Mechanical Ventilation Paediatrics & Neonates

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OBJECTIVES

- Basics of ventilators: control pattern and modes
- Indication / aims
- Modes of Ventilation – Either Control, or Support (Weaning) Modes: tmode of ventilation describes the way a mechanical breath is delivered
- Initial settings/ adjusting ventilator settings
- Complications
- Weaning

Always remember assisted ventilation is a supportive technique,

NOT curative

Who needs a ventilator?

- Can’t oxygenate (low PaO2/SPO2)
- Can’t ventilate (high PaCO2)
- Can’t participate or protect airway (low Glascow Coma Scale)
- If you’re not sure whether or not the patient needs a ventilator, the patient needs a ventilator

Remember: assisted ventilation is a supportive technique, NOT curative

Aims of ventilation

- Provide ventilation(CO2 removal)
- Optimal systemic oxygenation
- Decrease the work of breathing

Two ways to ventilate: Pressure or Volume?

- Pressure limit
- Inspiratory time
- Rate
- FiO2
- PEEP

- Volume controlled - you set:

Two ways to ventilate: Pressure or Volume?

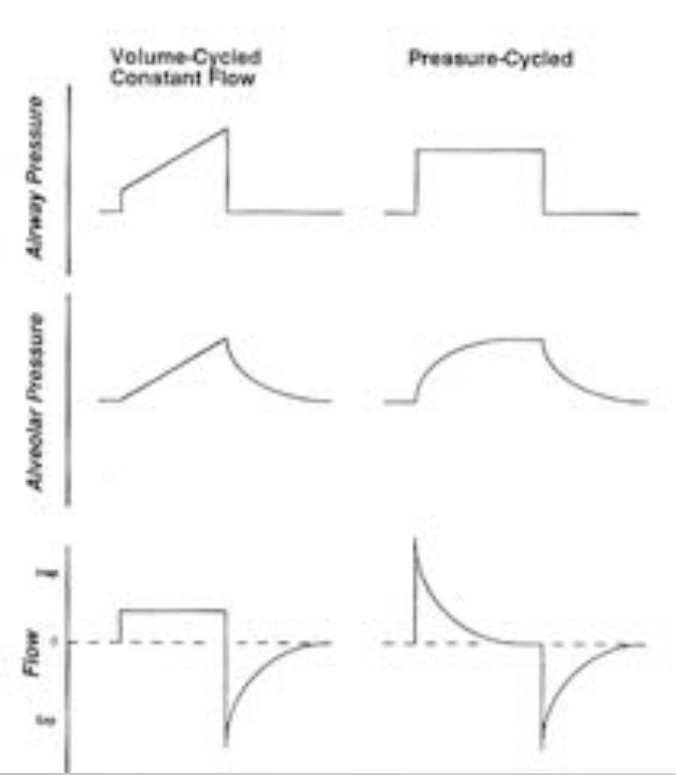
Pressure controlled - you set:

- Pressure limit
- Inspiratory time
- Rate
- FiO2
- PEEP

Volume controlled - you set:

- Tidal volume
- Peak flow
- Rate
- FiO2
- PEEP

Volume vs. Pressure

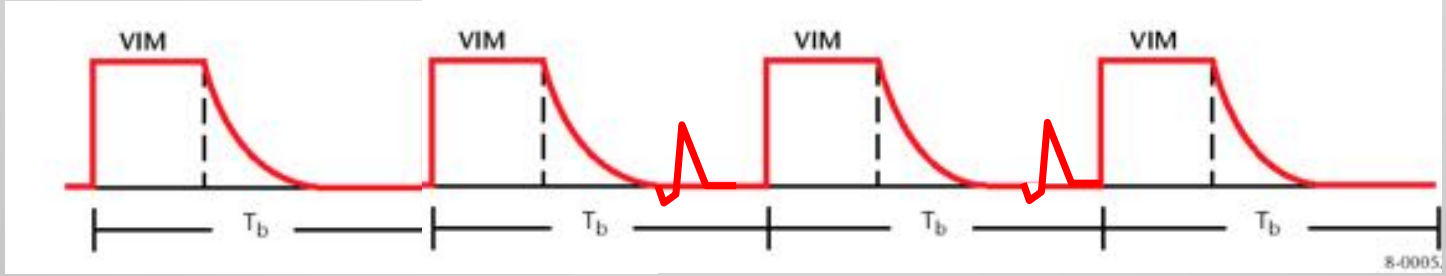


Pressure Control: preferable in paeds/ neonates

- Pressure is constant throughout inspiration.
- Ventilator adjusts the flow to maintain the pressure.
- Flow decreases throughout the inspiratory cycle.
- Volume delivered depends upon the inspiratory pressure, I-time, pulmonary compliance and airway resistance.
- The delivered volume can vary from breath-to-breath depending upon the above factors. MV not assured.
- Good mode in paediatrics & neonates if lots of dead space in tubing, and increased risk of Pneumothorax in Neonates.
- Good mode to use if patient has large air leak, because ventilator will increase the flow to compensate.

