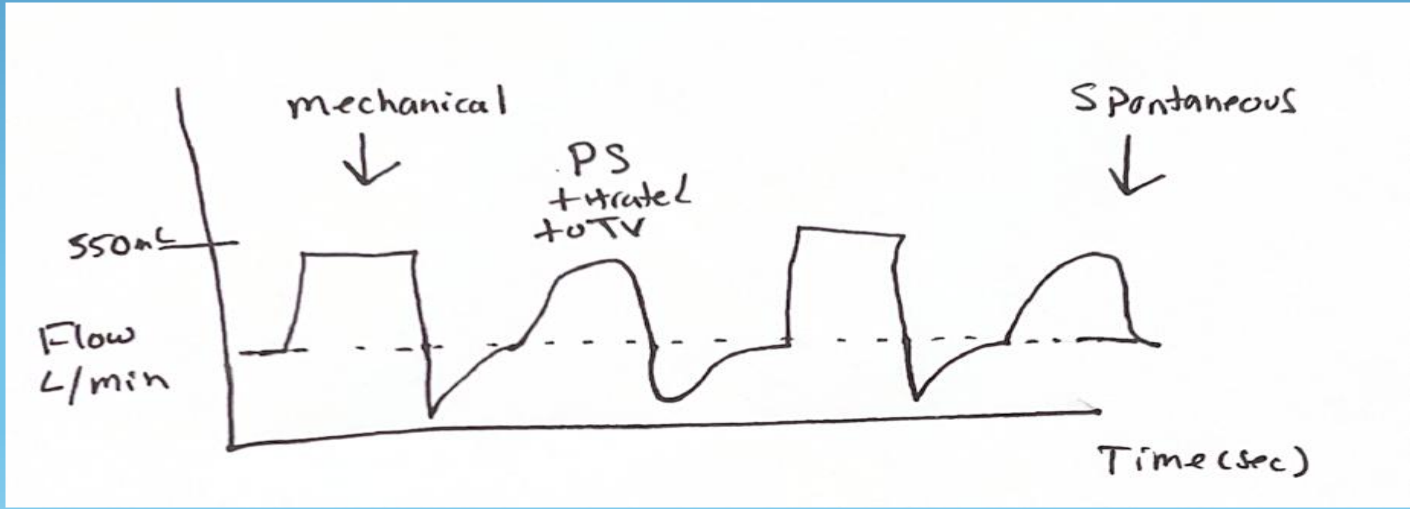
- Example of settings for 75 Kg person: SIMV
- R: 14
- Tidal volume 550ml
- Fio2 100%
- PEEP 5 CM H2O
- Pressure Support 10 cm H2O

A/C and SIMV Differ when it comes to Spontaneous Breathing

- Patient can breathe spontaneous on either mode
- Rate set at 10 BPM they can breathe at 20 BPM
- The first 10 BMP are the same the difference is in the spontaneous breathes.
- A/C every breathe is the same
- SIMV the spontaneous breathes are based on what the patient can do with pressure support help. PS = IPAP (BIPAP)

Adjusting PS to Obtain Desired Tidal Volume





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A/C Drawbacks

- If the patient is Tachypneic they can blow down their CO_2 and become alkalotic.
- Why?
  - High minute ventilation
  - Every Breathe delivers the entire tidal volume
  - Min vent = RR *TV

SIMV Drawback

- If the PS is not titrated up appropriately the patient will have
  - High PCOs from low tidal volume and decreased minute ventilation
  - Acidosis from hypoventilation
  - They will attempt to compensate by increasing the rate to blow off CO2
- Why?
  - Low minute ventilation
  - Spontaneous Breaths with deliver only what the patient can draw in
  - Min vent = RR *TV (If they can not get volume they will try to make if up with rate)
  - People that fail SIMV from tachypnea have not had adequate PS added
  - PS does not add to the mean airway pressure. You can titrate as high as needed to get desired tidal volume. (10-25 cm H2O)

Carbon Dioxide Calculation

Adjusting $PaCO_2$ Using Tidal Volume

$$VT_{new} = \frac{VT_{current} \times PaCO_{2\,current}}{PaCO_{2\,desired}}$$

Example

- VT current = 400 mL
- $PaCO_2$ current = 60 mmHg
- $PaCO_2$ desired = 40 mmHg

$$VT_{new} = \frac{400 \times 60}{40} = 600 \text{ mL}$$

Adjusting $PaCO_2$ Using Respiratory Rate

$$RR_{new} = \frac{RR_{current} \times PaCO_{2\,current}}{PaCO_{2\,desired}}$$

Example (Rate Goes Down)

