

## REVIEW

# Physiotherapy in the Intensive Care Unit

R Gosselink, B Clerckx, C Robbeets, T Vanhullebusch, G Vanpee, J Segers

Faculty of Kinesiology and Rehabilitation Sciences, Katholieke Universiteit Leuven, Belgium

Division of Respiratory Rehabilitation, University Hospital Gasthuisberg Leuven, Belgium

**Abstract** - Physiotherapists are involved in the management of patients with critical illness. Physiotherapy assessment is focused on physical deconditioning and related problems (muscle weakness, joint stiffness, impaired functional exercise capacity, physical inactivity) and respiratory conditions (retained airway secretions, atelectasis and respiratory muscle weakness) to identify targets for physiotherapy. Evidence-based targets for physiotherapy are deconditioning, impaired airway clearance, atelectasis, (re-)intubation avoidance and weaning failure. Early physical activity and mobilisation are essential in the prevention, attenuation or reversion of physical deconditioning related to critical illness. A variety of modalities for exercise training and early mobility are evidence-based and must be implemented depending on the stage of critical illness, co-morbid conditions and cooperation of the patient. The physiotherapist should be responsible for implementing mobilization plans and exercise prescription and make recommendations for progression of these plans, jointly with medical and nursing staff.

**Keywords** - physiotherapy, muscle weakness, deconditioning, pulmonary complications, mobilisation, weaning failure, atelectasis

## Introduction

The progress of intensive care medicine has dramatically improved survival of critically ill patients, especially in patients with acute respiratory distress syndrome (ARDS) [1]. This improved survival is, however, oftentimes associated with general deconditioning, muscle weakness, dyspnea, depression, anxiety and reduced health-related quality of life after intensive care unit (ICU) discharge [2]. Deconditioning and specifically muscle weakness are suggested to have an important role in the impaired long-term functional status in survivors of critical illness [3,4].

Bed rest and immobility during critical illness may result in profound physical deconditioning. These effects can be exacerbated by inflammation, lack of glycemic control and pharmacological agents [5]. Skeletal muscle weakness in the intensive care unit is observed in 25% of patients ventilated for more than 7 days [6]. Development of neuropathy or myopathy also contributes to weaning failure [7]. Finally, muscle weakness has been linked with increased mortality [8]. Respiratory dysfunction is a common problem in critically ill patients or accompanies other medical conditions necessitating ICU admission. Failure of either of the two primary components of the respiratory system (i.e. the gas exchange membrane and the ventilatory pump) can result in a need for mechanical ventilation. Impaired global and/or regional ventilation, decreased lung compliance and increased airway resistance may contribute to increased work of breathing and respiratory dysfunction. In addition, respiratory muscle

weakness affects the ventilatory pump capacity and may also lead to respiratory dysfunction. Although most patients on mechanical ventilation are extubated in less than 3 days, still approximately 20% require prolonged ventilatory support [9]. Prolonged ventilator dependence is a major medical problem but it is also an extremely uncomfortable state for a patient, carrying important psychosocial implications.

Physiotherapists are involved in the prevention and treatment of deconditioning and in the treatment of respiratory conditions in critically ill patients [10]. Their role varies across units, hospitals, and countries [11] and is appreciated by medical directors as well as patients. Physiotherapy assessment of critically ill patients is directed to deficiencies at a physiological and functional level and less by the medical diagnosis [12]. Accurate and valid assessment of respiratory conditions, deconditioning and related problems is of paramount importance for physiotherapists. In addition, physiotherapists can contribute to the patient's overall well-being by providing emotional support and enhancing communication.

