Vent II Introduction to Ventilator Management

- Medical Practice Improvement Project
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Disclosures

- None

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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

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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)

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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

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How to Correct CO2 and PaO2

Oxygenation

- Increased by increasing Fi02
- Mean Airway Pressure
- Peep

Carbon Dioxide Clearance

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

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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

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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 H_2O

- Example of settings for 75 Kg person: SIMV
- R: 14
- Tidal volume 550ml
- Fio2 100%
- PEEP 5 CM H_2O
- Pressure Support 10 cm H_2O

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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)

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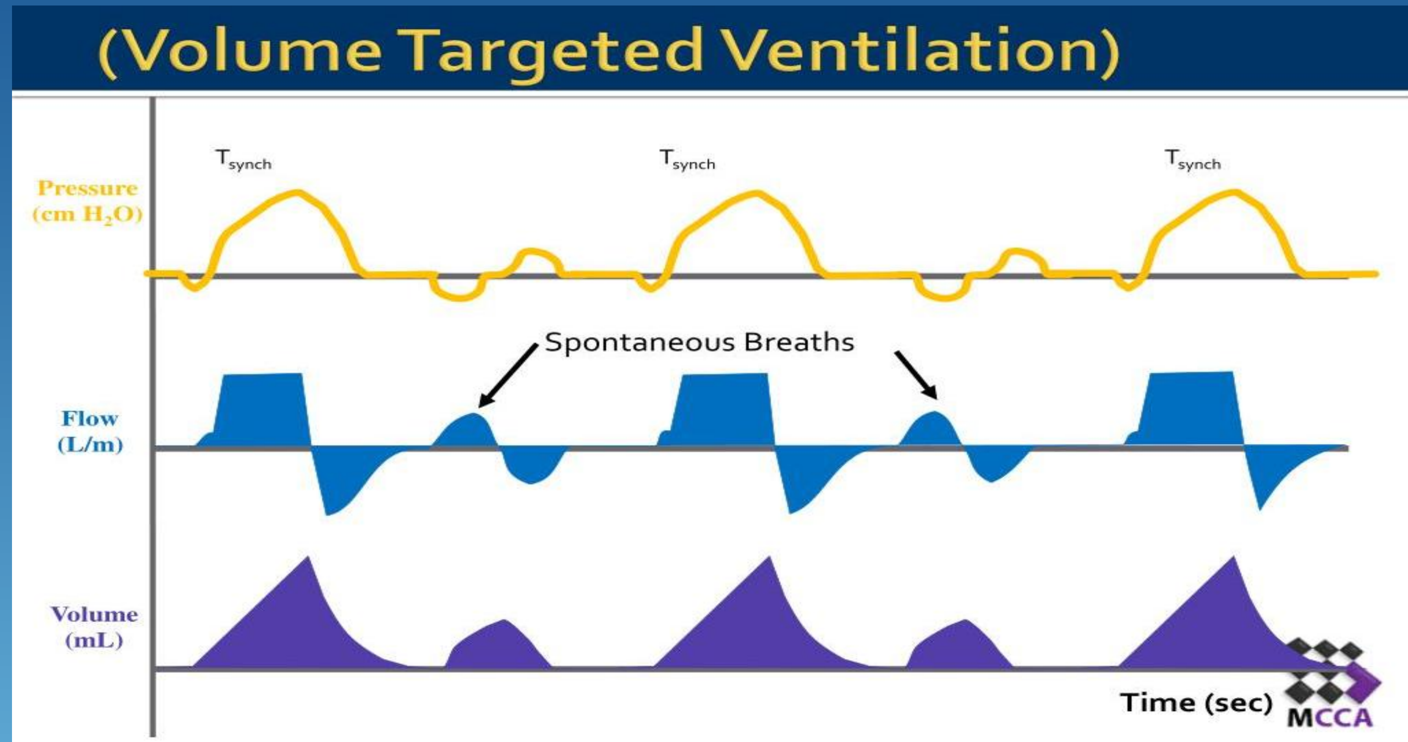
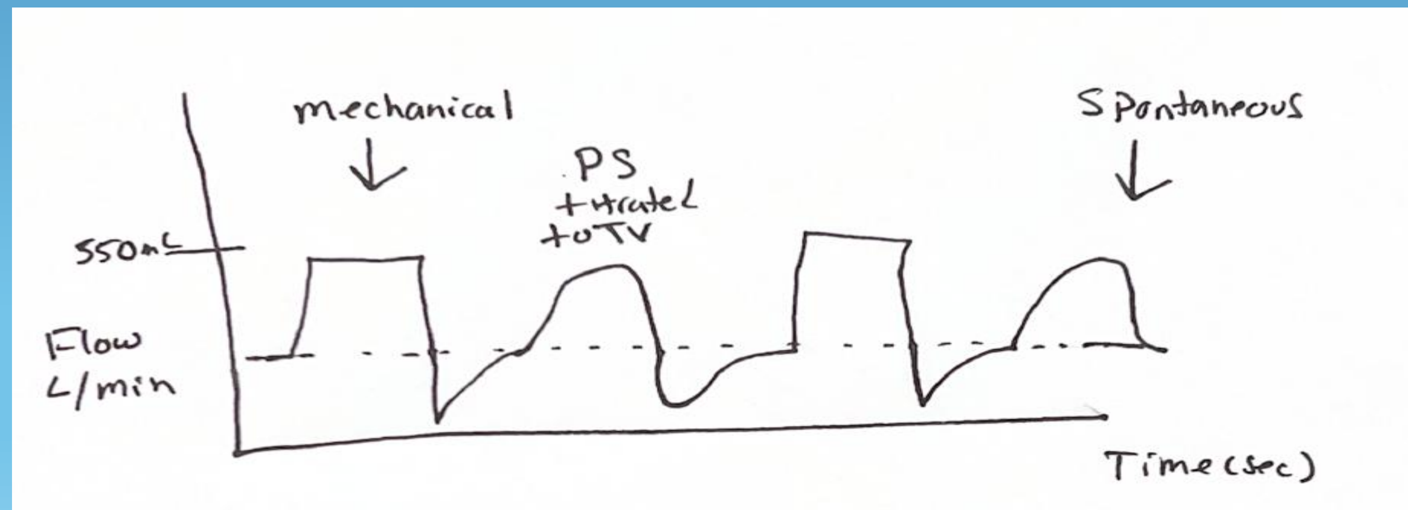
Adjusting PS to Obtain Desired Tidal Volume





