Respiratory physiotherapy in the critical care unit

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Key points

The effects of critical illness and mechanical ventilation lead to numerous adverse respiratory, musculoskeletal, and neurological complications.

Physiotherapists have many skills that they can use to effectively facilitate secretion clearance and improve ventilation.

Physiotherapy intervention in the critical care setting is safe and effective so long as it follows a thorough multisystem assessment.

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Physiotherapists are an integral part of the multidisciplinary team in the critical care unit and are skilled in the multisystem patient assessment and treatment of both intubated and spontaneously breathing patients. In addition to respiratory management, other key roles include the management of neurological and musculoskeletal complications of critical care. Historically, the main focus of physiotherapy in critical care had been the management of respiratory complications; however, there is now evidence that survivors of critical care have long-standing weakness and limitations of functional capacity that has led to exercise rehabilitation being incorporated into standard practice.[1]

Respiratory pathologies are among the most common cause of admission to critical care. A number of patients will also progress to respiratory failure during their admission; this could be secondary to postoperative respiratory failure, the development of pneumonia, in particular ventilator-associated pneumonia (VAP) or after a failed extubation.

While the exact role of the physiotherapist varies across critical care units within the UK and also worldwide, many of the techniques outlined below are likely to be used. There is a lack of randomized controlled trials to support the role of the physiotherapist, but there is a long history of physiotherapists playing a pivotal part in critical care teams. The aim of this article is to provide an overview of these techniques.

Effects of critical illness and intubation on the respiratory system

If cough is impaired or inhibited and the mucociliary escalator function is diminished by intubation, the sequestration of secretions is a potential growth medium for bacteria leading to pneumonia. Drugs such as opioids have an antitussive effect and the use of neuromuscular blockers eliminate the cough reflex. Furthermore, the presence of a tracheal tube interferes with the cough reflex and its presence can lead to bacterial translocation from the oropharynx. This impaired clearing mechanism can potentially lead to deteriorating lung function and VAP.

In the supine position, closing capacity may encroach on the functional residual capacity leading to airway closure in dependent lung regions and subsequent atelectasis. Airway resistance increases, mostly resulting from abdominal and chest wall compression and in addition, there is an increase in pulmonary blood volume all leading to a decrease in lung compliance, ventilation/perfusion mismatch, and an increase in the work of breathing.

The respiratory workload increases while the function of the respiratory pump may decrease. Immobility and critical illness lead to the common findings of skeletal muscle weakness, disuse atrophy, and deconditioning among critical care patients. Drugs such as steroids and neuromuscular blockers exacerbate this critical illness neuromyopathy and biochemical abnormalities and malnutrition further compound this problem. This respiratory muscle dysfunction is associated with prolonged ventilation and a delay in weaning.

Table 1 identifies the goals of physiotherapy within critical care. The goals are orientated around minimizing the adverse effects of critical illness and intubation on the respiratory system.

The physiotherapist has a number of techniques at their disposal (see Table 2 for summary).

Hyperinflation

Lung hyperinflation is commonly used to improve secretion removal and recruit areas of pulmonary collapse leading to improved lung compliance and gas exchange. Owing to the size of the tidal volumes delivered to the patient, there is the possibility that cardiovascular stability will be compromised. The increase in intra-thoracic pressure and

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Table 1 Goals of physiotherapy within critical care

Reduce secretion retention, atelectasis, and pneumonia
Maintain or recruit lung volume
Improve regional/global ventilation and compliance, improve ventilation/perfusion mismatch, reduce airway resistance and work of breathing
Optimize oxygenation and ventilation
Improve respiratory and peripheral muscle strength
Decrease patient's dependency on the ventilator and improve residual function
Minimize postoperative complications
Reduce patient morbidity and mortality and prevent increased length of ICU and hospital stay

Table 2 Summary of physiotherapy interventions

Manual techniques	Increase inspiratory volume	Increase expiratory flow/ volume
Percussion	Manual/ventilator hyperinflation	Mechanical in/exsufflator
Vibrations	Intermittent positive pressure breathing	Assisted cough
Assisted cough	Mechanical in/exsufflator	Positioning
	Incentive spirometry	
	Mobilization	
	Positioning	
	Deep breathing exercises	

subsequent reduction in venous return may lead to a reduction in arterial pressure. The increase in tidal volume may also lead to volutrauma potentially being detrimental to any recent surgical lung anastomosis.

