MECHANICAL VENTILATION
“THE BASICS”

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INDICATIONS OF MECHANICAL VENTILATION

Ventilation abnormalities

- Decreased ventilatory drive
- Neuromuscular disease
- Chest wall abnormalities
- Respiratory muscle dysfunction
- Respiratory muscle fatigue
- Increased airway resistance and/or obstruction

Oxygenation abnormalities

- Refractory hypoxemia
- Need for positive end-expiratory pressure

Other Indications

Work of breathing alterations

- **Shock/ Haemodynamic Instability**
- **Respiratory muscle fatigue**
- **Severe acidosis**

Need for sedation and/or neuromuscular blockade

Need to decrease systemic or myocardial oxygen consumption

Use of hyperventilation to reduce intracranial pressure

Facilitation of alveolar recruitment and prevention of atelectasis

Before Initiating Mechanical Ventilation always ask these 3 questions:

Is there failure in airway maintenance or protection (eg, inability to handle secretions)?

Is there failure to achieve desired goals with current respiratory support (oxygenation, ventilation, or work of breathing)?

Is the illness anticipated to worsen in the next 24 to 48 hours?

Case

- **A 35 year old man is taken to emergency department after motor vehicle accident. He is unconscious but spontaneous breathing is present.**
- **The result of ABG analysis are:**

pH-7.09, $PaCO_2$- 93 mm Hg, HCO_3- 27 meq/l, PaO_2- 47 mmHg.

- **Which of the following would you recommend ?**

A. **Recheck vital signs**

B. **Intubate and ventilate**

C. **Change to venturi mask**

D. **Begin CPR**

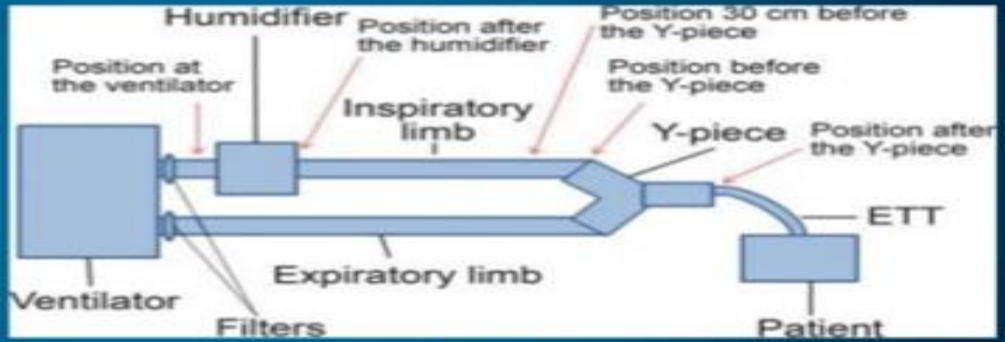
E. **Start NIV Trial**

Finally, in the light of available evidence and guidelines, the decision should be guided by the overall clinical condition.

Undue delay in intubation and Invasive Ventilation can be catastrophic.

HOW DOES A VENTILATOR WORK ?

Components of MV



FACTORS CONTROLLED AND MEASURED DURING INSPIRATION

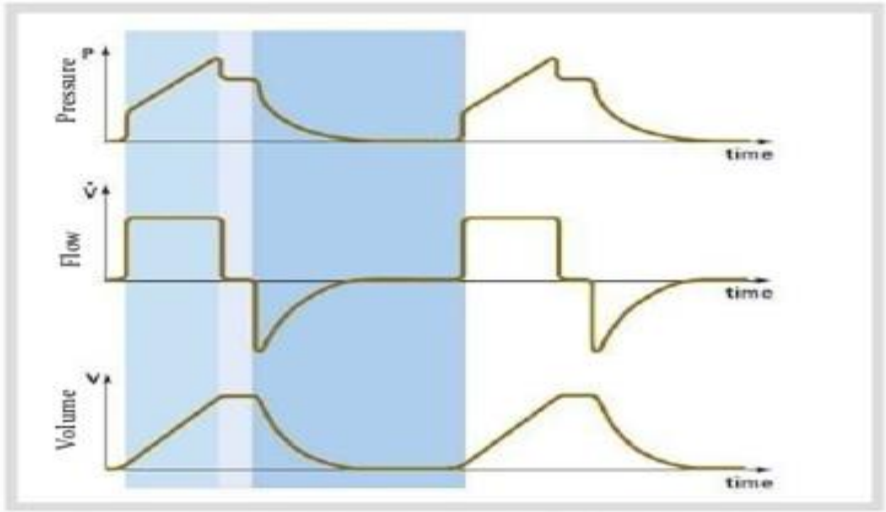
The primary variable the ventilator adjusts to achieve inspiration is therefore called the *control variable ;*