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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

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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)

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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

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

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Adjusting to compensate for high PCO2

- Min vent = RR *TV
- Adjust based on Volume
- Adjust based on Rate
- Example
- PCO2 is 55mm Hg
- TV 350 ml
- RR 10 BPM
- Desired 40 mmHg PCO2

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Calculations

- Tidal Volume
- Equation
- Tidal Volume PCO2 =

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

- Respiratory Rate equation
- Equation
- RR PCO2 =

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

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Calculations

- Tidal Volume
- Equation
- Tidal Volume PCO_2 =

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

$=481.25 \quad = 482$ml

- Respiratory Rate equation
- Equation
- RR PCO_2 =

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

$= 13.75 \quad 14$ BPM

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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

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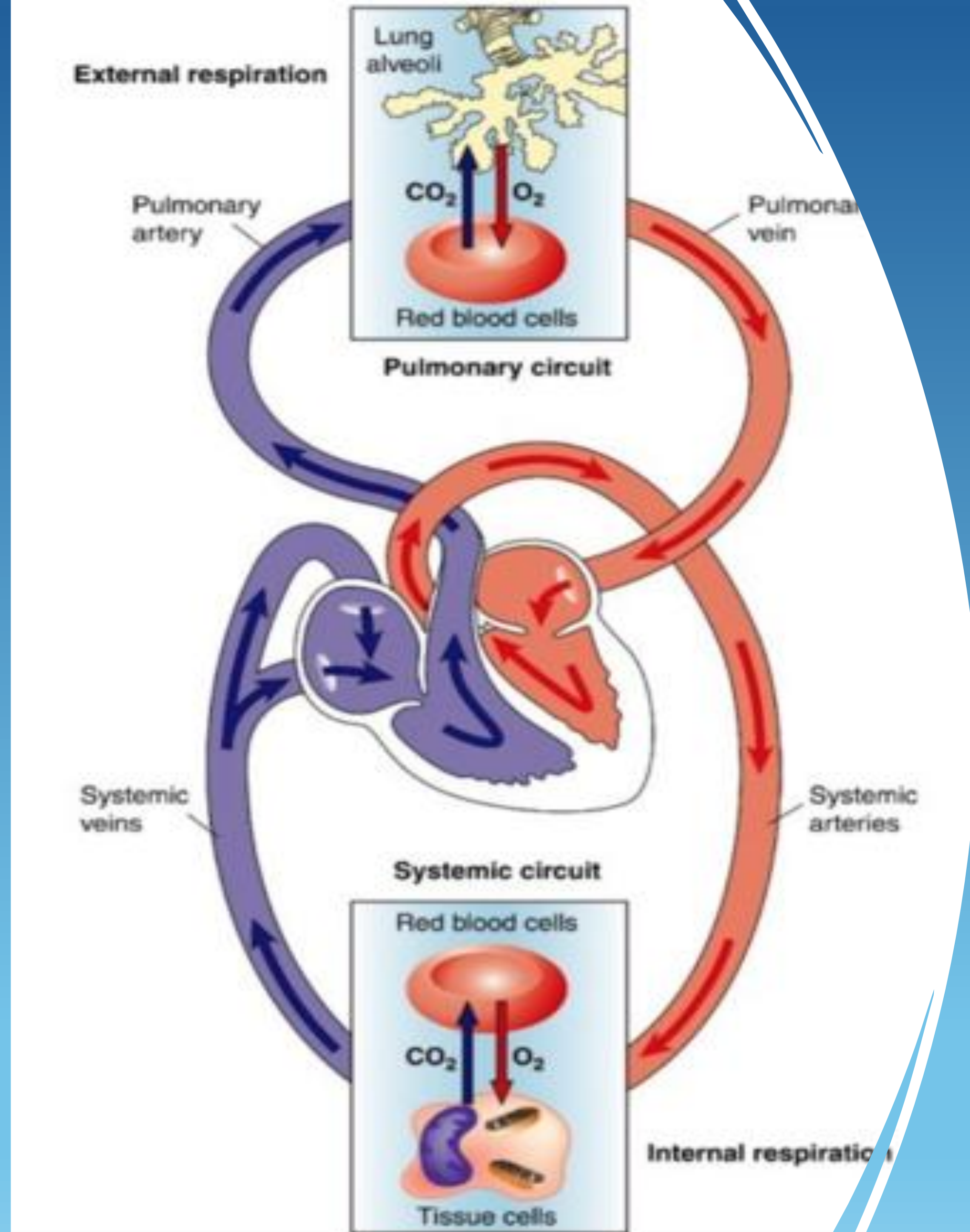
Management Strategies Improve Oxygenation

- 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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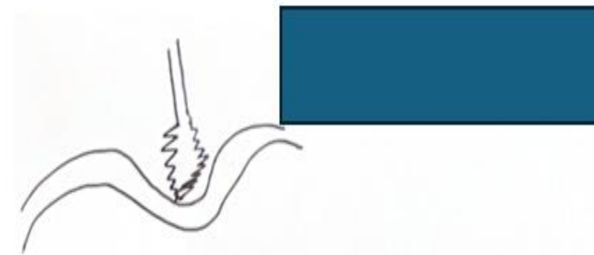
Management Strategies Improve Oxygenation

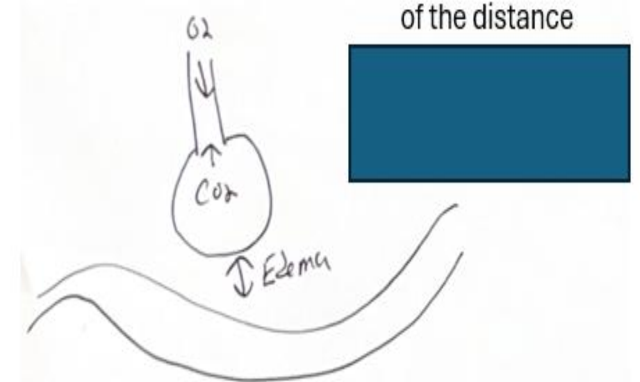
Oxygenation

- 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



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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

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Management Strategies Improve Oxygenation

FiO2 %	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

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Mean Airway Pressure

Mean Airway Pressure (ĀPaw) 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

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

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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)

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

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Mean Airway Pressure Increases

To Increase Mean Pressure

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

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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

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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

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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)

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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 .

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Bicarbonate Deficit Calculation

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

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)

Worked Example

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

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

Ampules needed (50 mEq/ampule):

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

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

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Next week

- Look at pressure control ventilation

  Calculating tidal volume

  Managing Pressures

  Increasing oxygenation

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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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