Review article

Current issues in mechanical ventilation

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Key points

This review deals with several grey areas in mechanical ventilation. Noninvasive ventilation for acute respiratory failure may be useful but careful choice of patients, identification of early signs of its failure and changeover to invasive ventilation is essential to improve outcome. Preservation of spontaneous ventilation during mechanical ventilation is currently being investigated. High frequency ventilation is useful in refractory cases. Rapid shallow breathing index corrected to weight needs to be studied. The ideal timing of tracheostomy is not known and is best to individualise the intervention.

Introduction

Mechanical ventilation is an established life saving measure in the management of the critically ill. Although it began by simulating the physiology of natural breathing by creation of negative intrathoracic pressure, mechanical ventilation in the present day almost always implies that it is intermittent positive pressure ventilation. The patient's lungs are ventilated with a specified amount of tidal volume at a specified rate to achieve the desired minute volume. The adequacy of which is checked by analysing arterial blood gases, particularly the pH and the carbon dioxide tension ($PaCO_2$).

Traditionally, volume controlled ventilation was used for all patients but pressure controlled modes evolved with increasing recognition of adverse effects of high pressures (barotrauma) on the alveoli. Dual controlled modes are now available where both volume and pressure can be controlled simultaneously. Present generation mechanical ventilators are so sophisticated and versatile that almost any combination of variables such as pressure, volume, time or flow can be chosen and adjusted as necessary with the aid of modern microprocessor systems. Despite all these, there are issues that remain to be addressed regarding mechanical ventilation.

Noninvasive ventilation for acute respiratory failure

Presence of tracheal tube itself has been a well recognised risk factor for nosocomial pneumonia. Non-invasive ventilation (NIV) is possible with modern ventilators that have improved capability to compensate for leaks. NIV may avoid the need for invasive ventilation, especially in early respiratory failure and has been increasingly used in this setting. It reduces the number of ventilated days and duration of ICU stay. Nava S and Hill N in their excellent review on NIV in acute respiratory failure have elaborated many issues with NIV.[1]

Girou *et al* found that NIV was associated with a reduced incidence of nosocomial pneumonia and reduced ICU stay compared to invasive ventilation.[2] This may be attributable to lesser number of invasive

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How to cite this article: Shenoy A. Current issues in mechanical ventilation. Ind J Resp Care 2012;1:15-20.

procedures, lesser microaspiration and better cough. Furthermore, the patients on NIV require less sedation and analgesia which may lead to shorter ICU stay.

The utility of NIV also extends to the management of cardiogenic pulmonary oedema and acute exacerbation of chronic obstructive pulmonary disease in selective group of patients.[3] Such patients should meet the criteria for instituting NIV (conscious with ability to maintain their own airway, minimal secretions and good cough). NIV may also be useful in immunocompromised patients where invasive procedures pose risk for development of life-threatening infections.[4] The role of NIV in acute lung injury is not yet clear as it has not shown to alter outcomes such as intubation rates and mortality.[5-11]

The issues about NIV in acute respiratory failure are two-fold: Firstly, the choice of patients and secondly, the time to intervene and institute invasive ventilation. Prolonging NIV with resultant delay in institution of invasive ventilation may adversely affect outcome. Failure to identify increasing hypoxia and respiratory failure may result in respiratory or cardiac arrest. Personnel experienced in tracheal intubation, initiation of mechanical ventilation and cardiopulmonary resuscitation must be immediately available to deal with these problems. Overuse of NIV for fear of nosocomial pneumonia or ventilator-associated lung injury must be avoided. One can wait for an hour to a maximum of six hours with NIV to assess its utility in a given situation. If oxygenation does not show significant improvement, it is better to institute invasive ventilation. When used prudently, NIV has been shown to avoid intubation in 33% of patients with acute hypoxaemic respiratory failure.[9]

The NIV is commonly provided through nasal mask or an oronasal mask. These may cause discomfort due to compression on the nose and chin and may be associated with leaks. To avoid this, a total face mask has been designed to improve patient comfort. However, a randomised trial involving sixty patients showed the total face mask to be equally comfortable as the oronasal mask during NIV. There were no differences with regard to changes in gas exchange and intubation rates.[12]