Pressure control breathing : *Pressure-controlled inspiration maintains the same pattern* of pressure at the mouth regardless of changes in lung condition.

Volume control breathing : *Volume-controlled inspiration maintains the same pattern* of volume at the mouth regardless of changes in lung condition and also maintains the same flow waveform.

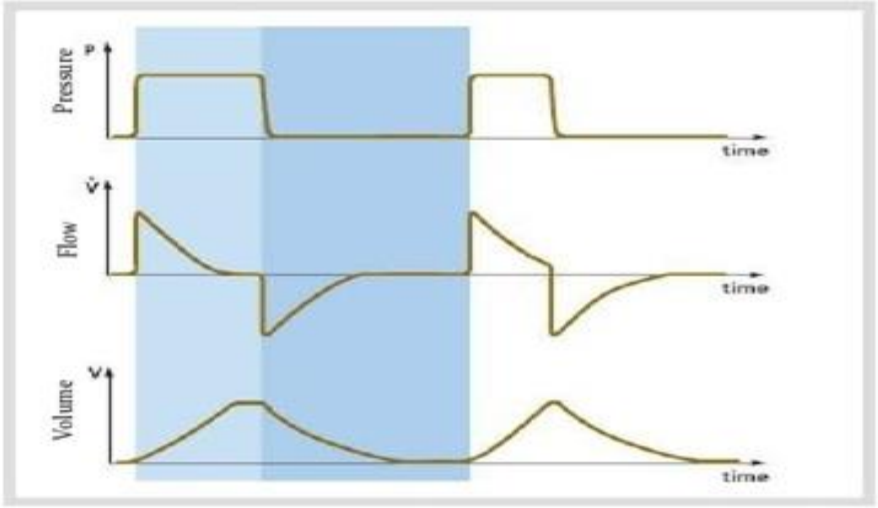
Types of Waveforms

Volume Modes



Volume Control/ SIMV (Vol. Control)

Pressure Modes



Pressure Control/ PRVC
SIMV (PRVC)
SIMV (Press. Control)