Lung hyperinflation can be performed using 100% oxygen, air alone, or air with oxygen entrained. Air alone or air with oxygen entrained can be used for patients who require a hypoxic drive and those who are on a self-ventilating mode of ventilation.

It is widely recognized that when patients are anaesthetized and ventilated on 100% oxygen that lung atelectasis occurs. This is correct; however, if hyperinflation is performed to an airway pressure of 40 cm H_2O and the pressure is maintained for a number of seconds any atelectasis that has occurred is re-expanded. Therefore, carrying out hyperinflation using 100% oxygen should not result in atelectasis. The clinician also needs to be mindful regarding the length of time the hold is carried out due to the potential negative effect it may have on venous return.

In clinical practice, hyperinflation is not done routinely on all patients; patients are carefully selected after thorough assessment and evaluation of appropriateness (see Table 3 for factors that may indicate caution during the assessment process before hyperinflation). After the assessment, it needs to be concluded that the benefits to the patient of performing hyperinflation outweigh any potential risks. In addition, any adjustments to the treatment technique can be made (e.g. the use of a PEEP valve for patients that have high ventilator requirements).

Hyperinflation can be performed manually or via a ventilator.

Manual hyperinflation

Manual hyperinflation (MHI) involves the delivery of larger than baseline tidal volumes to a peak pressure of 40 cm H_2O.

Table 3 Factors that may indicate caution during the assessment before performing hyperinflation

Undrained pneumothorax
Cardiovascular instability
Acute head injury
Tidal volume >700 ml, PEEP>10 cm H_2O
Recent pulmonary surgery
Emphysematous bullae
Bronchospasm
Presence of surgical emphysema

Technique: delivery of a slow inspiration, a 2–3 s inspiratory hold, and a fast uninterrupted expiratory flow that mimics a forced expiration.

There are MHI bags available that have PEEP valves within the circuit to ensure patients maintain PEEP and reduce de-recruitment and atelectotrauma. This is particularly useful in patients who are PEEP-dependent.

If there are concerns regarding the risk of barotrauma, a manometer can be put into the MHI circuit and the MHI breaths can be limited to a set pressure.

The main advantage of using MHI over ventilator hyperinflation (VHI) is that the physiotherapist can gain proprioceptive feedback from the bag, which can allow for assessment of lung compliance to take place.

Ventilator hyperinflation

As the name would suggest, these hyperinflation breaths are performed while the patient remains on the ventilator.

Technique: in the spontaneously breathing patient, VHI is achieved by making incremental increases in pressure support. When a patient is on controlled modes, it is done by either altering pressure or volume limits to reach a predetermined target volume or pressure. One recommended method for VHI is as follows: ventilator rate reduced to 6 min^{-1} and inspiratory flow reduced to 20 litre min^{-1}. The patient's tidal volume is increased by 100 ml increments until a peak pressure of 40 cm H_2O is achieved. Six breaths are delivered and then ventilation is returned to the original parameters and the patient is allowed to rest for 30 s and repeat as required.

The main advantage of performing VHI over MHI is the maintenance of PEEP (as the patient is not disconnected from the ventilator) and the reproducibility of the technique. The use of a high PEEP is currently thought to be part of an optimal ventilatory strategy for acute lung injury and the maintenance of the PEEP is beneficial in those patients who are at potential risk of ventilator-associated lung injury. The use of VHI as opposed to MHI may therefore lead to less de-recruitment and atelectotrauma.

Although the use of VHI may seem to be beneficial as opposed to MHI, this technique is not commonplace among physiotherapists in the UK. However, recruitment manoeuvres which are similar in principle to VHI are used more frequently by medical staff.

