

Noninvasive Mechanical Ventilation (NMV)

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Definition

Mechanical ventilation (MV) is used to augment or take over an individual's spontaneous respiration. This intervention may be required to address acute oxygenation difficulties or compensate for ventilatory pump failure. Mechanical ventilation is usually continued until the acute lung injury and/or pump failure recovers. Less commonly MV is used as a treatment to control chronic hypoventilation in patients with chest wall, neuromuscular or obstructive lung disease. Long-term ventilatory support may be continuous or used for shorter periods e.g. during sleep.

Indications

Acute respiratory failure (ARF)

The objectives of mechanical ventilation in ARF are considered to be: i) to buy time for the cause of ARF to subside; ii) to improve pulmonary gas exchange, iii) to increase ventilation and lung volume and iv) to unload the ventilatory muscles [1]. NMV has been used to treat: 1) Acute on chronic respiratory failure (from COPD, restrictive chest wall disease, neuromuscular disease); 2) Acute hypoxaemic respiratory failure (from pneumonia, post surgery, in immunocompromised patients).

Controlled randomised studies have shown that both pressure support (PSV) and assist control ventilation (ACV) may be useful to avoid endotracheal intubation in acute on chronic respiratory failure of COPD patients. It has been shown also that noninvasive PSV can be a bridge to weaning from mechanical ventilation. Both PSV and ACV can improve ventilation and arterial blood gases as well as unload the inspiratory muscles in line with the goals of mechanical ventilation. Also in patients with hypoxaemic ARF noninvasive PSV was as effective as invasive PSV in improving gas exchange and was associated with fewer serious complications and shorter stays in intensive care unit (ICU).

Chronic hypercapnia (2)

Restrictive chest wall and stable neuromuscular disease. There has been no long-term randomised controlled study of NMV in chest wall or neuromuscular disease. However as death is the almost inevitable outcome of hypercapnic respiratory failure and cor pulmonale in these patient groups, and the overwhelming burden of evidence suggests that NMV is effective, a controlled study is now probably unethical. The mechanism of action of NMV in restrictive chest wall and neuromuscular disease, is to increase ventilatory drive during sleep and wakefulness.

As a consequence of this, patients arterial blood gas tensions become better controlled when breathing spontaneously during sleep ventilatory support. The “preventive” use of NMV, that is, the use in normocapnic patients is still debated.

Progressive neuromuscular disease. In these patients, a flexible approach is necessary to meet evolving needs. Some patients who develop ventilatory failure may start with NIPPV and then progress to MV by tracheostomy (T-MV) as bulbar weakness and increased ventilatory dependence occur. In others T-MV may be necessary throughout, or NMV can be continued long-term. Careful evaluation of swallowing function, ability to cough, and ventilatory capacity are essential.

Stable hypercapnic COPD. Up to now there is no clear indication for generalized use of this treatment in this disease.

Classification of ventilators

Volume preset/pressure preset ventilators

A range of ventilators has been designed primarily for domiciliary use. These may offer advantages in terms of performance over ventilators intended for intensive care application and are more easy to use in the home. Broadly classified into volume preset and pressure preset devices, early studies of long-term domiciliary NMV mainly concern patients on volume preset ventilators, whereas in the last 5-10 yrs pressure preset machines, particularly bilevel pressure support equipment has become more prominent. The use of different types of nasal ventilators in various acute and chronic situation has been described. Different modalities of ventilation can be delivered:

Control mode (CMV). Here the ventilator provides a fixed level of support which is independent of patient effort. This mode is applied when the respiratory muscles are paralysed such as during general anaesthesia, or when ventilatory effort on the part of the patient is absent or minimal. In individuals with some spontaneous ventilatory activity CMV may be poorly tolerated as desynchronisation occurs between the applied cycle and patient generated breaths. Significant hyperventilation or hypoventilation can also occur, so that close monitoring is mandatory. It has been suggested that complete suppression of spontaneous respiratory activity may lead to respiratory muscle atrophy. CMV is rarely indicated long-term.

Assist modes. These modes favour synchronisation between spontaneous ventilation activity and ventilator delivery and may prevent disuse atrophy of respiratory muscles, allow support to be tailored to the patient's needs and decrease the need for sedation and/or muscle paralysis.