- RR current = 20
- $PaCO_2$ current = 30 mmHg
- $PaCO_2$ desired = 40 mmHg

$$RR_{new} = \frac{20 \times 30}{40} = 15$$

Adjusting to compensate for high PCO_2

- Min vent = RR *TV
- Adjust based on Volume
- Adjust based on Rate
- Example
- PCO_2 is 55mm Hg
- TV 350 ml
- RR 10 BPM
- Desired 40 mmHg PCO_2

Calculations

- Tidal Volume
- Equation
- Tidal Volume PCO2 =

$$\frac{(PCO2_{(Have)})*(TV)_{(Have)}}{(PCO2)_{(Want)}}$$

- Respiratory Rate equation
- Equation
- RR PCO2 =

$$\frac{(PCO2_{(Have)})*(RR)_{(Have)}}{(PCO2)_{(Want)}}$$

Calculations

- Tidal Volume
- Equation
- Tidal Volume PCO_2 =

$$\frac{(55)*(350)}{(40)_{(Want)}}$$

=481.25 = 482ml

- Respiratory Rate equation
- Equation
- RR PCO_2 =

$$\frac{(55)*(10)_{(Have)}}{(40)_{(Want)}}$$

= 13.75 14 BPM

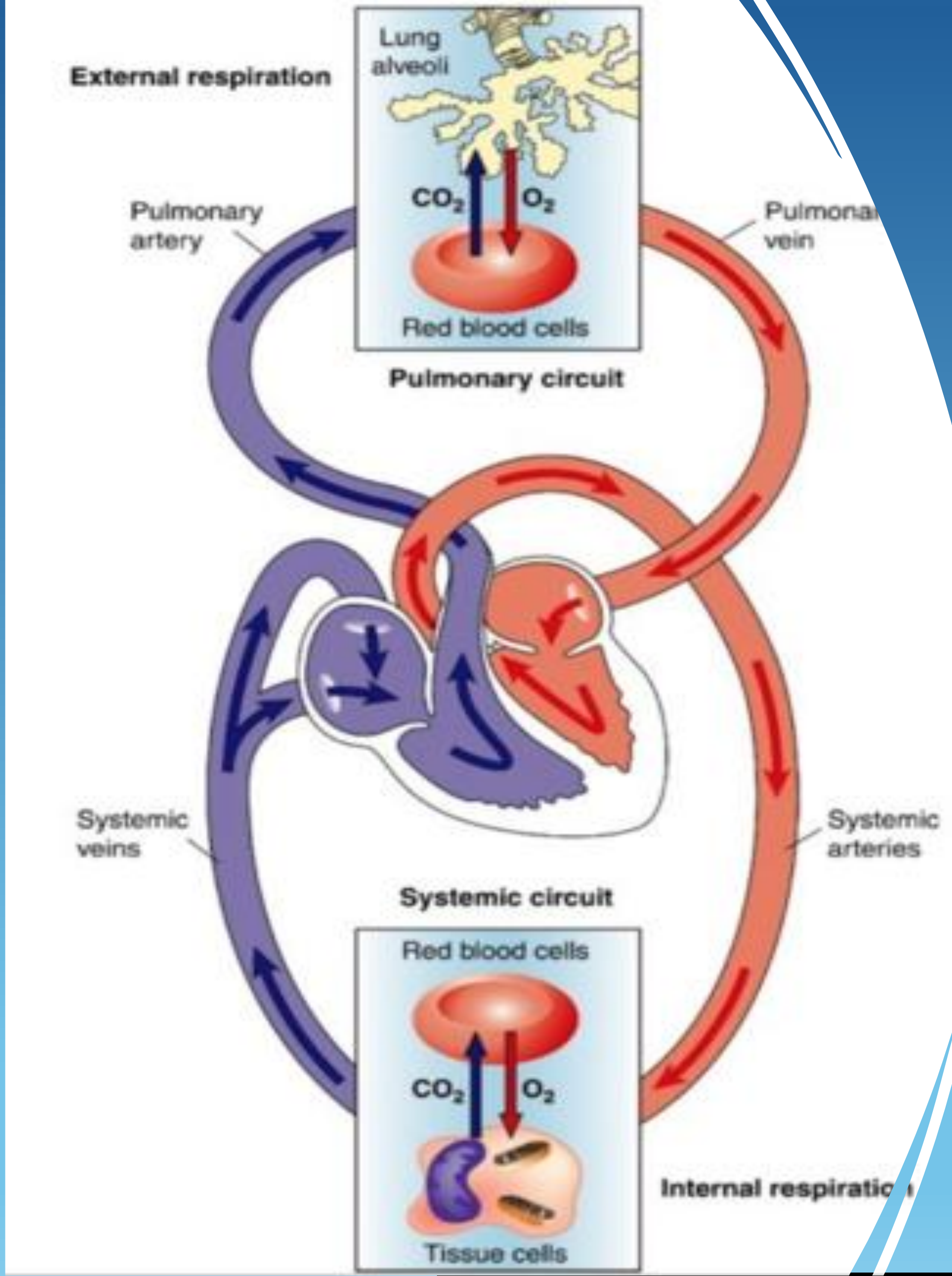
Carbon Dioxide Calculation

Clinical Pearl

- Increasing $PaCO_2$ → **decrease VT or RR**
- Decreasing $PaCO_2$ → **increase VT or RR**
- Assumes stable dead space and CO_2 production

Management Strategies Improve Oxygenation

- Recruit lung to save the day
- Increased Fi02 is the rescue maneuver
- If you increase FiO2 you should increase PEEP
- Need to fix the Right to Left Shunt



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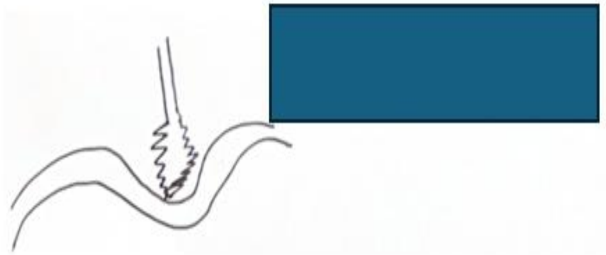
Management Strategies Improve Oxygenation

Oxygenation

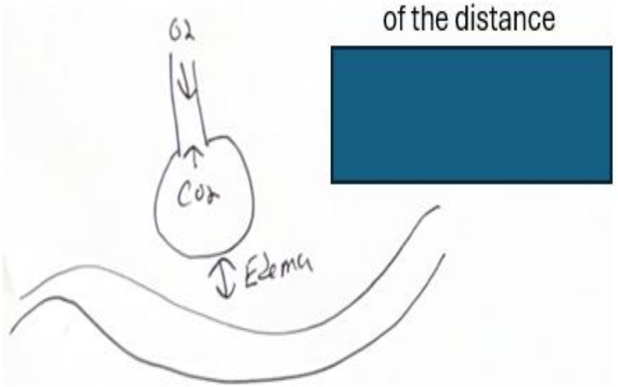
- Increased by increasing Fi02
- Mean Airway Pressure
- Peep



Atelectasis No gas exchange