Pressure Support/
Volume Support

PHASES OF A VENTILATOR BREATH

INSPIRATION

Trigger : Start

Limit : Target

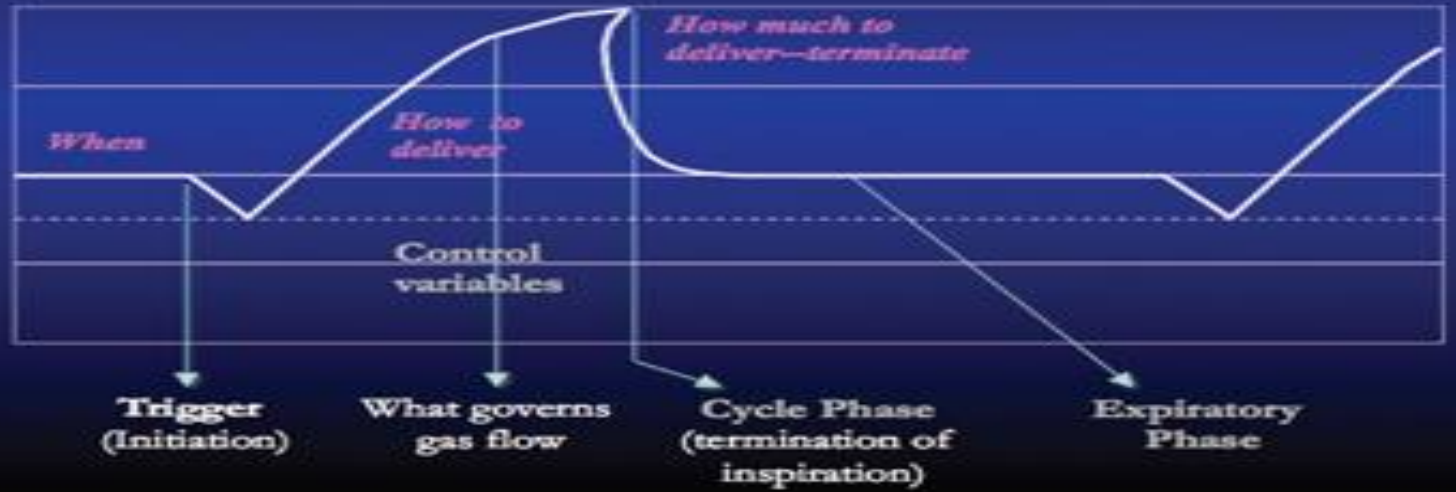
Cycling : Stop

EXPIRATION

PEEP and CPAP

Ventilator Breaths

- Four phases during each ventilatory cycle



Beginning of Inspiration: The Trigger Variable

Time Triggering

Controlled Mandatory Ventilation

Sedated / Paralysed patient : No respiratory efforts.

Patient Triggering

Assisted Breath

Pressure Trigger

Flow Trigger

EaDi

The Limit Variable During Inspiration

A *limit variable is the maximum value that a variable (pressure,* volume, flow, or time) can attain.

It may be for some reason less than desired, but it cannot be more.

It is important to emphasize, however, that reaching the set limit variable does not end inspiration.

Pressure limited

Volume limited

Flow limited

Termination of the Inspiratory Phase: Cycling

Volume Cycled

In cases where the clinician sets an inspiratory pause, inspiration will continue until the pause has ended and expiration begins.