Assist control ventilation (ACV). This mode is commonly used in both ICU and domiciliary settings. Each patient-triggered breath is aided by the ventilator. A back-up controlled respiratory rate is set and the machine will operate in this mode should spontaneous respiratory efforts fall below the preset level. With a volume preset ACV system, tidal volume (VT), inspiratory flow rate, flow wave form and trigger sensitivity are set. The patient will continue at his/her respiratory frequency providing this exceeds the back-up rate. There are also pressure targeted

assist control ventilators. In general ACV improves synchronisation and may be more comfortable for the conscious patient. However, the work of breathing (WOB) can be excessively high if peak flow generation is suboptimal. Hyperinflation can also occur. With pressure targeted ACV, VT may vary according to changes in airways resistance, lung compliance and ventilatory drive. However, as the preset pressure is rapidly achieved, inspiratory flow requirements are likely to be met [3].

Pressure support (PSV). PSV is most effective in patients with stable ventilatory requirements and those who are being weaned. Breaths are triggered by the patient and the method is unsuitable for individuals with significantly reduced ventilatory drive or fluctuating thoracic impedance. As each breath is triggered, pressure rises rapidly to a plateau and remains at this preset level for the duration of the inspiratory phase. Inspiration is terminated when inspiratory flow falls below a certain level, but if this change in flow rate is not detected time cycling usually occurs. The level of PSV may be adjusted to the patient's requirements as the reduction in WOB is directly related to the level of inspiratory pressure. High level can be provided to achieve near total ventilatory support and tailed to low levels to overcome the WOB generated by the ET, circuitry and demand valve as the patient's ventilatory ability recovers. Using PSV minute ventilation is not controlled and will be influenced by the spontaneous respiratory rate and respiratory mechanics of the patient. As a result hypoventilation may occur in an unstable patient [4].

Proportional assist ventilation (PAV). This mode is still under investigation. It provides a level of ventilatory assistance which is proportional to the patient's respiratory effort throughout the respiratory cycle [5].

“ICU” versus “home” ventilators

NMV with and without PEEP may be applied also by portable ventilators. Bilevel pressure ventilators are being used increasingly to provide ventilatory support also in the management of ARF. The ability of these ventilators to respond to inspiratory demand without exposing loads is variable. Most “home” ventilators perform as well as or significantly better than an adult “ICU” ventilator. Differences in the occurrence of rebreathing, and the speed of attainment of stable PSV level and expiratory resistance exist between “home” and “ICU” ventilators. A substantial rebreathing volume may be present for “home” devices with a constant inspiratory and expiratory level. This rebreathing volume decreases with increasing PEEP level, but may remain substantial at the widely used PEEP level of 5 cmH₂O. Use of a non-rebreathing valve may increase both the work imposed by the circuit during the expiratory phase and the time required to attain the relaxation equilibrium [6-8].

Hospital / home use

Hospital use of NMV is reserved to the treatment of ARF. For ARF NMV with and without PEEP may be applied by both “ICU” and “portable” ventilators.

Home use is reserved for treatment of Chronic Respiratory Insufficiency by portable ventilators. In these devices alarms should be required for less autonomous patients.

Cost considerations

The effectiveness of NMV with all modalities in ARF depends on strict staff supervision by nurses and physiotherapists. As a whole in an experienced unit, NMV is neither more time consuming nor more costly than endotracheal intubation [9].

Continuous positive airway pressure

Indications

Continuous positive airway pressure (CPAP) therapy is the treatment of choice for patients with symptomatic moderate or severe obstructive sleep apnoea syndrome. It may also be of value in some patients with mild sleep disordered breathing. CPAP is also used in the management of acute respiratory failure associated with pulmonary oedema, pneumonic consolidation and/or atelectasis.

Obstructive sleep apnoea/hypopnoea syndrome (OSA)

A placebo-controlled study and a sham CPAP controlled trial [10, 11] have now confirmed that CPAP is unquestionably effective at controlling daytime somnolence resulting from OSA and as a consequence improves quality of life, and may reduce the incidence of road traffic accidents. There is still controversy regarding the long-term cardiac and vascular consequences of OSA, and whether CPAP can modify these.

