The Basics of Mechanical Ventilation

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Objectives

1. Discuss advantages and disadvantages of noninvasive vs. invasive ventilation
2. Describe basic ventilator parameters and modes.
3. Distinguish between volume and pressure cycled ventilation.
4. State the therapeutic effects and dangers of PEEP.
5. Explain troubleshooting techniques for frequently occurring ventilator alarms.

Types of Mechanical Ventilation

- Noninvasive Positive Pressure Ventilation (NPPV)/BiPAP: mask
- Invasive ventilation: artificial airway

Basic Ventilator Parameters

FiO2
: Fractional concentration of inspired oxygen delivered or % (21-100)

Breath Rate (f)
: Number of times per minute inspiration is initiated (bpm)

Tidal volume (VT)
: Amount of gas delivered during inspiration in mLs or Liters

Peak Inspiratory Pressure (PIP)
: Set parameter in pressure control modes exhaled.

Flow
: The velocity of gas flow per minute

Volume or Pressure?

Volume controlled
: Volume is constant and not affected by condition of lungs/airways
: Pressure independent of volume and affected by patient's changing lung
: Used when goal is maintaining certain level of $PaCO_2$

Volume Ventilation

Advantage
: Delivers specific volume regardless of lung changes

Disadvantage
: When lung compliance worsens (lungs become "stiff")
: Requires higher pressure to deliver same tidal volume
: Overdistension occurs

Pressure Ventilation

Set pressure – pressure remains constant
Volume changes as lungs change

Advantages
- Set max. pressure
- Reduces risk of overdistention
- Lung protective

Disadvantages
- Volume varies
- Clinicians less familiar
- Tidal volume decreases as lungs deteriorate

Modes of Ventilation

- CMV, A/C, VC
- SIMV
- PSV
- SIMV and PS
- CPAP
- Bi-PAP
- PC
- PRVC

CMV

Continuous mandatory ventilation, Controlled mechanical ventilation, Continuous mechanical ventilation
- Every breath is mandatory
- Set minimum breath rate
- Patient can trigger more breaths if able
- A.K.A. Assist/Controlled ventilation or A/C
- Set volume or pressure is delivered with every breath
- All breaths are mandatory
- Volume or pressure targeted

Breaths can be
- Patient triggered – Assist/Control
- Patent can trigger or can be time triggered

Set minimum rate – patient can trigger additional breaths

Time triggered – CMV or controlled ventilation
- Patient does not trigger breath

Control
- Delivery of a mandatory breath at a set time interval
- Time is the trigger to start the breath
- In controlled mode, patient does not work

Assist, Assist Control
- Patient is able to trigger the start of inspiration

Synchronize Intermittent Mandatory Ventilation - SIMV

- A minimum mandatory breath rate is set
- Patient may take spontaneous breaths between mandatory breaths

Pressure Control Ventilation – PCV

- PC-CMV
- The ventilator delivers a set pressure limit over a set inspiratory time

Advantages

Limits risk of barotrauma
May recruit collapsed alveoli
Improved gas distribution

Disadvantages

Tidal volumes vary when patient compliance changes (i.e. ARDS, pulmonary edema)
PC - in SIMV mode
Can also be used in SIMV
Used when controlling pressure is more important than guaranteeing volume

Pressure Regulated Volume Control (PRVC)

- Achieves a target tidal volume
- Keeps PIP at lowest level possible
- Alters peak flow and inspiratory time as lung compliance and resistance changes
- Breath to breath, PIP is adjusted
- PIP fluctuates up to max of 5 cmH2O below set pressure limit

Spontaneous Modes/Spontaneous breathing

CPAP
PSV

Pressure Support Ventilation (PSV)

Set parameter

Inspiratory pressure

Once patient makes inspiratory effort
Provides consistent pressure during inspiration
Use of Pressure Support Ventilation