## Early mobilization and physical activity

Reductions in functional performance, exercise capacity, and quality of life in ICU survivors indicate the need for rehabilitation following ICU stay [3], but also underscore the need for assessment and measures to prevent or attenuate deconditioning and loss of physical function during ICU stay. It is important to prevent or attenuate muscle deconditioning as early as possible in patients with an expected prolonged bed rest [13]. Recent scientific and clinical interest and evidence have given support for a safe and early physical activity and mobilization approach towards the critically ill patient by ICU team members [14-18]. Despite the evidence, the amount of rehabilitation performed in ICUs is often inadequate and, as a rule, rehabilitation is better organized in weaning centres or

## Correspondence

R Gosselink

E-mail: rik.gosselink@faber.kuleuven.be

respiratory intensive care units [19,20]. The major reason is that the approach in rehabilitation is less driven by medical diagnosis, instead rehabilitation is focusing on deficiencies in the broader scope of health problems as defined in the International Classification of Functioning, Disability and Health [21]. This classification helps to identify problems and the prescription of interventions at the level of impairments of body structure (anatomical parts of the body, such as organs, limbs and their components) and body function (physiological functions of body systems (including psychological functions) as well as activity limitations (difficulties an individual may have in performing activities) and participation restrictions (problems an individual may experience in involvement in life situations). Therefore, accurate assessment of the level of cooperation, cardiorespiratory reserve, muscle strength (figure 1), joint mobility, functional status (Functional Independence Measure, Berg Balance scale, Functional Ambulation Categories) and quality of life (e.g. Short Form-36, disease-specific questionnaires) should precede early mobilization and physical activity.

Physical activity and exercise should be targeted at the appropriate intensity and with the appropriate exercise modality.

**Figure 1.** Assessment of muscle strength with a handgrip dynamometer



The risk of moving a critically ill patient is weighed against the risk of immobility and recumbency and when employed requires stringent monitoring to ensure the mobilization is instituted appropriately and safely. Acutely ill, uncooperative patients will be treated with modalities such as passive range of motion, muscle stretching, splinting, body positioning, passive cycling with a bed cycle, or electrical muscle stimulation that will not need cooperation of the patient and will put minimal stress on the cardiorespiratory system. On the other hand, the stable cooperative patient, beyond the acute illness phase but still on mechanical ventilation, will be able to be mobilized on the edge of the bed, transfer to a chair, perform resistance muscle training or active cycling with a bed cycle or chair cycle and walk with or without assistance. The flow diagram 'Start to move' was developed in our center (figure 2), inspired upon the flow diagram by Morris et al. [15], and is an example of a multidisciplinary step-up approach. Six levels are identified and each level defines the modality of body positioning (mobilization) and physiotherapy which are based on assessment of medical condition (cardiorespiratory and neurological status, level of cooperation and functional status (muscle strength, level of mobility). Each day the ICU team defines the 'start to move' level in every patient, especially in those facing an extended ICU stay.

#### *The uncooperative critically ill patient*

The importance of body positioning ("stirring up" patients) was reported as early as the 1940s [22]. To simulate the normal perturbations that the human body experiences in health, the patient who is critically ill needs to be positioned upright (well supported), and rotated when recumbent. These perturbations need to be scheduled frequently to avoid the adverse effects of prolonged static positioning on respiratory, cardiac, and circulatory function. Other indications for positioning include the management of soft tissue contracture, protection of flaccid limbs and lax joints, nerve impingement, and skin breakdown. The efficacy of two-hourly patient rotation which is common in clinical practice has not been verified scientifically. Bed design features in critical care should include hip and knee breaks so the patient can approximate upright sitting as much as can be tolerated. Heavy care patients such as those who are sedated, or have overweight may need chairs with greater support such as stretcher chairs. Lifts may be needed to change a patient's position safely. In sedated patients other treatment modalities than body positioning are often not considered. Rehabilitation was considered as contraindicated, mainly due to sedation and renal replacement, in more than 40% of the ICU days of critically ill patients [23]. However, other treatment modalities, such as passive cycling, joint mobility, muscle stretching and neuromuscular electrical stimulation, may not interfere with sedation of the patient or renal replacement therapy.

Passive stretching or range of motion exercise may have a particularly important role in the management of patients who are unable to move spontaneously. Studies in healthy subjects have shown that passive stretching decreases stiffness and increases extensibility of the muscle [24,25]. Continuous passive motion (CPM) prevents contractures and has been assessed in patients with critical illness subjected to prolonged inactivity [26]. In critically

ill patients, 3 times 3 hours of CPM per day reduced fiber atrophy and protein loss, compared with passive stretching for 5 minutes, twice daily [26]. For patients who cannot be actively mobilized and have high risk of soft tissue contracture, such as following severe burns, trauma, and some neurological conditions, splinting may be indicated.