Positioning

Body positioning and mobilization are potent options for treatment that may optimize oxygenation by improving ventilation and *V*/*Q* mismatching using gravity dependency to augment alveolar recruitment and lung perfusion.[2]

For patients with unilateral lung disease, placing the affected lung uppermost results in increased volume to that lung leading to enhanced recruitment and facilitating drainage from lung segments that may improve *V*/*Q* matching. There is some evidence to suggest that regular turning from side to side may reduce the incidence of VAP so long as a $>40^o$ lateral turn is achieved.[3]

Continuous lateral rotational therapy involves the use of specialized beds that rotate along the longitudinal axis with a pre-set speed and degree of rotation. The aim is to reduce atelectasis and improve drainage of secretions, although this therapy is not commonplace in the UK mainly due to a lack of evidence of cost-effectiveness.

Altering patients' positions alters their *V*/*Q* ratios. It has been found that when comparing supine with standing values, rib cage displacement increased by 63.8% when the patient was standing.[4] Such position changes result in increases in minute ventilation, respiratory rate, tidal volume, and inspiratory flow rate. Adverse effects to positioning patients with their heads down include arrhythmias and raised intracranial pressure. The most common arrhythmia is bradycardia; this is likely to be secondary to stimulation of sino-aortic baroreceptors, leading to a reflex sympathetic withdrawal or parasympathetic increase in nervous input to the heart.[5]

It is best being selective with positioning based on individual need and response to the process rather than it being routine.

Percussion and vibrations

Different mechanisms can be responsible for why patients are unable to clear secretions independently; therefore, it is important that the physiotherapist correctly identifies the problem and selects the correct intervention to facilitate sputum clearance.

Percussions are performed using cupped hands to clap over the affected part of the lung and can be added to postural drainage. The theory is that percussion generates flow transients in airways beneath a percussed segment.

Vibrations can be performed manually or using mechanical devices to compress the chest wall during the expiratory phase. McCarren and colleagues[6] found that vibrations increased peak expiratory flow rates by more than 50% over relaxed expiration.

Suctioning

The application of the aforementioned techniques mobilize secretions in the more peripheral airways centrally, so they can be removed via suction. Secretions in the more peripheral airways should not be removed by airway suction.

The recommended suction pressure is 11–16 kPa (this can be increased to 20 kPa if the secretions are very thick). The catheter diameter should be no greater than half the internal diameter of the tracheal tube (TT) or the tracheostomy. Alternatively, the following calculation can be used to establish the correct catheter size to use: $(\mathrm{TT}-2)\times 2$. The length of time for suction should be no greater than 15 s. The correct sizing, timing, and suction pressure are essential to reduce the risk of trauma, atelectasis, and hypoxia.

Table 4 Potential adverse effects of suction

Loss of PEEP leading to atelectasis and de-recruitment
Decrease in dynamic lung compliance and functional residual capacity
Hypoxia
Trauma to the tracheal, bronchial mucosa, or both
Bronchospasm
Microbial colonization of lower airways leading to an infection risk
Increased cerebral blood flow and increased intracranial pressure
Hypo- or hypertension
Cardiac arrhythmias, especially as a result of vagal stimulation
Patient distress and anxiety

Most contraindications to suction are relative to the patient's risk of developing adverse reactions or worsening clinical conditions as a result of the procedure. When indicated, there is no absolute contraindication. Table 4 identifies the potential adverse effects of suction. These adverse effects need to be taken into account before carrying out each suction and attempts made to ensure the potential for the adverse effects to occur are minimized.

Closed *vs* open suction

Suction can be performed via an open or a closed technique. The circuit is not broken using closed suction and disruption is minimized during the suction process, this being especially important if the patient has high oxygen or ventilatory requirements. There is also less chance of cross-infection, especially if secretions contain blood.

Saline instillation

With TTs *in situ*, 0.9% sodium chloride solution can be instilled directly into the trachea of patients. It is suggested that between 2 and 5 ml is used pre-suction if deemed necessary. It is thought instillation works by a combination of loosening any secretions present and by increasing spontaneous cough strength in adults. There is insufficient evidence to support the use of sodium chloride instillation and it should not be routinely performed when performing tracheal suction.