CPAP generators

CPAP prevents collapse of the upper airway by acting as a pneumatic splint. In addition it can augment functional residual capacity, recruit alveoli and reduce the work of breathing in acute respiratory failure. CPAP systems designed for home use consist of a pressure generator (blower) and patient interface. The compressor should be capable of delivering a constant pressure of around 3-20 cmH₂O throughout the respiratory cycle, despite inevitable leaks. The equipment should be compact, portable, inexpensive and function as quietly as possible. Several studies have suggested that there is little to differentiate between the CPAP machines on the market in terms of basic performance characteristics. However, there are a number of CPAP attributes which vary between models.

CPAP attributes

Constant delivery: Nearly all CPAP generators have the ability to compensate for leaks by adjusting flow delivery; *Ramp:* Many models provide an optional low initial pressure which rises to the preset CPAP level after a short delay, with the aim of allowing patients to gradually settle on to CPAP at night. This is not necessary for all patients; *Compliance record:* The ability of some CPAP machines to store data on average nightly and weekly usage for downloading is useful to monitor compliance; *Breathing detection:* Some models have the facility to detect

breathing for automatic start-up and shut down; Dual voltage: The ability to work at 110/220 volts is an advantage for patients who travel regularly; Humidification: Humidification is not necessary for all CPAP users, but may be helpful in patients with troublesome rhinitis. The simplest form of humidification consists of disposable heat and moisture exchangers which can be fitted into the circuit. Cold water bath pass-over humidifiers can be added to CPAP, and if these are not sufficient heated water bath humidification can be used.

Variable CPAP (Intelligent/ automatic CPAP): there are several systems now available which automatically adjust CPAP to match the patient's changing pressure needs. These can be employed initially to titrate CPAP in a single night study, or used long-term. While variable CPAP can be very useful for the purposes of titration, there is no evidence as yet to suggest that long-term variable CPAP is more effective than a standard fixed level. Further studies are needed to address this point, in particular in patients who find fixed CPAP difficult to tolerate.

Bilevel positive pressure therapy

This form of pressure support ventilation is discussed in the noninvasive mechanical ventilation section. Bilevel positive pressure ventilation may be helpful in patients with obesity hypoventilation syndrome, the overlap syndrome (COPD plus OSA), in mixed upper airway obstruction and hypoventilation due to neuromuscular disease, and in patients with ventilatory failure.

Cost considerations

Basic CPAP machines cost around one eighth of the cost of a bilevel positive pressure ventilator and are effective in uncomplicated cases of OSA. In the conditions complicated by hypoventilation listed above, bilevel ventilation may be indicated. There is no proof that bilevel positive pressure ventilation is better tolerated than CPAP in OSA.

Interfaces

The main interfaces for noninvasive ventilation and CPAP are nasal masks, full facemasks, mini masks, nasal plugs/seals or mouthpieces.

Masks

Usually made of silicone, masks need to be carefully fitted to the individual to obtain optimum results. Mask fit can be enhanced using mask cushions and seal/support rings which are supplied with the mask. Variations include the bubble-type mask, and gel masks.

1) Full facemasks cover the nose and mouth and can prove valuable in patients with nasal airway blockage or an acute confusional state. Some have a quick release mechanism to reduce the risk of aspiration. Mini-masks such as the Monarch (Respironics) have a reduced surface area in contact with the face and may be helpful in claustrophobic subjects;

2) Nasal plugs/seals are small interfaces which sit within the nares. Several sizes are manufactured, but at present none are small enough to use in young children; 3) Customised masks: can be constructed from kits e.g. Sefam kit. Semi customised masks are now coming

online. Here the mask frame is injected with a quick drying filler which facilitates moulding to the individual's facial contours; 4) Mouthpieces: as with nasal masks, commercial mouth pieces are available, but customised models can also be created. Mouthpiece ventilation is mainly used in patients with neuromuscular disease.

Summary

Non-mechanical ventilation is effective in the treatment of acute ventilatory decompensation due to COPD, and in selected other acute and chronic ventilatory disorders. Controlled studies have confirmed that CPAP is the management of choice in somnolent patients with moderate or severe obstructive sleep apnoea. There is no evidence that any one type of noninvasive ventilator or CPAP machine is superior, but a good understanding of physiology and the capabilities of equipment available will allow a more accurate matching of equipment to patient.

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