The application of exercise training in the early phase of ICU

admission is often more complicated due to lack of cooperation and the clinical status of the patient. Recent technological development resulted in a bedside cycle ergometer for (active or passive) leg cycling during bed rest (figure 3a). The bedside cycle ergometer (figure 3b) may allow prolonged continuous mobilization with rigorous control of exercise intensity and duration. Furthermore, the training intensity can be continuously adjusted

**Figure 2.** ‘Start to move’ – protocol Leuven: step-up approach for progressive mobilisation and physical activity program.

LEVEL 0	LEVEL 1	LEVEL 2	LEVEL 3	LEVEL 4	LEVEL 5
<b>NO COOPERATION</b> S5Q <sup>1</sup> = 0	<b>NO/LOW COOPERATION</b> S5Q <sup>1</sup> < 3	<b>MODERATE COOPERATION</b> S5Q <sup>1</sup> ≤ 3	<b>CLOSE TO FULL COOPERATION</b> S5Q <sup>1</sup> ≤ 4/5	<b>FULL COOPERATION</b> S5Q <sup>1</sup> = 5	<b>FULL COOPERATION</b> S5Q <sup>1</sup> = 5
<b>FAILS BASIC ASSESSMENT<sup>2</sup></b>	<b>PASSES BASIC ASSESSMENT<sup>3</sup> +</b>	<b>PASSES BASIC ASSESSMENT<sup>3</sup> +</b>	<b>PASSES BASIC ASSESSMENT<sup>3</sup> +</b>	<b>PASSES BASIC ASSESSMENT<sup>3</sup> +</b>	<b>PASSES BASIC ASSESSMENT<sup>3</sup> +</b>
<b>BASIC ASSESSMENT =</b> □ Cardiorespiratory unstable: MAP < 60mmHg or FiO <sub>2</sub> > 60% or PaO <sub>2</sub> /FiO <sub>2</sub> < 200 or RR > 30 bpm □ Neurologically unstable □ Acute surgery □ Temp > 40°C	Neurological or surgical or trauma condition does not allow transfer to chair  <b>BODY POSITIONING<sup>4</sup></b> 2hr turning Fowler's position Splinting  <b>PHYSIOTHERAPY<sup>4</sup></b> Passive range of motion Passive bed cycling NMES	Obesity or neurological or surgical or trauma condition does not allow <u>active</u> transfer to chair (even if MRCsum ≤ 36)  <b>BODY POSITIONING<sup>4</sup></b> 2hr turning Splinting Upright sitting position in bed Passive transfer bed to chair  <b>PHYSIOTHERAPY<sup>4</sup></b> Passive/Active range of motion Resistance training arms and legs Passive/Active leg and/or cycling in bed or chair NMES	MRCsum ≤ 36 + BBS Sit to stand = 0 + BBS Standing = 0 + BBS Sitting ≤ 1  <b>BODY POSITIONING<sup>4</sup></b> 2hr turning Passive transfer bed to chair Sitting out of bed Standing with assist (2 □ pers)  <b>PHYSIOTHERAPY<sup>4</sup></b> Passive/Active range of motion Resistance training arms and legs Active leg and/or arm cycling in bed or chair NMES ADL	MRCsum ≤ 48 + BBS Sit to stand ≤ 0 + BBS Standing ≤ 0 + BBS Sitting ≤ 2  <b>BODY POSITIONING<sup>4</sup></b> Active transfer bed to chair Sitting out of bed Standing with assist (□1 pers)  <b>PHYSIOTHERAPY<sup>4</sup></b> Passive/Active range of motion Resistance training arms and legs Active leg and/or arm cycling in chair or bed Walking (with assistance/frame) NMES ADL	MRCsum ≤ 48 + BBS Sit to stand ≤ 1 + BBS Standing ≤ 2 + BBS Sitting ≤ 3  <b>BODY POSITIONING<sup>4</sup></b> Active transfer bed to chair Sitting out of bed Standing  <b>PHYSIOTHERAPY<sup>4</sup></b> Passive/Active range of motion Resistance training arms and legs Active leg and arm cycling in chair Walking (with assistance) NMES ADL
<b>BODY POSITIONING<sup>4</sup></b> 2hr turning					
<b>PHYSIOTHERAPY:</b> No treatment					