Time Cycled

Flow Cycled

Pressure cycled

Inspiratory hold

Expiratory Phase

PEEP and CPAP

Types of Breath

- **Controlled**
- **Assisted**
- **Supported**
- **Spontaneous**

MODES OF MECHANICAL VENTILATION

CMV - Controlled Mandatory Ventilation : PC/VC

A/C V - Assist Control Ventilation : PC/VC

SIMV - Synchronised Intermediate Mandatory Ventilation

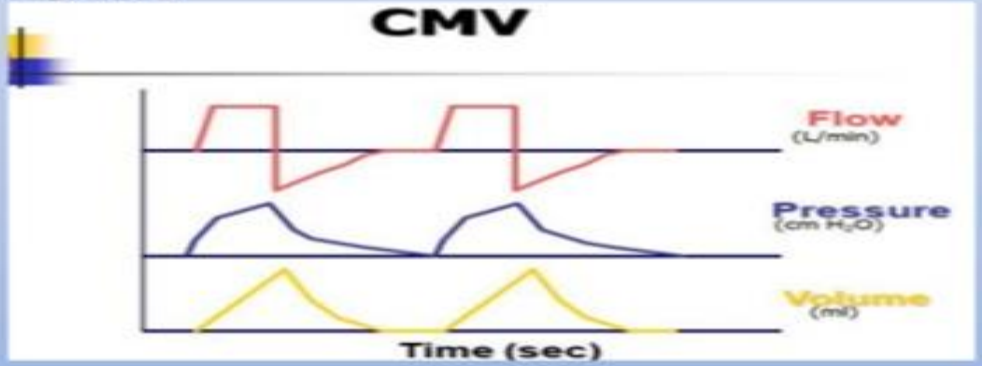
PSV – Pressure Support Ventilation

CPAP – Continuous Positive Airway Pressure

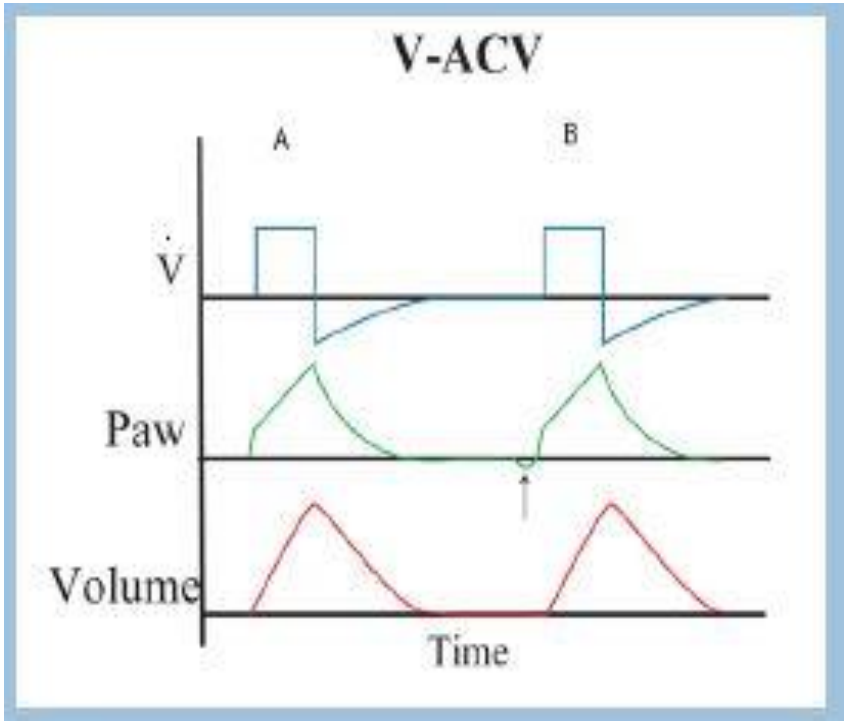
Controlled Mandatory Ventilation

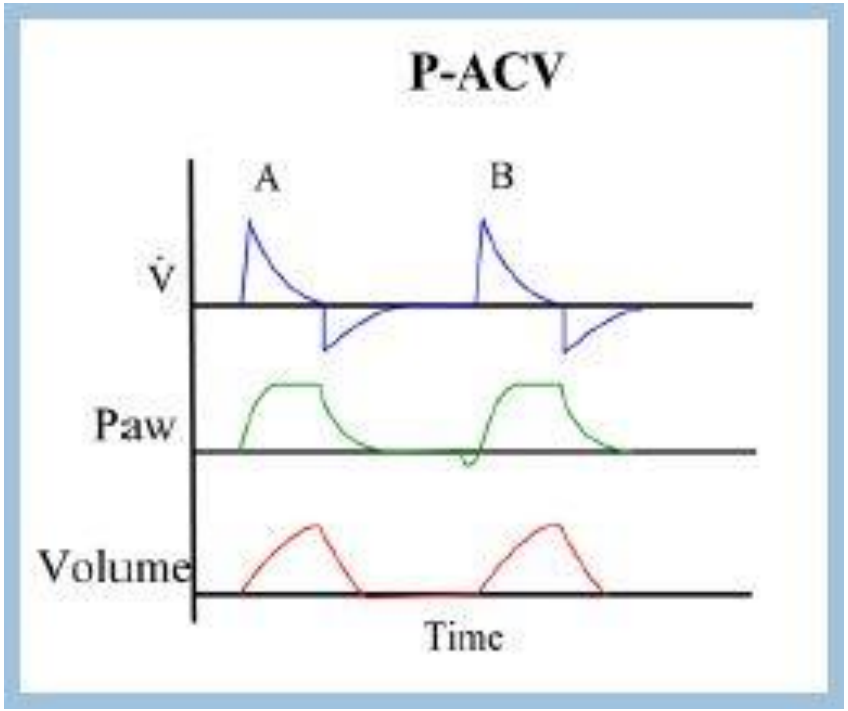
CMV (Continuous mandatory ventilation)mode

