

INVASIVE MECHANICAL VENTILATION

Defined as mechanical ventilation via an artificial airway which can either be via endotracheal tube or tracheostomy tube.

In our ICU, there are 3 types of ventilators: Servo^l, Servo 300 and Servo 900.

Invasive mechanical ventilation is indicated for patients with severe hypoxaemia, which cannot be oxygenated by other less invasive means. It is also indicated for patients incapable of maintaining adequate alveolar hypoventilation.

Common indications for invasive mechanical ventilation: (list not exhaustive)

1. Acute pulmonary oedema
2. Pneumonia
3. ARDS
4. Severe asthmatic attack
5. Severe acute exacerbation of COPD
6. Guillain-Barre syndrome
7. Myasthenia gravis
8. Drug overdose
9. Shock
10. Severe sepsis

Invasive mechanical ventilation using Servo 300 ventilator

You can get an interactive tutorial on how to use the Servo 300 from one of the ICU computers

Common modes of ventilation in our ICU using Servo 300:

- 1) Volume control ventilation (VCV)
- 2) Synchronized intermittent mandatory ventilation + pressure support (SIMV+PS)
- 3) Pressure support /CPAP (PS/CPAP)
- 4) Pressure control ventilation (PCV)
- 5) Pressure regulated volume control ventilation (PRVC)
- 6) Volume support ventilation

The control panel of Servo 300 ventilator:

- 1) CMV frequency breaths per minute

It must be set in all ventilation modes even in spontaneous mode.

What does it mean?

In **VCV**, **PCV** and **PRVC** ventilation, it is the minimum respiratory rate the patient will receive. It is the rate of ventilator triggered breaths if the patient is apnoeic.

In **SIMV+PS**, it controls the duration of SIMV period, which is equal to 60/CMV rate in seconds. It must be higher than the SIMV rate you prescribe.

In **PSV** and **VS** ventilation, it determines the maximum duration of inspiration, beyond which the ventilator will automatically switch to expiration. The maximum duration of inspiration cannot exceed 80% of respiratory cycle (=60/CMV in seconds). It should be set higher than the patient spontaneous respiratory rate.

2) Inspiratory time %

It ranges from 10% to 80% of the breath cycle. It should be set in all modes except pressure support ventilation. Note: In SIMV + PS, the SIMV period is used in the calculation of inspiratory time, not the SIMV cycle. In PS ventilation, the patient controls the duration of inspiration, but it cannot exceed 80% of the duration of breath cycle determined from the prescribed CMV rate.

3) Pause time %

It ranges from 0 to 30% of the breath cycle. It determines the duration of end-inspiratory pause when there is zero flow. The pressure at the end-inspiratory pause is more reflective of the alveolar pressure and therefore, more related to the risk of barotrauma. Large difference in peak airway pressure and pause pressure (> 10 cm water) is suggestive of airway obstruction (eg in acute asthmatic attack or kinking of endotracheal tube). The sum of inspiratory time % and pause time % cannot exceed 80%. If it does, the duration of pause time will be reduced.

4) Inspiratory rise time %

It ranges from 0% to 10%. It determines the time required for the pressure to increase to the preset level. It should be prescribed in all ventilation modes.

5) SIMV frequency breaths per minute

It controls the duration of SIMV cycle, the number of mandatory breaths delivered by the ventilator. If the patient is apnoeic, this is the minimum number of breaths the patient will receive (not the CMV rate!). It should be set lower than the CMV rate.

6) Triggering sensitivity

It controls the sensitivity and methods by which the ventilator detects patient inspiratory effort. It can be flow-triggered or pressure-triggered. If the triggering is too sensitive, there is risk of auto-triggering, in which small leaks in the circuit might erroneously be interpreted as inspiratory effort of the patient. The ventilator might deliver breaths when patient actually does not need it. If the triggering is too insensitive, the work of breathing of the patient might actually increase.

7) Pause hold

- Inspiratory pause hold knob: When turned, the inspiratory and expiratory valves close after inspiration. As long as the knob remained turned to inspiratory pause, the pause is prolonged for a maximum up to 5 seconds. This allows the exact measurement of end inspiratory pause pressure, which is useful in ventilation of patients with obstructive airway diseases.
- Expiratory pause hold knob: When turned, the inspiratory and expiratory valves close after expiration. As long as the knob remained turned to expiratory pause, the pause is prolonged for a maximum up to 30 seconds. This allows the exact measurement of the end-expiratory lung pressure. Auto-PEEP can be measured in ventilation of patients with obstructive airway diseases.