‘Start to move’ - protocol Leuven: step-up approach of progressive mobilisation and physical activity program

1S5Q: response to 5 standardized questions for cooperation:

Open and close your eyes

Look at me

Open your mouth and stick out your tongue

Shake yes and no (nod your head)

I will count to 5, frown your eyebrows afterwards

2 : FAILS = at least 1 risk factor present

3 : if basic assessment failed, decrease to level 0

4 : safety: each activity should be deferred if severe adverse events (cv, resp. and subject. intolerance) occur during the intervention

MRC (Medical Research Council) muscle strength sum scale(0-60)

BBS: Berg Balance Score

SITTING TO STANDING

4 able to stand without using hands and stabilize independently

3 able to stand independently using hands

2 able to stand using hands after several tries

1 needs minimal aid to stand or stabilize

0 needs moderate or maximal assist to stand

STANDING UNSUPPORTED

4 able to stand safely for 2 minutes

3 able to stand 2 minutes with supervision

2 able to stand 30 seconds unsupported

1 needs several tries to stand 30 seconds unsupported

0 unable to stand 30 seconds unsupported

SITTING WITH BACK UNSUPPORTED BUT FEET SUPPORTED ON FLOOR OR ON A STOOL

4 able to sit safely and securely for 2 minutes

3 able to sit 2 minutes under supervision

2 able to sit 30 seconds

1 able to sit 10 seconds

0 unable to sit without support 10 seconds

to the patient's health status and the physiological responses to exercise. A recent randomized controlled trial of early application of daily bedside (initially passive) leg cycling in critically ill patients showed improved functional status, muscle function and exercise performance at hospital discharge compared to patients receiving standard physiotherapy without leg cycling [18].

In patients unable to perform voluntary muscle contractions, electrical muscle stimulation (EMS) has been used to prevent disuse muscle atrophy. A slower muscle protein catabolism and increase in total RNA content were also seen after EMS in patients with major abdominal surgery [27]. In acute critically ill patients not able to move actively, a reduction of muscle atrophy [28] and critical illness neuropathy [29] was observed when using EMS. EMS of the quadriceps in patients with protracted critical illness, in addition to active limb mobilization, enhanced muscle strength and hastened independent transfer from bed to chair [30].

#### *The cooperative critically ill patient*

Mobilization has been part of the physiotherapy of acutely ill patients for several decades. Mobilization refers to physical activity sufficient to elicit acute physiological effects that enhance ventilation, central and peripheral perfusion, circulation, muscle metabolism, and alertness. Strategies –in order of intensity- include

transferring in bed, sitting over the edge of the bed, moving from bed to chair, standing, stepping in place and walking with or without support. Standing and walking frames (figure 4) enable the patient to mobilize safely with attachments for bags, lines and leads that cannot be disconnected. The frame either needs to be able to accommodate a portable O<sub>2</sub> tank, or a portable mechanical ventilator and seat, or a suitable trolley for equipment can be used. Walking and standing aids, and tilt tables, enhance physiological responses and promote early mobilization of critically ill patients. Transfer belts facilitate heavy lifts and protect both the patient and the nurse and physiotherapist. In ventilated patients, the ventilator settings may require adjustment to the patients' needs (i.e. increased minute ventilation). Although the approach of early mobilization seems face valid, only recently the concept was studied in two trials [15,17]. Morris et al. demonstrated in a prospective cohort study that patients receiving early mobility therapy by physical therapists had reduced ICU and hospital stays with no differences in weaning time. No differences were observed in discharge location or in hospital costs of the usual care and early mobility patients. Schweickert et al. observed in a Randomized controlled trial (RCT) that early physical and occupational therapy improved functional status at hospital discharge, shortened duration of delirium and increased ventilator-free days. These

**Figure 3a.** Device for active and passive cycling in a bedridden patient in the intensive care unit





findings did not result in differences in length of ICU or hospital stay [17].