- Patient receives a preset TV at a preset RR.
  - Pt. Cannot increase RR or breathe spontaneously
  - Should only be used if the patient is properly medicated and paralyzed

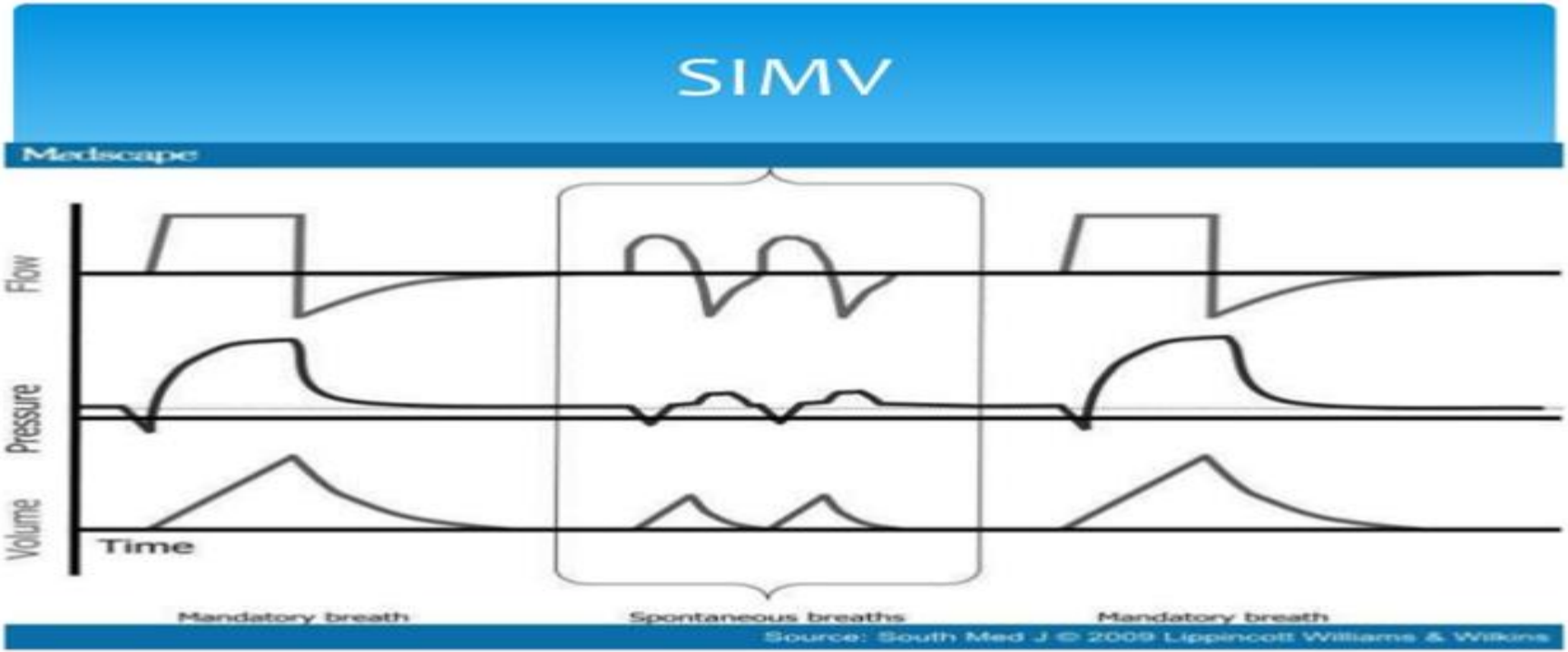


Assist Control Ventilation