Effects of exercise and mobility

Mobilization refers to any activity sufficiently performed to produce physiological effects on the body that enhance ventilation, perfusion, circulation, and muscle metabolism. It may involve any of the following: passive and active turning and moving in bed, active-assisted and active exercises, pedal cycles in bed, tilt table, sitting at the edge of the bed, standing (with the assistance of the physiotherapist and with or without the help of standing or walking aids), transfers from bed to chair, chair-based exercises, and walking.

The rationale for mobilization is to optimize oxygen transport by enhancing alveolar ventilation and *V*/*Q* matching and it also represents a gravitational stimulus to maintain or restore normal fluid distribution in the body.[7]

Improvements in ventilation associated with early mobilization

Bed rest and deconditioning are major problems associated with prolonged mechanical ventilation. Martin and colleagues[8] looked at the impact of whole body rehabilitation in chronically (over 14 days) ventilated patients and found a positive correlation between upper limb motor strength at the time of admission to the rehabilitation programme and the time it took to wean from the ventilator. In addition, they showed improvements in upper limb muscle strength associated with the rehabilitation programme.

Early mobilization leads to improvements in peripheral and respiratory muscle strength. It has also been found to result in greater ventilation-free time compared with those that are not mobilized early.[9]

Zafiropoulos and colleagues[4] showed that early rehabilitation can lead to increases in minute ventilation, tidal volume, and respiratory rate above baseline measurements. It is unclear if these physiological changes were clinically significant, although it seems plausible that increases in tidal volumes and minute ventilation in conjunction with position changes will have a positive effect on lung compliance, recruitment of areas of collapse/consolidation, and sputum clearance.

The European Society of Intensive Care Medicine statement on physiotherapy for adult patients with critical illness (2008)[2] suggests that:

(i) Active or passive mobilization and muscle training should be instituted early.
(ii) The physiotherapist should be responsible for implementing mobilization plans and exercise prescription, and make recommendations for progression of these in conjunction with other team members.

Non-intubated patients

Patients who do not have an artificial airway *in situ* may benefit from percussions, vibrations, suctioning, positioning, and mobilization. Additional therapies that can be delivered are outlined below.

Deep breathing exercises

Deep breathing exercises can be used in conjunction with other treatments or as a standalone treatment. Patients are taught to take a deep breath in using their diaphragm rather than their accessory muscles of respiration. The diaphragm forces the abdomen to expand and the negative pressure generated within the chest forces air into the lungs. The benefits to the patient are reversal of atelectasis, increased oxygenation, alveolar recruitment, increased functional residual capacity, and tidal volumes and potentially the removal of secretions.

Incentive spirometry

Incentive spirometry uses a device to reduce or prevent atelectasis and improve airway clearance after operation (Fig. 1). The manoeuvre mimics a sigh or a yawn with the aim of increasing lung volume and re-recruiting atelectatic or collapsed areas of the lung. The patient holds the device and after a normal expiration, breathes in slowly and deeply for as long as possible (maximizing distribution of ventilation), and then holds their breath for a period of 5–10 s. This is followed by a normal expiration. The device gives feedback on performance from the gauge. One of the main limitations is patient co-operation and technique, effective patient education being essential.

Intermittent positive pressure breathing

Intermittent positive pressure breathing (IPPB) (known commonly as the bird) uses a pressure-limited ventilator that applies an inspiratory positive pressure to the patient via a mask or mouthpiece. IPPB can be used with spontaneously breathing patients and spontaneously breathing patients with a tracheostomy. The technique is used as an intermittent or short-term basis typically for ∼15 min and can be repeated several times during a day.

The aim is to augment lung expansion, recruit collapsed alveoli, improve oxygenation and ventilation, and reduce the work of breathing. It can also be used for inspiratory muscle training. In addition, the IPPB has the facility to deliver aerosol medication. The only absolute contraindication is the presence of an un-drained pneumothorax. As with other forms of positive pressure treatments, extreme caution needs to be observed when treating patients with major haemodynamic instability, active pulmonary haemorrhage of unknown origin, recent facial, oral, or skull surgery. Potential adverse effects are decreased cardiac output due to the changes in intrathoracic pressure, barotrauma, and volutrauma.

