MECHANICAL VENTILATION

In Critical Care we generally use servo I ventilators which can be used for invasive (ETT) and non-invasive (Mask/Nasal CPAP) ventilation. We also use the oscillator for invasive ventilation and CPAP drivers (Infant Flowcare) for neonates. Other machines you may see are the VISION for non-invasive ventilation in HDU, and VPAP, Sullivan, Legendair and BREAS, which are mainly used for children who require respiratory support at home.

Basic Concepts of Mechanical Ventilation

The function of the respiratory and cardiovascular systems is to deliver oxygen (O2) to the tissues and to eliminate carbon dioxide (CO2).

The aim of ventilation is to maintain adequate gas exchange in the Lungs. Patients with respiratory problems will generally have an increase in CO2 in their blood gases. CO2 can be reduced by clearing the airways with suction, or by mechanically increasing the respiratory rate or the size of the breath (i.e. increasing ventilation rate, pressure or volume).

To generate the necessary pressure, access to the child's airway is required. This is normally obtained using an oral or nasal endotracheal tube (ETT), a tracheostomy tube, or if non-invasive ventilation is desirable, by a well sealed mask.

Modes of Ventilation

Different modes/methods of ventilation allows an individualised treatment plan responsive to the child's presenting pathology and needs.

CONTROLLED MODES	SUPPORTED MODES	COMBINED MODES	SPONTANEOUS BREATHING
VC	PS	AUTOMODE: VC-VS	CPAP
PC	VS	AUTOMODE: PC-PS	Nasal CPAP
PRVC	NIV-PS	AUTOMODE: PRVC-VS	
NIV-PC		SIMV: VC+PS	
		SIMV: PC+PS	
		SIMV: PRVC+PS	

PC (Pressure Controlled Ventilation) [servo i]

In this controlled mode of ventilation, the ventilator delivers a breath to a set pressure, and at a set rate. This is primarily used when the patient has no spontaneous breathing but will support the patient if they are able to trigger a breath.

If the pressure is set at PC 16 above PEEP of 4, then the ventilator will deliver a top pressure (peak pressure) of 20 (PC level of 16 plus PEEP) with an end pressure of 4. This keeps the airways slightly open, making it easier to inflate them, and help prevent collapse and consolidation.

VC (Volume Control Ventilation) [servo i]

In volume control mode a preset tidal volume is delivered at a set rate, primarily used when the patient has no spontaneous breathing.
If the volume is set at 4.5 litres and a rate of 20, then the volume delivered with each breath will be 225mls per breath (4500mls/20 =225mls). The air is delivered during the inspiratory phase, held in the lungs during the pause phase, and then released during the expiratory phase.
Peak pressure can vary from breath to breath depending on the patient's compliance and resistance. If the patient's compliance reduces or resistance increases the peak pressures will increase to ensure the set tidal volume is achieved. This volume would be delivered with each breath regardless of the pressure required so it is very important to check the upper pressure alarm setting is at a suitable value to protect the patient's lungs. (If the upper pressure limit is reached inspiration will stop and change to expiration.)

PRVC (Pressure Regulated Volume Control) [servo i]

PRVC is a controlled mode of ventilation which combines pressure and volume controlled ventilation. A preset tidal volume is delivered at a set rate, similar to VC, but it is delivered with the lowest possible pressure.
It is very important to check the upper airway pressure preset alarm limits as this is the only factor that limits the pressures from increasing to potentially damaging levels. The maximum available pressure limit is 5cmH2O below the preset upper pressure alarm limit. If this is reached the ventilator will alarm "regulation pressure limited", switch to expiration, and will not be able to deliver the preset tidal volume.