Aerobic training and muscle strengthening, in addition to routine mobilization, improved walking distance more than mobilization alone in ventilated patients with chronic critical illness [20]. A RCT showed that a 6-week upper and lower limb training program improved limb muscle strength, ventilator-free time and functional outcomes in patients requiring long-term mechanical ventilation compared to a control group [31]. These results are in line with a retrospective analysis of patients on long term mechanical ventilation who participated in whole-body training and respiratory muscle training [32]. In patients recently weaned from mechanical ventilation [33], the addition of upper limb exercise enhanced the effects of general mobilisation on exercise endurance performance and dyspnea. Low-resistance multiple repetitions of resistive muscle training can augment muscle mass, force generation, and oxidative enzymes. Sets of repetitions within the patient's tolerance can be scheduled daily, commensurate with their goals. Resistive muscle training can include the use of pulleys, elastic bands and weight belts. The chair cycle and the earlier mentioned bed cycle allow patients to perform an individualized exercise training program. The intensity of cycling can be adjusted to the individual patient's capacity, ranging from passive cycling via assisted cycling to cycling against increasing resistance.

**Figure 3b.** Device for active and passive cycling in a patient in the intensive care unit



Members of the rehabilitation team in the ICU (physicians, physiotherapists, nurses and occupational therapists) should be able to prioritize and identify aims and parameters of treatment modalities of early mobilization and physical activity, ensuring that these treatment modalities are both therapeutic and safe by appropriate monitoring of vital functions [34]. The early intervention approach is, although not easy, specifically in patients still in need of supportive devices (mechanical ventilation, cardiac assists) or unable to stand without support of personnel or standing aids, a worthwhile experience for the patient [15,16]. The benefits of this multidisciplinary team approach outweigh the costs. The difference in the mentality of the team approach was elegantly demonstrated in the study of Thomsen et al. [19]. Transferring a patient from the acute intensive care to the respiratory intensive care unit increased the number of patients ambulating three-fold compared with pre-transfer rates. Improvements in ambulation with transfer to the respiratory intensive care unit were attributed to the differences in the team approach towards ambulating the patients [19]. The physiotherapist, however, should be responsible for implementing mobilization plans and exercise prescription and make recommendation for progression of these issues jointly with medical and nursing staff [10].

### Respiratory conditions

The aims of physiotherapy in respiratory dysfunction are to improve lung inflation, to clear airway secretions, reduce the work of breathing, and enhance inspiratory muscle function promoting recovery of spontaneous breathing [10]. In the following paragraphs the physiotherapy treatment will be discussed in different clinical conditions.

#### *Prevention of postoperative pulmonary complications*

The majority of patients undergoing major thoracic or abdominal surgery recover without complications. Preoperative physiotherapy, including inspiratory muscle training, in cardiac surgery patients with an increased risk profile for postoperative pulmonary complications reduced the development of postoperative pulmonary complications [35]. After routine cardiac surgery, optimal post-operative management includes early mobilization and body positioning [36]. Further prophylactic physiotherapy interventions are not required in uncomplicated patients [37] or during (short time) intubation and mechanical ventilation [38]. Early mobilization and upright body positioning after major surgery is of primary importance to increase lung volume and to prevent pulmonary complications. Routine breathing exercises should not be used following uncomplicated coronary artery bypass surgery. Perioperative physiotherapy should be instituted if warranted, e.g., in high risk patients, rather than administered routinely. Two randomized controlled studies have provided strong evidence that supports the role of prophylactic physiotherapy in preventing pulmonary complications after upper abdominal surgery [39,40]. However, in contrast, a meta-analysis showed no added value of physiotherapy to the effectiveness of early mobilization in high risk patients after abdominal surgery [41].