Volume controlled ventilation (VCV)

- It provides a controlled ventilation with a preset tidal volume and respiratory rate independent of the respiratory compliance or resistance (within upper pressure limit)
- The inspiratory time and pause time is controlled.
- The flow is constant.
- This is the same as assisted controlled ventilation (ACV) as described in many textbooks
- If the patient is inspiring while on VCV causing sufficient pressure drop or flow changes (as determined by triggering sensitivity), the ventilator will deliver a volume controlled breath according to the preset values.
- The maximum allowed inspiratory time is 80% of the respiratory cycle (duration = $60/CMV$ in seconds)

- If the set upper pressure limit is reached, the ventilator will shift to expiration and alarm for high airway pressure.

The parameters you need to prescribe are:

1. Tidal volume
2. CMV frequency
3. Inspiratory time %
4. Pause time %
5. Rise time %
6. FiO₂
7. Trigger sensitivity
8. PEEP
9. Upper pressure limit

Pressure support / CPAP

- When the patient inspires, the inspiration is assisted by pressure at preset pressure support level. The actual level of airway pressure = PS + PEEP
- The flow is decelerating.
- All breaths are triggered by the patient
- The patient determines the respiratory rate and I:E ratio. This might change from time to time
- Inspiratory phase will be switched to expiratory phase if
 - a) The inspiratory flow drops to 5% of the peak flow necessary to deliver the breath
 - b) The inspiratory time exceed 80% of the cycle (60/CMV in seconds)
 - c) The upper pressure limit is reached

Parameters you need to prescribe in PS/CPAP:

- 1) Upper pressure limit
- 2) Pressure support level above PEEP
- 3) PEEP
- 4) CMV frequency
- 5) FiO₂
- 6) Inspiratory rise time %
- 7) Trigger sensitivity

Synchronized intermittent mandatory ventilation (volume controlled) + pressure support

- A breath cycle consists of SIMV period and non-SIMV period
- SIMV period precedes non-SIMV period
- The duration of SIMV period equals $60/\text{CMV}$ in seconds. The duration of a breath cycle equals $60/\text{SIMV rate}$ in seconds.
- The preset CMV rate must be greater than the SIMV rate
- If the patient triggers within the SIMV period, the ventilator will deliver a SIMV breath (volume controlled breath with constant flow) as determined by the preset tidal volume, inspiratory time and pause time.
- If the patient triggers the ventilator after the SIMV breath within the same breath cycle, a pressure support breath will be delivered as determined by the prescribed pressure support level and PEEP.
- If the patient does not trigger the ventilator, a mandatory SIMV breath will be delivered by the ventilator at the end of SIMV period according to the preset tidal volume, inspiratory time and pause time.
- If a patient is apnoeic, the patient will receive volume controlled ventilation according to the preset tidal volume with the breathing rate same as the SIMV rate.

The parameters you need to prescribe when using SIMV(VC) +PS:

- 1) Tidal volume
- 2) Inspiratory time %
- 3) Pause time %
- 4) SIMV rate
- 5) CMV frequency
- 6) PEEP
- 7) Pressure support above PEEP
- 8) Trigger sensitivity
- 9) FiO_2
- 10) Upper pressure limit

Pressure control ventilation (PCV)

- Constant pressure breaths are delivered during inspiration
- Ventilation is either by started by the ventilator or by a patient triggering effort.
- "Protect" patient against high peak pressure
- Decelerating flow pattern

- Controlled respiratory rate and I:E ratio
- In Servo 300, the inspiratory time is set according to the CMV rate and the inspiratory time. The maximum inspiratory time is 80% of the respiratory cycle
- There is no inspiratory pause. Expiration starts as soon as inspiration ends.
- Tidal volume is variable, depending of the changes in respiratory compliance and resistance.
- If the set upper pressure limit is reached, the ventilator will immediately shift to expiration and give alarm for high airway pressure.

