

AIRWAY CLEARANCE IN THE INTENSIVE CARE UNIT

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ABSTRACT

Mechanically-ventilated patients in the intensive care unit (ICU) may suffer from retained secretions from several causes. Airway clearance techniques have the potential to improve mucociliary clearance by reducing mucus plugging and enhancing the removal of secretions, including inflammatory cells and bacteria. This short review describes recent progress in airway clearance management in ICU patients.

Keywords: Mechanical ventilation, airway clearance, chest physiotherapy, intrapulmonary percussive ventilation, in-exsufflation.

INTRODUCTION

Mechanically-ventilated patients in the intensive care unit (ICU) may suffer with retained secretions from several causes. Endotracheal intubation reduces the mucociliary clearance, increasing infectious risks by increasing mucus volume and consistency. Prolonged immobility can result in atelectasis, impairment of cough, and secretion retention. Expiratory muscle weakness, by reducing the expulsive force needed to perform cough and fluid restriction, may also contribute to secretion retention.¹⁻³

Airway clearance techniques (ACTs) have the potential to improve mucociliary clearance by reducing mucus plugging and enhancing the removal of secretions, including inflammatory cells and bacteria. These techniques may result in improved ventilation, a reduction of airway obstruction and atelectasis, an improved ventilation-perfusion mismatch, and a decrease in proteolytic activity in the airways.⁴⁻⁶ Nevertheless, the role of ACTs is poorly defined, and there is a paucity of supporting evidence in the ICU,^{7,8} especially due to the difficulties in assessing the effectiveness of ACT. Among these are the choice of outcomes to evaluate therapeutic effects; either physiological outcomes, such as mucus transport or change in

pulmonary function, or clinical outcomes, such as days spent in the hospital or quality of life.^{9,10}

PERCUSSION AND VIBRATION

Manual percussion of the chest wall and vibrating the chest during expiration, in patients under mechanical ventilation (MV) with retained secretions, are useful in order to move secretions from the peripheral towards the central airways¹¹⁻¹³ (Figure 1). Increase in mucus clearance was described by Stiller¹⁴ in critically ventilated patients with normal cough competence without a significant change in blood gases and lung compliance. However, there are some negative effects of this modality, such as pain, anxiety, atelectasis, and increase of oxygen consumption.¹⁵

INTRAPULMONARY PERCUSSIVE VENTILATION

Another technique used is intrapulmonary percussive ventilation (IPV), which improves mucus clearance through direct, high-frequency, oscillatory ventilation, helping alveolar recruitment.¹⁶ With this technique, high-frequency ventilation is delivered into the lungs in the form of intrapulmonary percussions through a face mask, a mouthpiece, an endotracheal tube, or a tracheostomy.¹⁷

Dimassi et al.¹⁸ studied patients at high risk for extubation failure who were receiving preventive non-invasive ventilation (NIV) after extubation. They concluded that both NIV and IPV reduced the respiratory rate and the work of breathing, but IPV was less effective in improving alveolar ventilation. The addition of IPV was associated with improvement of oxygenation, expiratory muscle performance and reduced risk of late onset pneumonia in tracheostomised patients.¹⁹

POSITIVE EXPIRATORY PRESSURE

Positive expiratory pressure (PEP) is defined as breathing with a positive expiratory pressure of 10-20 cmH₂O.⁶ The system employs a mask, or a mouth-piece connected to a resistance nipple, to provide positive pressure during expiration, and the blow-bottle device in which the resistance consists

of a water seal. The pressure achieved is dependent on the performance of the manoeuvre, the adjustable expiratory resistance, and the patients' active expiratory flow.^{6,20}

Ingwersen and colleagues²¹ conducted a prospective randomised trial in post-operative patients to compare continuous positive airway pressure (CPAP), PEP and several airway clearance techniques. There were comparable decreases in pulmonary function and arterial oxygen tension (PaO₂), and comparable rate of atelectasis in all the treatment groups. Authors concluded that PEP therapy was a preferable technique by the patient without any significant difference in outcomes.

Richter-Larsen and colleagues²² studied post-operative patients treated with routine chest physiotherapy alone or supplied with either PEP or a device creating both inspiratory and expiratory



Figure 1. Nurse and Physical Therapist performing manual clapping of thorax in a mechanically ventilated patient.

resistance. PEP and postural drainage and percussion were preferred methods by the patient. This study also suggested that the patients using PEP and the device had tendency toward less risk of postoperative complications.

IN-EXSUFFLATION

The Cough Assist In-Exsufflator has proven to be a useful adjunct for airway clearance in patients with ineffective cough, and may result in benefit for intubated and tracheotomised patients.²³ Mechanical insufflation-exsufflation (in-exsufflation) consists of insufflation of the lungs with positive pressure, followed by an active negative-pressure exsufflation that creates a peak and sustained flow high enough to provide adequate shear velocity to loosen and move secretions toward the mouth for suctioning or expectoration^{1,24,25} (Figure 2).