Incentive spirometry (IS) and non-invasive ventilation (NIV) are frequently used in the postoperative setting. IS is used in the management of non-intubated patients to encourage lung volume recruitment, but has not been shown to additionally benefit (beyond physiotherapy, early mobilization and body position) the routine management of postoperative patients [42]. NIV has been used successfully to support patients following thoracotomy [43]. Continuous positive airway pressure (CPAP) is effective in the treatment of atelectasis, since it increases functional residual capacity (FRC) and improves compliance, minimizing post-operative airways collapse. Non invasive ventilation (NIV) has been shown superior to CPAP in the treatment of atelectasis in patients after cardiac surgery [44].

#### *Retained airway secretions and atelectasis.*

Figure 5 provides an overview of pathways and treatment modalities for increasing airway clearance. Interventions aimed at increasing inspiratory volume (deep breathing exercises, mobilization and body positioning) may affect lung expansion, increase regional ventilation, reduce airway resistance and optimize pulmonary compliance. Interventions aimed at increasing expiratory flow include forced expirations, such as huffing and coughing. Manually-assisted cough, using thoracic or abdominal compression may be indicated for patients with expiratory muscle weakness or fatigue

**Figure 4.** Walking frame to assist a ventilator-dependent patient



[45]. The mechanical in- and exsufflator can be used to deliver an inspiratory pressure followed by a high negative expiratory force, via a mouthpiece or facemask. It has been successfully applied in the management of neuromuscular patients with retained secretions secondary to respiratory muscle weakness [46], but has not been studied in ICU patients. Airway suctioning is used solely to clear central secretions that are considered a primary problem when other techniques are ineffective. Treatment of acute lobar atelectasis and airway clearance should incorporate body positioning and techniques to increase inspiratory volume and enhance forced expiration. The effectiveness of physiotherapy has been confirmed in several studies [47,48]. Chest wall vibration provided no additional benefit. CPAP has been shown to be effective in the treatment of atelectasis [49].

#### *Mechanically ventilated patients*

In intubated and ventilated patients manual hyperinflation (MHI) or ventilator hyperinflation, positive end-expiratory pressure ventilation, postural drainage, chest wall compression and airway suctioning may assist in clearance of secretions. The aims of MHI are to prevent pulmonary atelectasis, re-expand collapsed alveoli, improve oxygenation, improve lung compliance, and facilitate movement of airway secretions towards the central airways [50,51]. MHI involves a manual slow deep inspiration with a resuscitator bag, an inspiratory hold of 2-3 seconds [52], followed by a quick release of the bag to enhance expiratory flow and mimic a forced expiration. MHI might have important negative side-effects. First, MHI can precipitate marked hemodynamic changes associated with a decreased cardiac output, which result from large fluctuations in intra-thoracic pressure [53]. Second, MHI can also increase intracranial pressure which might have implications for patients with brain injury. This increase is, however, usually limited, so that cerebral perfusion pressure remains stable [54]. A pressure of 40 cm H<sub>2</sub>O has been recommended as an upper limit. Two studies in ventilated patients reported that bronchoscopy offered no additional benefit over physiotherapy (postural drainage, percussion, manual hyperinflation and suctioning) in the management of acute lobar atelectasis [55,56].

Airway suctioning may have detrimental side effects (bronchial lesions, hypoxaemia), but reassurance, sedation, and pre-oxygenation of the patient may minimize these effects [57]. Suctioning can be performed via an in-line closed suctioning system or an open system. The in-line system increased the costs, but did not decrease the incidence of ventilator-associated pneumonia (VAP) nor the duration of mechanical ventilation, length of ICU stay or mortality [58]. Closed suctioning may be less effective than open suctioning for secretion clearance during pressure support ventilation [59]. The routine instillation of normal saline during airway suctioning has potential adverse effects on oxygen saturation and cardiovascular stability, and variable results in terms of increasing sputum yield [60]. Chest wall compression prior to endotracheal suctioning did not improve airway secretion removal, oxygenation, or ventilation after endotracheal suctioning in an unselected population of mechanically ventilated patients [61]. VAP is a common complication in mechanically ventilated patients and

is associated with higher mortality rates, prolonged hospitalization, and high medical costs [62]. Studies have shown that avoidance of intubation by NIV reduces the incidence of nosocomial pneumonia in a subgroup of patients [63,64]. Physiotherapy including manual hyperinflation, positioning plus suctioning showed no differences in VAP versus suctioning alone [65]. Yet, in contrast, another study reported a lower incidence of VAP (8% vs 39%) in the group receiving physiotherapy [66]. However, the duration of mechanical ventilation, length of ICU stay and mortality did not differ between the groups. The addition of physiotherapy in a population of ventilated patients for various reasons of respiratory insufficiency was associated with prolongation of mechanical ventilation [67].