Interstitial edema it take longer for the gas to diffuse over the distance

It is to the 4th power of the distance



Management Strategies Improve Oxygenation

High & Low PEEP tables from ARDSnet

FiO2	Low PEEP	High PEEP
0.3	5	5-14
0.4	5-8	14-16
0.5	8-10	16-20
0.6	10	20
0.7	10-14	20
0.8	14	20-22
0.9	14-18	22
1.0	18-24	22-24

PEEP tables don't need to be followed precisely, but can be useful as a general guide. The WHO recommends using a high-PEEP strategy, which seems consistent with available experience thus far with COVID-19. If high PEEPs are used, make sure to keep tidal volumes low to prevent excessively high plateau pressures. APRV is an alternative strategy which would likewise provide high mean airway pressures.

-The Internet Book of Critical Care, @PulmCrit

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PEEP

- As FiO2 increases, PEEP should also increase

Lower PEEP/higher FiO2

FiO_2	0.3	0.4	0.4	0.5	0.5	0.6	0.7	0.7
PEEP	5	5	8	8	10	10	10	12

FiO_2	0.7	0.8	0.9	0.9	0.9	1.0
PEEP	14	14	14	16	18	18-24

ARDSnet. *NEJM* 2004; 351, 327

Management Strategies Improve Oxygenation

FiO_2 %	30	40	50	60	70	80	90	100
PEEP (cm H_2O)	5	5	8	10	12	14	16	18

Wisniewski Simplified Version

Mean Airway Pressure

- Think of PEEP in terms of the Diastolic BP
- PEEP is the DP

- Mean Arterial Pressure is defined as

$$mAP = \frac{1}{3} systolic\ pressure + \frac{2}{3} diastolic\ pressure$$

- Biggest Contributor to MAP is the DP
- Biggest Contributor to Mean Airway Pressure is PEEP