IMV (Intermittent Mandatory Ventilation)

- **Characteristics:** set breath delivered at a fixed interval. No patient interaction, but allows the patient to breath through the ventilator circuit by providing gas flow(unlike CMV).
- Can be pressure or volume control
- **Contraindications:** none but unfriendly to older patients
- **Advantages:** regular guaranteed breath
- **Disadvantages:** does not allow patient to breath with ventilator except by chance. Does not work with the patient



Assist Control: Pressure or Volume Control

- **Characteristics**:
  - preset rate and tidal volume/ PIP
  - full mechanical breath is delivered either triggered by patient's respiratory efforts, or if not sufficient preset mechanical rate is maintained automatically
- **Uses**: for patients with very weak respiratory effort, allows synchrony with the patient but maximal support.
- NOT a weaning mode, as getting complete mechanical support.

- **Advantages**: a fairly comfortable mode, providing a lot of support.
- **Disadvantages**: can lead to hyperventilation if not closely monitored, can't wean

Assist Control (Trigger - A/C)

Patient efforts recognized by ventilator:

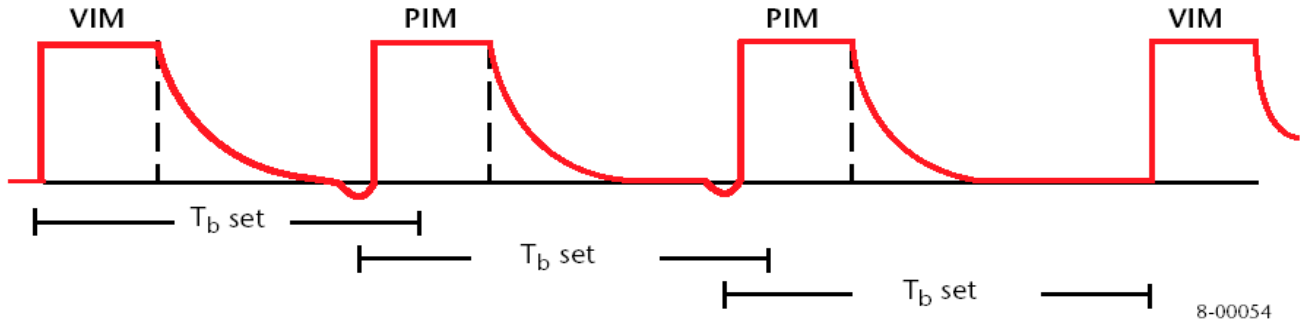


Figure 6-3. A/C mode, VIM and PIM breaths

Modes for Ventilation AND Weaning

The following modes fall into both Control and Support categories in that they have set rates, but the spontaneous breaths are not controlled, so they can be used in weaning.

- SIMV
- SIMV/PS
- CPAP +/- PS
- VS
- PS

SIMV (Synchronized IMV)

- Present breath delivered within interval based on preset RR.
- Pressure or volume controlled
- Ventilator waits for spontaneous breath from patient -> uses as trigger to deliver fully supported breath.
- If no spontaneous breath ventilator automatically delivers at end of period - TRIES TO SYNCHRONIZE WITH PATIENT

- Uses: commonly uses, also a weaning mode (with pressure support)
- CI: none
- Adv: patient friendly
- Disadv: any other breaths not supported

SIMV: synchronised & spontaneous

If patient tries to breathe during Tm, the ventilator gives a FULLY ASSISTED BREATH

If patient tries to breathe during Ts, ventilator ALLOWS patient to take the breath

Assistance may or may not be provided with PRESSURE SUPPORT

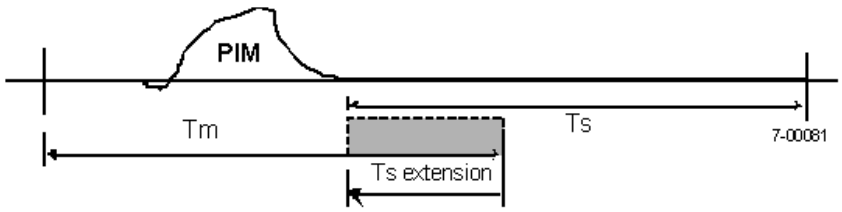


Figure D-3. Synchronizing breath intervals with patient effort

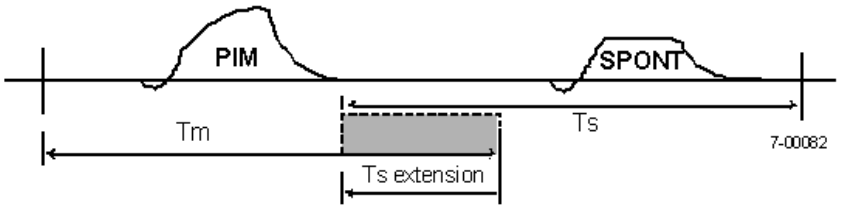


Figure D-4. Spontaneous breaths during SIMV

VS/Volume Support

- **Characteristics:** variable level of pressure support is delivered on each spontaneous patient-triggered breath in order to achieve preset tidal volume.
- All breaths are triggered by the patient.
- The clinician presets: V_T, FiO2, PEEP,
- The patient determines the RR, Ti, I:E ratio.