Mechanical insufflation–exsufflation

This device uses positive pressure to promote maximal lung inflation and this is followed by a rapid switch to a negative pressure. This change produces a high expiratory flow rate which simulates a powerful cough. The technique is used by physiotherapists for patients with an impaired cough and when secretions cannot be cleared effectively by the patient. It can also be used to maintain lung compliance, respiratory muscle length, and thoracic rib cage mobility. Sputum clearance can be further facilitated by the physiotherapist using the machine in conjunction with other manual techniques such as assist

Fig 1 Incentive spirometry device.

cough or thoracoabdominal thrust. The contraindications to use are an un-drained pneumothorax, major cardiovascular instability, and flail segments. Relative contraindications are emphysematous bullae (in this case, you may consider using exsufflation only or lower insufflation pressures compared with exsufflation) and also in the head-injured patient where consideration needs to be given to the potential effects on intracranial pressure and cerebral perfusion pressure.

There are currently two devices that work the way described above: the Cough Assist made by Philips Respironics™ and the Nippy Clearway™.

Oro-nasal suctioning

A nasopharyngeal airway is indicated when a patient requires repeated suctioning to help with secretion clearance in order to reduce trauma to the nasopharyngeal mucosa on repeated passage of the suction catheter. Standard contraindications to passage of the airway include severe coagulopathy and basal skull fracture.

Oro-pharyngeal airways are occasionally used to permit passage of suction catheters when there are contraindications to nasal airways and the patient has a low enough level of consciousness to tolerate an oral airway. Vomiting and laryngospasm may occur if upper airway reflexes are still present.

Non-invasive ventilation

Physiotherapists are often involved in the assessment of patients for non-invasive ventilation (NIV), in setting up patients on NIV and in treating patients both within and outside of critical care. There has been increasing involvement of physiotherapists in non-invasive ventilation as the aims of respiratory physiotherapy and non-invasive ventilation frequently overlap.

Bilevel positive airway pressure (BiPAP) is used predominantly for patients with exacerbations of chronic pulmonary obstructive disease (COPD). However, there is increasing use among patients who are at risk of post-extubation respiratory failure and also as part of a weaning strategy for patients with hypercapnic respiratory failure. Continuous positive airway pressure (CPAP), BiPAP, or both are used for patients with acute cardiogenic pulmonary oedema and can also be used for selected patients with acute hypoxaemic respiratory failure from other aetiologies.

NIV can lead to decreased work of breathing and an increase in dynamic lung compliance, tidal volume, and inspiratory capacity with a subsequent improvement in blood gases. Cardiac output is usually decreased in 'normal' and COPD patients, whereas in some congestive cardiac failure patients, there may be an increase.

Physiotherapy can be performed with patients on NIV and indeed be preferable due to potential increased patient co-operation and improvement in lung mechanics aiding secretion expectoration.

Safety of respiratory physiotherapy

It has been shown that techniques such as positioning (supine to side lying) and suctioning may increase oxygen consumption (VO_2) by ~40–50%. These effects, however, are short-lived with recovery to baseline VO_2 shown to be within 7 min.[10]

A large Australian multicentre observational study of physiotherapy interventions[11] reported an adverse event rate of 0.2% (27 of 12 281 physiotherapy interventions). The most common adverse events were changes in mean arterial pressure (both increase and decrease), a decrease in oxygen saturations, and arrhythmias, chiefly bradycardias. Patients were more likely to suffer adverse events if already unstable (on vasopressor or inotropic support) and 96% of patients who suffered adverse events had pre-existing cardiac comorbidities and a high percentage of patients (78%) demonstrated abnormal vital signs before intervention.

The available evidence suggests that so long as a detailed multi-system assessment of each patient is carried out before the commencement of physiotherapy intervention, during which the benefits and adverse effects are evaluated and patient stability is evaluated, the treatments that are carried out are both safe and effective.

Summary

Intensive care is a dynamic environment where physiotherapists are an integral part of the multidisciplinary team providing various types of care, from acute respiratory interventions to rehabilitation. The ultimate goal of intensive care is quality long term, rather than short-term survival, physiotherapists play a valuable part in achieving this goal.

Declaration of interest

None declared.

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Please see multiple choice questions 13–16.