Mean Airway Pressure

Mean Airway Pressure ($\bar{A}$Paw) Equation

$$\bar{P}_{aw} = \left(\frac{T_I}{T_{tot}}\right) P_{IP} + \left(\frac{T_E}{T_{tot}}\right) PEEP$$

Legend

- $\bar{P}_{aw}$ = Mean airway pressure (cmH_2O)
- P_{IP} = Peak inspiratory pressure (cmH_2O)
- **PEEP** = Positive end-expiratory pressure (cmH_2O)
- T_I = Inspiratory time (seconds)
- T_E = Expiratory time (seconds)
- T_{tot} = Total respiratory cycle time

$$T_{tot} = T_I + T_E$$

Mean Airway Pressure

Mean Airway Pressure (A/C Volume)

$$\bar{P}_{aw} = \left(\frac{T_I}{T_{tot}}\right) P_{IP} + \left(\frac{T_E}{T_{tot}}\right) PEEP$$

Common ICU Shortcut (I:E = 1:2)

$$\bar{P}_{aw} = \frac{1}{3} P_{IP} + \frac{2}{3} PEEP$$

Mean Airway Pressure Increases

<u>To Increase Mean Pressure</u>

1. increase flow
2. increase PIP
3. increase I:E
4. increase PEEP

- Increasing the Time in Inhalation increase Airway pressure. More time at PIP
- More Flow through the same size tube has to increase pressure
- Increasing the Peak Inspiratory Pressure (PIP) adds to Airway pressure
- PEEP Moves the Lower end of the pressure reading upward

ABG Analysis

- pH 7.35-7.45
- PCO_2 35- 45 mmHg
- PO_2 60-90 mmHg
- Be +2 to -2
- HCO_3 22-28

We have addressed

Fixing PCO_2 , PO_2

ABG Analysis

- Fixing pH
- Acidosis
  - Metabolic
    - BE - < -4
    - pH < 7.35
    - PCO_2 < 35 (compensating) tachypneic patients are worrisome)
    - HCO_3 < 22

    - Addressed this with Shock lectures Resuscitation is the answer
  - Respiratory
    - BE- > -4
    - pH < 7.35
    - PCO_2 >45
    - HCO_3 >28 (Compensatory mechanism)

    - Mechanical Ventilation is the answer

ABG Analysis

- Fixing pH
- Alkalosis
  - Metabolic
    - BE - > +2
    - pH < 7.45
    - PCO_2 >45 (compensating) slowed breathing (Bradypnea) patients are worrisome)
    - HCO_3 >28
  - Respiratory
    - BE- = neutral
    - pH > 7.45
    - PCO_2 <35
    - HCO_3 = 22 to 28 (slow Compensatory mechanism)

Alkalosis is Lethal

- A direct relationship between mortality and blood pH exists when the blood pH is >7.48.

- Mortality rates of 45% and 80% have been noted at blood pH levels of 7.55 and 7.65, respectively .

Bicarbonate Deficit Calculation

Symbol	Meaning
HCO_3^- dose	Total sodium bicarbonate needed (mEq)
0.3	Approximate bicarbonate distribution (30% of body weight)
Weight (kg)	Patient body weight in kilograms
Base Deficit	Absolute value of base deficit (mEq/L)

$$\mathrm{HCO_3^-\ dose\ (mEq) = 0.3 \times Weight\ (kg) \times Base\ Deficit\ (mEq/L)}$$

Worked Example

- **Patient:** 90 kg
- **Base deficit:** –10 mEq/L

$$HCO_3^- = 0.3 \times 90 \times 10 = 270\ \mathrm{mEq}$$

Ampules needed (50 mEq/ampule):

$$270/50 = 5.4 \approx 5\text{–}6\ \mathrm{ampules}$$

> ⚠️ Clinically, usually give **half initially**, then reassess ABG.

Next week

- Look at pressure control ventilation
  - Calculating tidal volume
  - Managing Pressures
  - Increasing oxygenation

Works Cited

- Modes Of Mechanical Ventilation Explained | Tracheostomy Education
- pressure control ventilation – Search
- simv ventilation with too little ps pressure PV loop - Search Images
- Picture of Right to left pulmonary shunt - Search Images
- table for peep and fio2 titration - Search Images
- table for peep and fio2 titration - Search Images
- mean arterial pressure equation - Search Images

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