- **Uses:** a weaning mode. The concept is that as the patient becomes stronger, or more awake they will make more respiratory effort on their own. The more effort they make the less support they will need from the ventilator and hence the level of pressure delivered will get smaller.
- **Contraindications:** patient who is not spontaneously breathing, as there is no back-up rate.
- **Advantages:** greatly decreases the number of interventions needed to wean patient from a ventilator versus traditional weaning

PS /Pressure Support

Characteristics: each spontaneous breath supported with supplemental flow to achieve a preset pressure.

1. All the breaths are triggered by the patient
2. Preset value : PIP, PEEP, FiO2.
3. Patient determine: rate, Ti, I:E ratio, TVi.
4. Needs intact resp. drive.

Uses: In the spontaneously breathing patient this helps overcome the airway resistance of the endotracheal tube. Can be very helpful for weaning.

Contraindications: patient who is not spontaneously breathing, i.e. on muscle relaxants

Advantages: helps overcome resistance of tube, making spontaneous breathing easier

SIMV / PS

- Combination SIMV and Pressure Support
- Extra breaths in cycle are supplemented with Pressure Support
- CI: None
- Adv: Allows synchrony with patient and helps overcome resistance in ETT, to allow easier spontaneous breathing.
- Disadv: none

Continuous Positive Airway Pressure (CPAP)

- Ventilator mode where pressure above atm. pressure maintained throughout respiratory cycle during spontaneous breathing
- Pressure in the airway is always positive: →
  - support on inspiration
  - resistance on expiration
- Use: Assisted Spontaneous Breathing → reduced work of breathing, prevention muscle fatigue
- Adv: increased lung volume, Ventilation / perfusion
- Prevention & resolution atelectasis; decreased VILI

CPAP

Indications

- Pts with upper airway soft tissue obstruction
- Tendancy for airway collapse
- Final mode prior to extubation in patients intubated > 3 days
- Preterms
- (avoid intubation)

Contraindications

- asthma, other obstructive disease
- Hypercapnia
- No spontaneous effort

PEEP

Good….

- Good….
  - Recruits Alveoli
  - ↑ FRC
  - Redistributes Pulmonary Edema Fluid
  - ↓intrapulmonary shunt
  - ↑ PaO_2

Bad…

- ↓'d Venous Return / C.O.
- May ↑ ICP,/ intensify cerebral ischemia
- Overdestention/↑'s Risk of Barotrauma
- May impair oxygenation????

Tracheo-bronchial distention due to PEEP application leads to a progressive recruitment of alveoli. On the left, PEEP 2cm ; on the right, 10 cm H2O PEEP

Ventilator Settings: (1) Remember!

- No optimum mode of ventilation for any disease state
- No optimum method of weaning patients from mechanical ventilation.
- Mechanical ventilation is associated with adverse consequences: volutrauma, barotrauma, oxygen toxicity.
- To minimize side effects, physiologic targets need not be in normal range.
- Aim $FiO_2 < 0.5$ to avoid VILI & retinopathy
- For lung disease without brain injury: use controlled hypoventilation,
- Neonates & infants: good lung up for better gas exchange (opposite in adults – dependent)

Ventilation: Settings (2)

Start & Settings

- PIP or Tidal vol (V_T) → watch chest move
- Pressure-controlled* if < 15 kg
- PIP 24 cm
- PEEP 3-5cm
- FiO2 0.6-1.0
- V_T : 8-10 ml/ kg*
- I time 0.2/ 0.3-0.5
- Triggered Ventilation:
  - more comfortable than IMV
  - uses lower airway pressures & lower V_T

*Pressure-controlled always easiest

Rate (breaths/min)

• Neonate	30-40
• Six months- 1 yr	24-30
• 1 -5 years:	20-24
• 5-12 years	16-20
• >12	12-16

Do ABG @ 15 mins

Troubleshooting:

PCO_2 too high

- Patient's minute ventilation too low:
  - increase rate or TV or both.
  - If using PC ventilation, increase PIP.
- If PIP too high: increase the rate
- Air-trapping:
  - decrease rate and I-time
  - increase the TV to allow complete exhalation.