Parameters you need to prescribe when you are using PCV

- 1) Upper pressure limit
- 2) Pressure control above PEEP
- 3) PEEP
- 4) Trigger sensitivity
- 5) CMV frequency
- 6) Inspiratory time%
- 7) Inspiratory rise time
- 8) FiO₂

Pressure-regulated volume control (PRVC)

- Breaths are delivered with preset tidal volume and frequency with preset inspiratory time
- The ventilator automatically adjusts the inspiratory pressure control level to ensure the lowest level of inspiratory pressure in delivering the preset tidal volume
- The inspiratory pressure is maintained constant during the whole inspiratory period
- The inspiratory flow is decelerating.
- Upper pressure limit is particularly important in PRVC mode.
 - If the upper pressure limit is reached, the ventilator immediately changes to expiration and gives alarm for high airway pressure.
 - If the difference between the upper pressure limit and the peak airway pressure is less than 5 cm water, a "limited pressure" alarm is given. The tidal volume delivered will be less than the preset.
- Maximum allowed inspiratory time is 80%
- The patient can initiate breaths depending on the trigger sensitivity.

Parameters you need to prescribe when you use PRVC:

1. Upper pressure limit
2. PEEP
3. Trigger sensitivity
4. CMV frequency
5. Inspiratory time %
6. Inspiratory rise time %]
7. Tidal volume
8. FiO₂

Volume support (VS)

- Patient triggers every breath.
- The ventilator automatically adjust the inspiratory pressure to ensure the lowest possible inspiratory pressure to deliver the preset tidal volume
- The inspiratory pressure is maintained constant during inspiration
- The inspiratory flow is decelerating
- The patient triggers every breath. The patient determines the breathing rate and the inspiratory time
- If there is apnoea, there is automatic back-up with PRVC mode of ventilation
- Inspiration stops and expiration starts when the peak flow drops to 5% of the initial flow
- The upper pressure limit is also important in VS.
 - ◆ If the upper pressure limit is reached, the ventilator immediately changes to expiration and gives alarm for high airway pressure.
 - ◆ If the difference between the upper pressure limit and the peak airway pressure is less than 5 cm water, a "limited pressure" alarm is given. The tidal volume delivered will be less than the preset.
- Maximum inspiratory time is 80% of the respiratory cycle.
- If there is apnoea, the ventilator will revert to the PRVC mode at the set CMV rate, inspiratory time, tidal volume as specified in the volume support mode. It will remains in the PRVC mode until the alarm is reset.
- As the patient pulmonary compliance improves, the respiratory rate and the difference between peak airway pressure and PEEP should decrease.

Parameters you need to prescribe in VS

1. Tidal volume

2. Upper pressure limit
3. PEEP
4. Trigger sensitivity
5. CMV frequency
6. Inspiratory time %
7. Inspiratory rise time %

Invasive mechanical ventilation using Servo/

Compared with Servo 300, Servo/ is a much more sophisticated ventilator. The basic principles described are also applicable in most of time when Servo/ ventilator is used. The reader is strongly advised to refer the Servo/ ventilator tutorial (<http://www.aic.cuhk.edu.hk/web8/download.htm>) written by Dr Charles Gomersall for more comprehensive information.

Servo/ is different from Servo 300:

- 1) For Servo 300, in SIMV mode, a mandatory breath will be delivered by the ventilator at the end of SIMV period if the patient does not trigger the ventilator. However, for Servo/, the mandatory breath will be delivered at 90% of the SIMV period if the patient does not trigger the ventilator.
- 2) In Servo/, I:E ratio, ranging from 1:10 to 4:1, can be directly dialed in. In Servo 300, it is calculated from the inspiratory time %.
- 3) For VSV and PSV, in Servo 300, inspiratory phase ends when the inspiratory flow falls to 5% of the maximum inspiratory flow. In Servo/, this value can be adjusted by changing the inspiratory cycle-off (1-40%).
- 4) For VSV and PSV, the apnoea time for Servo 300 is fixed at 20 seconds. The apnoea time for Servo/ can be adjusted from 15 s to 45 s. If patient remains apnoeic for longer than the preset apnoeic time, the ventilator will switch from a support mode to control mode
- 5) In Servo 300, the inspiratory rise time (range: 0-10%) is adjusted as a percentage of total breath cycle. In Servo/, the inspiratory rise time (range: 0-20%) is adjusted as a percentage of total breath cycle in control mode and SIMV. It is adjusted in absolute time in support mode (range: 0-0.4 s).
- 6) In Servo 300, the SIMV period is equal to 60/CMV rate in seconds. In Servo/, the SIMV period is equal to the set breath cycle time.