AUTOMODE [servo i]

All three of these controlled modes of ventilation have an option called automode which automatically controls the transition between controlled (ventilator triggered) and support (Patient triggered) mode in accordance with the patient's breathing efforts.
Automode allows the patient to go into a support mode automatically if they trigger the ventilator:

Pressure Control ⇒ Pressure Support
Volume Control ⇒ Volume Support
PRVC ⇒ Volume Support

If the patient does not make any respiratory effort, the ventilator will remain in the controlled mode or revert back to the controlled mode from the support mode.
Note: Automode is not possible in NIV

* A Purple "T" appears on the screen when the patient triggers a breath on any mode

SIMV (Synchronised Intermittent Mandatory Ventilation) [servo i]

This mode is used to assist patient's who have some, but not sufficient breathing and can be used for weaning. The ventilator provides mandatory breaths which are synchronised with the patient's spontaneous efforts at a pre-set rate. There are three different SIMV modes on the servo I:

- SIMV Volume control and Pressure support
- SIMV Pressure Control and Pressure Support
- SIMV PRVC and Pressure Support

The mandatory breath is defined by the basic settings (control mode), the SIMV rate is the rate of mandatory breaths per minute, and the spontaneous/supported breath is defined by setting the pressure support level above PEEP

Pressure Support Ventilation (PS) [servo i]

Pressure Support provides support for every patient triggered breath and is used for patients who do not have sufficient capacity or to facilitate weaning. The patient initiates the breath and the ventilator delivers support with the preset pressure level above PEEP. With the support of the ventilator, the patient regulates the respiratory rate and tidal volume. Although there is no respiratory rate set on this mode there is a safety back-up ventilation function on the servo i if the patient becomes apnoeic. (This may not be the case with other ventilators).
*It is very important to monitor the tidal volumes and respiratory rate as this mode is completely spontaneous.

Volume Support (VS) [servo i]

Volume support works in a very similar way to pressure support but the tidal volume and PEEP are set rather than the pressure. The patient initiates the breath and the ventilator delivers support in proportion to the inspiratory effort and the target volume. The set tidal volume is delivered to the patient with different support from the ventilator depending on the patient's activity.

Continuous Positive Airway Pressure (CPAP) [servo i]

When PEEP is applied without other forms of ventilation it is called CPAP. Continous Positive Airway Pressure is maintained in the airways preventing collapse, but the patient regulates all other respiratory functions.
On the Servo I CPAP works in the same way as PS but the PS level is set to zero, and if the apnoea alarm is triggered it will switch to backup ventilation.
Note: As with all spontaneous modes it is very important to monitor the respiratory rate and effort.

TROUBLESHOOTING

Remember DOPE:
D: Displaced Tube?
O: Obstruction?
P: Pneumothorax?
E: Equipment Failure?

POSSIBLE COMPLICATIONS OF MECHANICAL VENTILATION
• ACCIDENTAL EXTUBATION • BLOCKAGE [SECRETIONS / BLOOD] • ASPIRATION • TRACHEAL DAMAGE [ETT/SUCTION] • INFECTION • INTUBATION OF RIGHT BRONCHUS • BAROTRAUMA [PNEUMOTHORAX] • HYPO/HYPERVENTILATION • VENTILATOR DEPENDANCY /INABILITY TO WEAN • STRESS ULCERATION OF THE GI TRACT • HYPOTENSION • RISE IN CVP • DECREASE IN RENAL FUNCTION • MECHANICAL EQUIPMENT FAILURE

Always ask more senior members of staff or the education team if you feel there may be a problem with your patient or you have any queries. If there is a serious problem with your patient or the equipment call for help or pull the emergency buzzer.

Ventilator and Ventilator Alarm Setting

In the PICU the Medical staff are responsible for programming all ventilator setting and alarm limits. Nursing staff should not alter ventilator settings or alarm limits but are responsible for checking them and informing the medical staff or senior nursing staff if they are not appropriately set and need changed. In the case of faults, alarms should not be continuously overridden. The nurse in charge and the bioengineering department should be informed.

All monitoring equipment should be checked by the nurse and documented at the beginning of each shift (as part of the safety checks) and ventilator settings should be checked every hour and documented.

Non Invasive Ventilation (NIV)

Non-Invasive Ventilation refers to the delivery of mechanical ventilation using a face mask or similar device, rather than an ETT.

It is important that the following criteria are met before commencing NIV:

- ❑ The patient must be conscious and breathing spontaneously
- ❑ The patient must have an adequate gag and cough reflex.

NIV Pressure Control (Servo i)

In this controlled mode of ventilation, the ventilator delivers a flow to maintain the preset pressure at a set respiratory rate and inspiratory time (similar to invasive PC). The patient can also trigger a patient controlled breath.