Sometimes you have to live with the high pCO_2: so use bicarbonate to increase the pH to >7.20.

PCO_2 too low:

- Minute ventilation is too high: Lower either rate or V_T
- Don't need to lower the V_T if PIP is <20.
- TV needs to be 8ml/kg or higher to prevent progressive atelectasis
- If patient spontaneously breathing, lower pressure support if spontaneous TV >7ml/kg.

pO_2 Too Low

- Increase either the FiO_2 or the mean airway pressure (MAP).
- Try to avoid FiO_2 >70%.
- Increasing the PEEP is the most efficient way of increasing the MAP in the PICU.
- Can also increase the I-time to increase the MAP (PC).
- Can increase the PIP in Pressure Control to increase the MAP,
- May need to increase the PEEP to over 10, but try to stay <15 if possible.

PIP Too High

- Decrease the PIP (PC) or the TV (VC).
- Increase the I-time (VC).
- Change to pressure control: achieves same TV at a lower PIP than volume control.
- If the high PIP is due to high airway resistance, generally the lung is protected from barotrauma unless air-trapping occurs.

Complications of Mechanical Ventilation

- Pulmonary
  - Barotrauma
  - Ventilator-induced lung injury
  - Nosocomial pneumonia
  - Tracheal stenosis
  - Tracheomalacia
  - Pneumothorax
- Cardiac
  - Myocardial ischemia
  - Reduced cardiac output
- Gastrointestinal
  - Ileus
  - Hemorrhage
  - Pneumoperitoneum
- Renal
  - Fluid retention
- Nutritional
  - Malnutrition

Acute Deterioration

Differential Diagnosis

- Pneumothorax
- Pneumonia
- Malposition of the ETT
- Pulmonary edema
- Airway occlusion
- Ventilator malfunction
- Mucus plugging
- Air leak

Physical Exam

- Tracheal shift
  - Pneumothorax
- Wheezing
  - Bronchospasm
  - Mucus plugging
  - Pulmonary edema
  - Pulmonary thromboembolism
- Asymmetric breath sounds
  - Pneumothorax
  - Mainstem intubation
  - Mucus plugging with atelectasis
- Decreased breath sounds bilaterally
  - Tube occlusion
  - Ventilator malfunction

Weaning

A. Infants intubated < 3 days: extubate from rate of 6-10, no not need endotracheal CPAP before extubation.

B. Infants intubated > 3 days: extubate to nasal CPAP

C. CPAP/PS for 1hr for older children and adolescents

1. Rapid reduction IMV rate to 5/min (NOT gradual reduction)
2. Wean I-time to <50%
3. Wean PEEP to <3-5cm H_2O
4. Wean FiO_2 to <40%
5. Extubate when spontaneous breathing from rate 5/min

- Patient should have normal blood gas and work-of-breathing on the following settings:
  - FiO_2 <40%
  - PEEP 3-5cm H_2O
  - Spontaneous TV of 5-7ml/kg

Extubation Criteria

Neurologic

- Level of sedation low enough that the patient doesn't become apneic once the ETT is removed.
- No apnea on the ventilator.
- Patient must be able to protect airway - cough, gag, swallow reflexes.
- Must be strong enough to generate a spontaneous TV of 5-7ml/kg
- Being able to follow commands is preferred.

Cardiovascular

- Patient must be able to increase cardiac output **(HR, BP)** to meet demands of work of breathing.
- Patient should have evidence of adequate cardiac output without being on significant inotropic support i.e **PU'g**
- Patient must be hemodynamically stable: good perfusion & age-appropriate blood pressure.

Neonatal Ventilation (1): Ventilator set up

	IMV	SIMV	A/C	Pressure-Control
Inspiratory time I_T	0.2-0.5	0.2-0.5	0.2-0.5	Set time 0.3-0.5
Respiratory rate RR	Set based on condition	Set based on condition	Set lower limit for apnea	Set lower limit for apnea
Peak Insp Pressure PIP	Set based on condition V_T	Set based on condition V_T	Set limit based on V_T	Set limit based on V_T
PEEP	4-10	4-10	4-10	4-10
Tidal volume V_T	4-8ml/kg	4-8ml/kg	4-8ml/kg	4-8ml/kg
Flow	3-15 L/min	3-15 L/min	3-15 L/min	3-15 L/min
FiO_2	Adjust according to O_2 sats	Adjust acc to O_2 sats	Adjust acc to O_2 sats	Adjust acc to O_2 sats

Neonatal Ventilation (2) Principles Less is More!

- Minimum flow rate: 2-3L/kg*/min
- Headbox O_2: gas flow 2-3L/kg*/min
- Nasopharyngeal Oxygen: Insert distance Ala nasi→ tragus; 150ml/kg*/min delivers ~50% oxygen

*estimated weight