Overcome resistance related to ET tube
Spontaneously breathing, CPAP, SIMV
Spontaneous breaths can be pressure supported
Increases baseline pressure
Reduces excessive work on spontaneous breaths

Spontaneous Breathing

Spontaneous breathing trial (SBT)

ETT or trach tube connected to "T" adapter
Humidified O2 used with large bore tubing
Determine readiness to D/C vent
15 – 30 minute trial

PEEP (Positive End Expiratory Pressure)

Application of a constant, positive pressure such that at end exhalation, airway pressure does not return to a 0 baseline

PEEP is used with other mechanical ventilation modes such as A/C, SIMV, or PCV

Referred to as CPAP when applied to spontaneous breaths

Advantages

Improves oxygenation
Recruits collapsed alveoli
Splints and distends patent alveoli

Redistributes lung fluid from alveoli to perivascular space

Hazards of PEEP
- Increases mean airway pressure, leading to alveolar overdistension or barotraumas
- Decreases venous return, may cause
  - decrease in cardiac output and oxygen delivery to the tissues
  - hypotension

CPAP (Continuous Positive Airway Pressure)

- Application of constant positive pressure throughout the spontaneous ventilatory cycle
- No mechanical inspiratory assistance is provided
- Requires active spontaneous respiratory drive
- Same physiologic effects as PEEP
- May decrease patient work
- Tidal volume and rate determined by patient
- Often final form of support before extubation

Noninvasive Positive Pressure Ventilation (NPPV)

Provides positive pressure through the upper airway by some type of mask or other noninvasive interface
Pressure is applied intermittently with inspiration having a higher pressure than expiration (Bi-PAP)
Lung Disease that may Benefit from NPPV in the Acute Care Setting
- Acute Exacerbation of COPD
- Hypoxemic Respiratory Failure/ARDS
- Community Acquired Pneumonia (CAP)
- Asthma
- Immunocompromised states
- Acute Cardiogenic Pulmonary Edema (CPE) - when hypercapnia is present.

Benefits of Using NPPV
- NPPV provides greater flexibility in initiating and removing mechanical ventilation
- Permits normal eating, drinking and communication with your patient
- Preserves airway defense, speech, and swallowing mechanisms

Benefits of Using NPPV Compared to Invasive Ventilation
- Avoids the trauma associated with intubation and the complications associated with artificial airways
- Reduces the risk of ventilator associated pneumonia (VAP)
- Reduces requirements for heavy sedation
- Preserves the ability to communicate
- Enhances patient comfort

Example NPPV Settings

Common IPAP orders
- 10 - 12 cm H2O
- Adjust to change tidal volume

Typical EPAP setting
- 4 - 5 cm H2O
- Increase to improve oxygenation
- FiO2 and backup rate

Ventilator Alarms

High Inspiratory Pressure/Pressure Limit

Common causes
Coughing
Secretions in airway
Biting on ET tube
Bronchospasm
Patient ventilator asynchrony
Kinking of ventilator circuit

Low Inspiratory Pressure
Patient disconnection
Circuit leaks
Disconnection from
In-line nebulizers
Temperature monitors
Airway leaks
Inadequate ET cuff inflation or rupture of cuff
Chest tube leaks

Low Volume Alarms

Low Exhaled Tidal Volume
Common causes are same as those for low pressure, or
Spontaneous breathing has decreased
Low minute volume
Minute volume = tidal volume x rate
Normal = 6 – 10 L/min
Common causes same as low pressure and low tidal volume

High Volume/High Rate Alarms
Common causes
Patient is hyperventilating or tachypneic
Alarms not set appropriately
External nebulizer in-line

Low PEEP/CPAP
Activates when pressure falls below set level of PEEP/CPAP
May be caused by circuit leak

Apnea
Patient is apneic, or
Patient disconnect, system leaks
Inappropriately set apnea parameters

Most ventilators provide backup mode of ventilation when apnea alarm is activated