NIV Pressure Support (Servo i)

NIV PS is a spontaneous mode of ventilation where the patient initiates the breath and the ventilator delivers support with the preset pressure level. The patient regulates the respiratory rate and tidal volume so the alarm parameters must be set appropriately.

Note: CPAP can be delivered on this mode by turning the PS to 0 and only setting the PEEP.

Nasal CPAP (servo i)

Nasal CPAP can be delivered on the servo i by nasopharyngeal tube, nasal mask or nasal prongs on infants from 500g to 10kg. The CPAP Level (cmH2O) and oxygen concentration is set and the ventilator will deliver the flow necessary to maintain the desired pressure compensating for the leak. (The max flow is 33L/min)

During all servo i NIV the ventilator automatically adapts to the variation of leakage in order to maintain the set pressures. However, if the leakage is excessive or the patient is disconnected the ventilator will alarm and pause the ventilation.

Vision

Non Invasive BiPAP, or S/T (Spontaneous Trigger) Mode, works in a similar way to PS.

In normal respiration each breath consists of two phases: an inspiratory and an expiratory phase. BiPAP works by providing assistance during the inspiratory phase of respiration and preventing airway closure during the expiratory phase. Assistance during the inspiratory phase (Inspiratory Positive Airway Pressure- IPAP) is in the form of pressure support. At the end of each inspiratory phase a continuous positive pressure (CPAP) is maintained and is termed expiratory positive airway pressure (EPAP)

The BiPAP ventilator alternates between IPAP and EPAP synchronising with the patient's breathing pattern or at a set synchronised rate.

Viasys Infant Flow SiPAP (CPAP Driver)

The Infant Flow SiPAP provides non-invasive respiratory support via nasal prongs or nasal mask.

The O2 and Flow (pressure flow) is set (usually 8-10 l/min) and the level of CPAP achieved is dependent on the leak. Generally a CPAP of 4-6cmH2O is required to be effective. An apnoea sensor can be attached to the machine for monitoring and alarms

Frequently Used Terms

Auto-Triggering/Self-Triggering: ventilator self-triggering caused by water in the tubing or the trigger sensitivity being set too high.
Automode: Mode that automatically switches between controlled and supported mode depending on patients needs.
BIPAP: Biphasic positive airway pressure (non-invasive)
CPAP: Continuous positive airway pressure
EMV: Expired minute volume (l/min)
EPAP: Expired positive airway pressure
IPAP: Inspired positive airway pressure
IPPV: Intermittent positive pressure ventilation (fully controlled ventilation)
IMV: Intermittent mandatory ventilation – also known as intermittent mechanical ventilation (fully controlled ventilation)
Inspiratory Cycle Off: The point at which inspiration changes to expiration in spontaneous and supported modes (The servo I default is 50% for adults and 30% for infants)
Inspiratory Rise Time: The time taken to reach peak inspiratory flow or pressure at the start of each breath (either as % or time in seconds)
Leak: Air escaping around the ETT causing a sound a bit like snoring
MV (IMV): Minute Ventilation (Inspired minute volume l/min) [tv x RR]
Pause Time: Time between the end of an inspired breath and exhalation (no flow)
PCV: Pressure controlled ventilation
PEEP: Positive end expiratory pressure
PIP: Peak inspired pressure: maximum pressure measured during a breath
Peak pressure: Maximum pressure measured during a breath
PRVC: Pressure regulated volume control
PS/CPAP: Pressure support / Continuous positive airway pressure (Supportive mode where the patient is initiating all their own breaths).
SIMV PC/S: Synchronised intermittent mandatory ventilation pressure control / support (Supportive mode. Can be full ventilation or used for weaning)
SIMV VC/S: Synchronised intermittent mechanical ventilation volume control / support (Supportive mode. Can be full ventilation or used for weaning)
Ti (IT): Inspiratory time. Time for active flow or pressure delivery to the patient
Trigger Sensitivity: Setting that can be changed to make it easier or harder for the patient to initiate (trigger) their own breathing.
Tv (Vt): Tidal volume (mls). The amount of air being inspired/expired during a breath.
VCV: Volume controlled ventilation