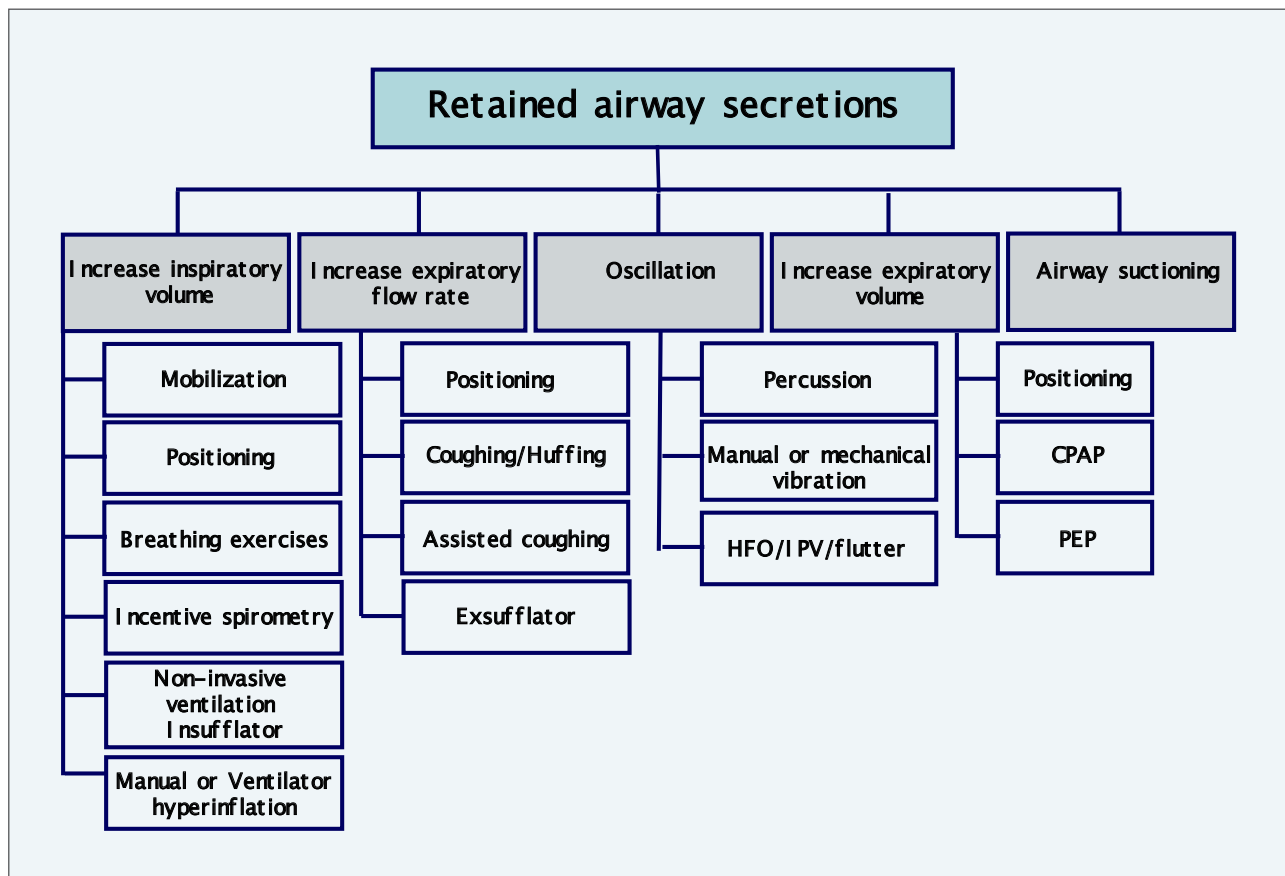
**Weaning failure**

Only a small proportion of patients fail to wean from mechanical ventilation, but they require a disproportionate amount of resources. A therapist-driven weaning protocol was shown to reduce the duration of mechanical ventilation and ICU cost [68]. However, a recent study showed that protocol-directed weaning may be unnecessary in an ICU with generous physician staffing and