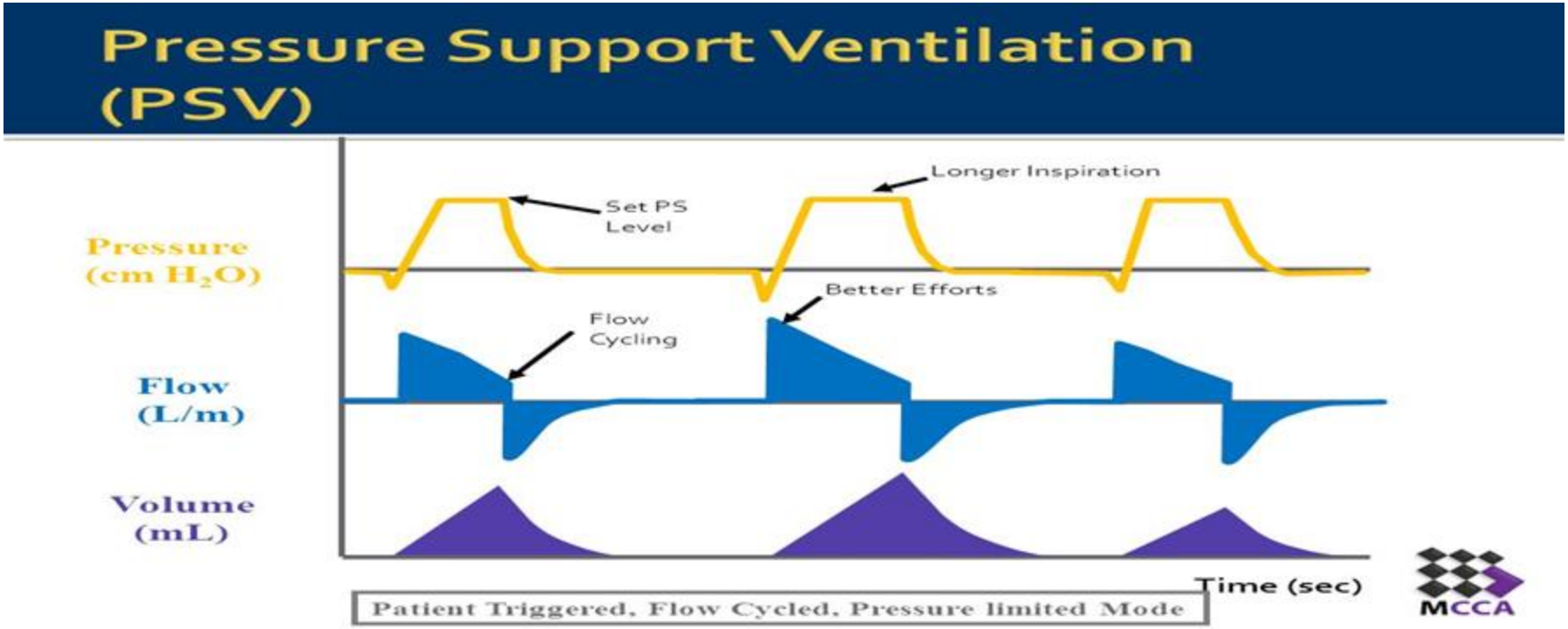




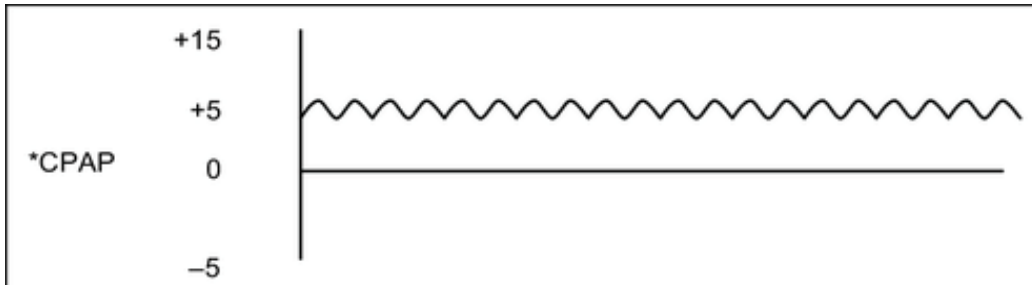
SIMV


SIMV
Medscape
Flow
Pressure
Volume
Time
Mandatory breath
Spontaneous breaths
Mandatory breath
Source: South Med J © 2009 Lippincott Williams & Wilkins