MANUAL HYPERINFLATION

Manual hyperinflation (MH) is frequently used in critically ill intubated and mechanically-ventilated patients.²⁶ The effectiveness of MH depends on higher expiratory flow and movement of sputum from distal to more proximal areas.^{27,28} A study by Paulus et al.,²⁹ concluded that the rate of haemodynamic and respiratory adverse effects with MH is low when performed by experienced and trained nurses in stable, critically ill patients. Blattner et al.³⁰ conducted a randomised controlled trial to compare MH and standard care in post cardiac surgery patients. The result was an improvement in pulmonary compliance and PaO₂ and a reduction of MV duration. Improvement in pulmonary compliance with MH compared to standard care was also reported by several studies evaluating unselected ICU patients.^{31,32} A summary of safety, effectiveness, and pros and cons of described techniques is shown in Table 1.

HUMIDIFICATION

Adequate humidification is important for airway clearance³³ since heating and humidifying the inspired gas is an established standard of care during MV,⁷ although the contribution to temperature regulation appears small.³⁴ Appropriate heating and humidifying inspiratory gas are necessary to prevent complications associated with the drying of the respiratory mucosa, such as mucus plugging and endotracheal tube occlusion,³⁵ if impaired mucociliary clearance and cough have been



Figure 2. In-exsufflation device is applied through the tracheostomy tube and manually operated.

observed.³⁵⁻³⁸ Solomita et al.³⁹ compared non-heated to heated-wire humidification over a wide range of minute ventilation values and concluded that at the same Y-piece temperature, heated-wire humidification may provide significantly less humidification than physiologic levels.

TRACHEA SUCTIONING

Routine suctioning via endotracheal tubes in intubated patients facilitates the removal of airway secretions, maintains airway patency and prevents pulmonary infection. Normal saline is frequently instilled into the trachea before suctioning as it may help to dislodge secretions and facilitate airway clearance.⁴⁰ However, tracheal suctioning is associated to mucosal injury,⁴¹ and other adverse side-effects including decreased arterial oxygen tension.⁴² Closed (in-line) endotracheal suction eliminates the need for disconnection from MV

Table 1. Safety, effectiveness, and pros and cons of airway clearance techniques in the ICU.

Technique	Safety	Effectiveness	Pros	Cons
PERCUSSION AND VIBRATION	+++	++	Improved ventilation, reduction of airway obstruction and atelectasis, correction of ventilation-perfusion mismatch	Pain, anxiety, atelectasis, and increase of oxygen consumption
INTRAPULMONARY PERCUSSIVE VENTILATION	++	+++	Improvement of oxygenation, expiratory muscle performance and reduced risk of late onset pneumonia in tracheostomised patients	Expensive
POSITIVE EXPIRATORY PRESSURE	++++	++++	Low cost	-----
IN-EXSUFFLATION	++	++++	Better airway clearance in neuromuscular patients	Expensive
MANUAL HYPERINFLATION	++++	++	Low rate of haemodynamic and respiratory adverse effects. Low cost	Experienced and trained nurses needed

and does not require single-hand sterile technique like open suction methods. Although data are not evidence-based since a meta-analysis showed no difference in mortality or VAP rates between open and closed suction systems,⁴³ closed systems came with higher costs; these devices may be preferable because of their efficiency and smaller number of suction-induced complications.⁴⁴ The other risk of frequent suctioning is loss of PEEP and potential derecruitment. This can be potentially serious in a patient with high PEEP levels and severe hypoxaemia.

CONCLUSION

Patients in the ICU may suffer from retained secretions. Secretion clearance is therefore an integral component of disease management in these critically ill patients. In mechanically-ventilated patients, appropriate heating and humidifying inspiratory gas is necessary to prevent and remove complications associated with the drying of the respiratory mucosa, such as mucus plugging and endotracheal tube occlusion. Routine suctioning facilitates the removal of airway secretions, maintains airway patency and prevents pulmonary

infection. Manually clapping the chest wall and vibrating the chest during expiration are useful to move secretions from the peripheral towards the central airways. Intrapulmonary percussive ventilation improves mucus clearance through direct high-frequency oscillatory ventilation, helping the alveolar recruitment. Positive expiratory pressure can be easily applied and is low-cost. The Cough Assist In-Exsufflator has proven to be a useful adjunct for airway clearance in patients with ineffective cough, especially due to expiratory muscle weakness. Manual hyperinflation is frequently used in critically ill intubated and mechanically-ventilated patients.

There is still limited evidence to support the use of any secretion clearance techniques such as a comprehensive approach in intensive care patients. Therefore randomised studies, with solid clinical short and long-term outcome measures, are needed. In the meantime, to choose a technique, care givers should consider the pathophysiologic rationale for the therapeutic use, the equipment cost, the adverse effect of the therapy, and patient preference.

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