structured rounds [69]. A spontaneous breathing trial can be used to assess readiness for extubation with the performance of serial measurements, such as tidal volume, respiratory rate, maximal inspiratory airway pressure, and the rapid shallow breathing index [70]. Early detection of worsening clinical signs such as distress, airway obstruction, and paradoxical chest wall motion, ensures that serious problems are prevented. Airway patency and protection (i.e., an effective cough mechanism) should be assessed prior to commencement of weaning. Peak cough flow is a useful parameter to predict successful weaning in patients with neuromuscular disease or spinal cord injury when extubation is anticipated [71]. An airway care score has been developed based on quality of the patient's cough during airway suctioning, the absence of 'excessive' secretions, and the frequency of airway suctioning [68]. NIV can facilitate weaning [72], reduces ICU costs [73], and is effective in preventing post-extubation failure in patients at risk [74].

There is accumulating evidence that weaning problems are associated with failure of the respiratory muscles to resume ventilation [75]. Inspiratory muscle training might be beneficial in patients with weaning failure. Uncontrolled trials of inspiratory

**Figure 5.** Pathways and treatment modalities for increasing airway clearance(10). (PEP=positive expiratory pressure, CPAP=continuous positive airway pressure, HFO=high frequency oscillation, IPV=intrapulmonary percussive ventilation, NIV=non-invasive ventilation, IPPB=intermittent positive pressure breathing).



muscle training (IMT, Threshold loading, figure 6) observed an improvement in inspiratory muscle function and a reduction in duration of mechanical ventilation and weaning time [76]. Interim analysis of a randomized controlled trial comparing inspiratory muscle training at moderate intensity (~50% of the maximal inspiratory pressure (P<sub>lmax</sub>) versus sham training in patients with weaning failure showed that a larger proportion of the training group (76%) could be weaned compared to the sham group (35%) [77]. The addition of IMT in acute critically ill patients from the beginning of mechanical ventilation has shown contrasting findings. Caruso et al. submitted their patients in a RCT to IMT for 30 minutes per day and found that IMT neither improved P<sub>lmax</sub> or abbreviated the weaning duration, nor decreased the reintubation rate [78]. In contrast, Cader et al. observed in a RCT that twice daily IMT sessions at 30%P<sub>lmax</sub> for 5 minutes improved P<sub>lmax</sub> and reduced the weaning period (3.6 vs 5.3 days in the control group)[79].

Biofeedback to display the breathing pattern has been shown to enhance weaning [80]. Voice and touch may be used to augment weaning success either by stimulation to improve ventilatory drive, or by reducing anxiety [81]. Environmental influences, such as ambulating with a portable ventilator have been shown to benefit attitudes and outlooks in long-term ventilator-dependent patients [82].

In conclusion, physiotherapists are involved in the management of patients with critical illness. Their assessment and treatment of critically ill patients concentrate on deconditioning and related problems (muscle weakness, joint stiffness, impaired functional exercise capacity, physical inactivity), and respiratory conditions (retained airway secretions, atelectasis and respiratory muscle weakness) to identify targets for physiotherapy. Evidence-based targets for physiotherapy are deconditioning, impaired airway clearance, atelectasis, (re-)intubation avoidance, and weaning

failure. A variety of modalities for exercise training and early mobility are evidence-based and must be implemented depending on the stage of critical illness, co morbid conditions and cooperation of the patient. The physiotherapist should be responsible for implementing mobilization plans and exercise prescription and make recommendations for progression of these issues, jointly with medical and nursing staff.

**Supported by:** this work is partially funded by Research Foundation - Flanders grant G0523.06.

**Figure 6.** Respiratory muscle resistive training with Threshold loading in a patient weaning from mechanical ventilation



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