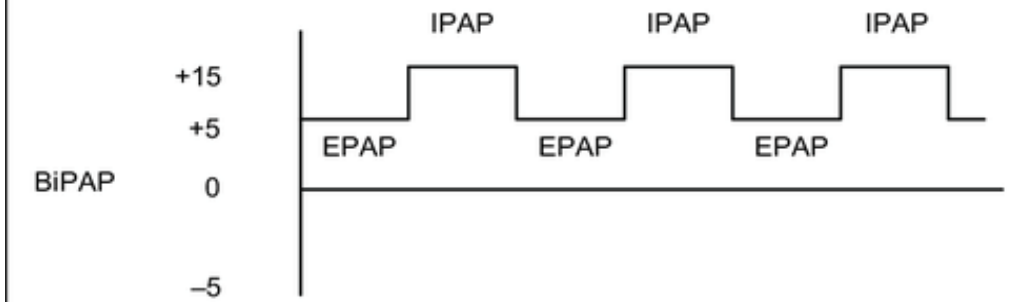
Pressure Support Ventilation



CPAP



Note CPAP (+5) is maintained during spontaneous breathing.



Note IPAP (+15) is the PSV value and EPAP (+5) is the CPAP value.

HOW TO INITIATE MECHANICAL VENTILATION

- **Mode**
- **Tidal Volume/Inspiratory Pressure**
- **Respiratory rate**
- **Fraction of inspired oxygen**
- **Positive end-expiratory pressure (PEEP)**
- **Flow rate**
- **Inspiratory time (I : E ratio)**

General Guiding Principles

1. Choose the ventilator mode with which you are most familiar.
2. Primary goals of ventilatory support –
   - Adequate oxygenation/ventilation
   - Reduced work of breathing
   - Synchrony between patient and ventilator
   - Avoidance of high end-inspiration alveolar pressures.

3. The initial FIO2 should be 1.0.

4. The FIO2 thereafter can be titrated downward to maintain the SpO2 at 92% to 94%.

5. In severe ARDS, SpO2 ≥88% may be acceptable to minimize complications of mechanical ventilation.

6. Initial VT = 6 to 8 mL/kg in patients with relatively normal lung compliance.

7. In patients with poor lung compliance (eg, ARDS), a target VT of 6 mL/kg by PBW is recommended to avoid overdistension and maintain an inspiratory plateau pressure ≤30 cm H2O.

General Guiding Principles (Contd.)

8. Choose a respiratory rate and minute ventilation appropriate for the particular clinical requirements. Target pH, not $PaCO_2$.

9. Use PEEP in diffuse lung injury to maintain an open alveoli at end expiration. If volume is held constant, PEEP may increase peak inspiratory plateau pressure, a potentially undesirable effect in ARDS.

10. Set the trigger sensitivity to allow minimal patient effort to initiate inspiration. Beware of auto cycling if the trigger setting is too sensitive.

11. In patients at risk of obstructive airway disease, avoid choosing ventilator settings that limit expiratory time and cause or worsen auto-PEEP.