Failure to wean and extubate occurs in 15% of the patients and is associated with 30-40% mortality.[13] NIV is used to support those patients who fail extubation after invasive ventilation. The utility of NIV in preventing intubation is controversial but several reports suggest that if instituted early, it may be helpful.[14,15]

Use of NIV in patients with communicable diseases such as H1N1 influenza or suspected viral pneumonias is a concern. Although NIV has been used in these conditions without report of spread of the disease with appropriate precautions,[16] spread of these diseases to treating personnel is a concern in a developing country such as India. Use of heat and moisture exchangers with bacterial/viral filter may reduce this concern. A recent study on the impedance to gas exchange with small dead space heat and moisture exchangers with NIV showed no impedance to gas exchange.[17]

Low *vs* high tidal volume strategy

The multicenter ARDS network trial compared traditional mechanical ventilation with large tidal volumes (12 ml/kg of predicted body weight) with low tidal volume ventilation (6 ml/kg predicted body weight) ensuring the plateau pressure did not exceed 50 cm H_2O in the traditional group while it was limited to 30 cm H_2O in the low tidal volume group. The mortality was lower in the low tidal volume group (31%) as compared to higher tidal volume group (39.8%). Lower tidal volume ventilation has since then become the norm in the ventilation of patients with acute lung injury. Low tidal volumes with positive end-expiratory pressure is called the 'lung-protective strategy'.[18]

However, low tidal volume ventilation require higher respiratory rates (upto 35 breaths/min) to compensate for the reduction in the minute ventilation. Thereafter, permissive hypercapnoea is an accepted strategy as long as pH remained > 7.2. In the event of pH being < 7.2, tidal volume can be increased in increments of 1 ml/kg to correct it.

However, the mortality benefit of low tidal volume strategy in ARDS network trial is not replicated by other studies. Other studies argue that the ARDS network trial found significant mortality benefit as this study used unduly high tidal volumes in the traditional group.[19] Despite this argument, low tidal volume ventilation is currently the accepted ventilator strategy for patients with ALI/ARDS requiring mechanical ventilation.

Preservation of spontaneous ventilation

It is often taught that when a patient has refractory hypoxaemia, neuromuscular blockade may be induced to ventilate more effectively, the rationale being that abolition of controlled ventilation saves the oxygen cost of breathing and rests the fatigued muscles. However, this strategy is associated with two problems. First, the respiratory muscles become deconditioned and disuse atrophy ensues. Second, a combination of low tidal volume strategy with neuromuscular blockade would invariably result in lower minute ventilation contributing to hypercapnoea. Hence, maintaining spontaneous ventilation might help maintain minute ventilation. Therefore, there is a renewed interest in maintaining spontaneous ventilation during mechanical ventilation of patients with ALI.

Relatively newer modes of ventilation such as airway pressure release ventilation (APRV) that encourage spontaneous ventilation have been used as rescue therapy in ALI. APRV results in higher mean airway pressure and is a variation of inverse ratio ventilation but permits spontaneous breathing superimposed on controlled ventilation.

A small retrospective study in 18 patients compared APRV with pressure support ventilation (PSV) in patients with ALI / ARDS.[20] All these patients had also undergone helical computed tomography (CT) scan of the lungs at baseline and after three days of ventilation. They found a decrease from 41% to 19% in the amount of atelectasis and better oxygenation (even when corrected for mean airway pressure) with APRV as compared to PSV based on which they concluded that APRV is more efficient than PSV in patients with ARDS.

A comparison of APRV with pressure controlled ventilation showed that the mean airway pressure is lower with APRV.[21] Consequently, the cardiac preload is better and cardiac function is better with APRV. Since the patients are allowed to breathe spontaneously, they require less sedation. Hence, APRV is associated with reduced duration of ventilator support, length of intubation and length of ICU stay.[21] However, larger randomised controlled trials are required to support this claim.

High frequency ventilation

In an attempt to reduce both volutrauma and barotrauma, high frequency ventilation was evaluated as a possible ventilator mode in ALI. Of the three types, high frequency oscillatory ventilation (HFOV) has established as a rescue method of ventilation as early institution appears to improve the survival rate in ARDS.