12. Call the critical care consultant or other appropriate consultant for assistance.

PROTOCOL FOR MANAGEMENT OF VENTILATION IN COVID-19 PATIENTS

Indications for intubation
1. ARDS with PaO_2/FiO_2 of <200
2. Worsening respiratory distress even on NIV
3. Patient in shock

INTUBATION & VENTILATION

Initial settings
Controlled mode ventilation - VCV/PCV
Tidal Volume (TV)- 6-8ml/PBW
PEEP - 5-10 cmH2O
FiO_2- target O_2saturation (SpO_2) to 92-96% with lowest FiO_2 possible
Respiratory rate (RR)- 14-18/min
Plateau pleasure - < 30 cmH2O

Ventilation Targets
Plateau Pressure(Pplat) < 30 cmH2O
Driving Pressure (Pplat - PEEP) <16 cmH2O

ABG targets
PaO_2- 55-80mmhg
pH- >7.3

Optimize sedation with midazolam + fentanyl

Predicted body weight (PBW)
Males = 50 + 2.3 [height (inches) - 60]
Females = 45.5 + 2.3 [height (inches) -60]

Measure compliance (TV in ml/P.Plat- PEEP)

Follow ARDSnet protocol
TV- 6-8ml/PBW
(can reduce up-to 4ml/PBW maintain P.plat <30)
PEEP : 8 -10 cmH20
(titrate PEEP according to PEEP-FiO_2 table)
P.Plat : < 30 cmH20
RR- 14-18/min (maximum <35/min; adjust RR to achieve baseline minute ventilation)

Monitor compliance
4 - 6th hourly

Persisting hypoxemia with
SpO2 <88% inspite of ARDSnet protocol

Increase depth of sedation
Optimize secretions clearance / bronchodilation
Initiate early muscle relaxant infusion
(cis-atracurium or vecuronium)
Early prone ventilation

Compliance >40

L- type
Low elastance (high compliance)
Low recruitability
Low lung weight

↓ V/P

Patients are at increased risk of microthrombi

- Maintain euvolemia
- Consider therapeutic anti-coagulation with enoxaparin (discuss with subject expert)

Compliance <40

H- type
High elastance (low compliance)
High recruitability
High lung weight

↑ Right - Left shunt

Disclaimer: "L" and "H" type is conceptual at this stage, more evidence needs to be validated for safe and effective clinical application

Prone ventilation

1. Intubation & Mechanical ventilation for <36hours
2. Recommended for 12-16hours/day ~ multiple sessions until favourable trends achieved
3. Moderate to severe ARDS with PF ratio < 150, FiO2 > 60%, PEEP > 5, TV~6ml/PBW

Refractory hypoxemia inspite of prone ventilation, muscle relaxants for >6hours

Review ventilatory setting
Consider ECMO therapy
where ever feasible

Incremental PEEP FiO2 table

FiO2	0.3	0.4	0.4	0.5	0.5	0.6	0.7	0.7	0.7	0.8	0.9	0.9	0.9	1.0
PEEP	5	5	8	8	10	10	10	12	14	14	14	16	18	18 - 24

Ancillary Therapies

- Antibiotics guided by protocols
- Meduri's regime methyl-prednisolone 1mg/kg as infusion over 24hrs (discuss with subject expert)
- Steps to reduce ventilator associated pneumonia (VAP) by following VAP bundles

- "F": Early enteral nutri[illegible]on < 48hrs
- "A": Adequate analgesia
- "S": Adequate sedation
- "T": Thrombo-prophylaxis
- "H": Head end elevation
- "U": stress ulcer prophylaxis
- "G": Glycemic control BSL < 180

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Complication of Ventilatory support

- **Non invasive Ventilatory support**
  - **Aerophagia**
  - **Retching, Nausea, Vomiting**
  - **Vomitus aspiration**

- **Invasive Ventilatory support**
  - **Barotrauma**
  - **VAP**

Case Study

Noninvasive positive pressure ventilation is initiated. Two hours after initiation, the patient exhibits persistent marked accessory muscle use. Vitals signs are heart rate 130 beats/min, blood pressure 160/90 mm Hg, respiratory rate 32 breaths/min, and temperature 36.6ºC (98°F). Arterial blood gas demonstrates pH 7.27, PCO_2 60 mm Hg, and PO_2 90 mm Hg.

1. Should this patient be intubated and invasive mechanical ventilation initiated?

2. What are the initial setting on invasive mechanical ventilation?

3. How should patients on invasive mechanical ventilation be monitored?

Thank You