The Multicentre Oscillatory Ventilation for Acute Respiratory Distress Syndrome Trial (MOAT) study in adults showed improved oxygenation with HFOV in < 16 hours, however, the effects did not persist beyond 24 hours.[22] A decrease in oxygenation index and small increase in survival rate (36% in HFOV vs 31% in the conventional group) was found although the complication rates were comparable with the conventional group. They concluded that HFOV is a useful mode of ventilation.

A study showed allowing spontaneous breathing to improve pulmonary gas exchange, systemic blood flow and oxygen supply to tissues. Computer tomography showed that there is a better gas exchange between the alveoli and capillaries and this is because there is better exchange with spontaneous ventilation.[23,24]

Weaning

One of the most important criteria for weaning a patient from mechanical ventilation is that the precipitating factor should have been corrected.

According to the European consensus conference in 2005, there are six steps in weaning, namely, 1) treatment of respiratory failure, 2) feeling that weaning may succeed, 3) assessment of success of weaning, 4) spontaneous breathing trials 5) extubation and 6) reintubation as necessary.[25] Weaning delay is associated with increased mortality. Generally, the first accepted criterion for weaning is alleviation of the underlying aetiology. Once weaning is assumed to be possible, the patient undergoes a formal assessment of weaning criteria that are widely accepted. Subsequently, the patient undergoes a spontaneous breathing trial either with a T-piece or pressure support. Apart from this, several criteria have been proposed to assess ability to wean.

The rapid shallow breathing index is one such criterion. The frequency is measured in breaths/min and the tidal volume in litres and a value of < 105 is favourable for weaning.[26] Although the tidal volume varies with weight of the patient, this index uses the absolute value. A respiratory rate of 15/minute may be associated with a tidal volume of 300 ml, 500 ml or 750 ml, resulting in a frequency/tidal volume ratio of 50, 30 or 20. Similarly, a respiratory rate of 30/minute may be associated with a tidal volume of 300 ml, 500 ml or 750 ml, resulting in a frequency/tidal volume ratio of 100, 60 or 40. A ratio corrected to weight may be more appropriate for weaning. Even then, the weight of the critically ill patient is often a guess as many centres do not have the facility to weigh such patients.

Spontaneous breathing trial (SBT)

This is a commonly employed method for weaning which can be done with T-piece, pressure support, CPAP or gradual reduction in SIMV rate. Although T-piece trials were found to result in marginally faster weaning, pressure support or CPAP is better as the patient is still on the ventilator allowing all the respiratory mechanical parameters to be monitored. In addition, reinstitution of ventilator support, if necessary can be done immediately. Weaning with pressure support also represents gradual reduction in ventilator support and is more comfortable for the patient.

Weaning protocol: Physician-based or respiratory therapist (RT) based

There have been a few studies on whether protocol based weaning is better than physician based weaning a patient off a ventilator.[27-29] As long as the protocol is correctly made and the person using it understands the procedure thoroughly, it should not matter who does it. In the event of the physician being busy, if the respiratory therapist can do this work, more attention can be given to the patient and permits the physician to attend to other clinical work where expertise of the clinician is more in need. Protocol driven weaning has been shown to reduce the time spent on mechanical support, weaning and requirement of tracheostomy.[27]

Early *vs* late tracheostomy

Prolonged intubation can cause laryngeal damage and tracheal stenosis. Early tracheostomy has been advised to avoid this. Although, tracheostomy is better tolerated by the patient, it is not without complications. Availability of tracheal tubes that possess high volume-low pressure cuff, increasing awareness of the need for regular cuff pressure measurement and the use of sedatives such as dexmedetomidine or propofol have resulted in much less incidence of restlessness in the ICU and perhaps the incidence of laryngeal injury.[28]

Mechanical ventilation is a life saving intervention and is extensively used but certain issues are yet unresolved. Future directions for research and clinical practice include supported spontaneous breaths, non-invasive ventilation, increased adoption of protocol based weaning and tracheostomy only if required.

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