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Invited review

Rehabilitation, Weaning and Physical Therapy Strategies in the Chronic Critically Ill patients

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Summary

In critically ill patients prolonged hospital stay due to the initial acute insult, and adverse side effects of drug therapy, may cause severe late complications like muscle weakness, prolonged symptoms, mood alterations and poor health-related quality of life.

The clinical aims of physical rehabilitation in both medical and surgical intensive care units (ICUs) are focussed on the patient as a whole to improve his/her short- and even long-term care Purpose of this article is to review the currently available evidence of comprehensive rehabilitation programs in critically ill patients, with a description of the key components and techniques used particularly in specialised ICUs.

Despite literature suggests that several techniques have led to beneficial effects, and that muscle training is associated with weaning success, scientific evidence is limited. Due to limitations in undertaking comparative studies in the ICUs, further studies with solid clinical short- and long-term outcome measures are now welcomed.
**Key words**: rehabilitation, mechanical ventilation, physiotherapy, weaning, respiratory failure
Progress in treatment has markedly improved survival of critically ill patients admitted to Intensive Care Units (ICUs) or respiratory intermediate intensive care units (RIICUs). Increasing evidence, however, point to persisting physical disability in many survivors, even years after the acute event, associated with reduced quality of life [1-3]. Several problems may contribute to these physical limitations, including decline in pulmonary function, contractures and pressure palsies as well as persistent muscle weakness [4], also leading to a growing number of partial or complete dependence on mechanical ventilation.

**Consequences of prolonged mechanical ventilation**

Long stay in hospital, lack of response to or inadequate level of appropriate therapy can lead to severe complications such as muscle wasting and weakness, deconditioning, recurrent symptoms, and mood alterations [5,6]. “Chronic critical illness” occurs in almost half of the ICU patients with sepsis, multiple organ failure or need of prolonged mechanical ventilation and involves muscle weakness, neuropathy, loss of lean body mass, increased adiposity, and anasarca [5-7]. This condition is also associated to
low serum hormone levels, catabolism [6,8], increased prevalence of difficult-to-eradicate infections [9], prolonged coma or delirium [10], skin wounds, oedema, incontinence, and prolonged bed-rest [11,12].

There is a growing need for recognition of the role of rehabilitation programs in the short- and even long-term care of patients admitted to ICUs or RIICUs [14-17]. The aims of these programs in critically ill patients is to apply advanced cost-effective therapeutic tools to decrease bed-rest complications and patient’s ventilator-dependency, to improve residual function, to prevent the need for new hospitalisations and to improve the health status and quality of life. [18-20]. Physical therapy in patients undergoing cardiac, upper abdominal, and thoracic surgery, may prevent and treat respiratory complications such as secretion retention, atelectasis, and pneumonia by means of different techniques. Long-term outcomes include improvement in respiratory function, reduction in readmission to hospital and overall improvement in the health status.[21,22] Early mobilisation and maintenance of muscle strength may reduce the risk of difficult weaning, limited mobility and ventilator dependency [23,24].
Table 1 summarises the interventions of a rehabilitation course for critically ill patients.

**Treatment of muscle weakness**

Prolonged immobility is a contributing factor of muscle weakness of ICU patients. Therefore, passive and active mobilisation may represent substantial contribution to the patient's recovery in the critical care area. Mobilisation is generally delivered, increasing progressively both intensity and duration of exercises.

Mobilisation- Early mobilisation is a feasible and safe intervention to be delivered after the cardio-respiratory and neurological stabilisation [25-27]. This approach, together with specific muscle training, can improve functional outcomes, cognitive and respiratory conditions [26], and reduces venous stasis and risk of deep vein thrombosis [28]. In particular, Continuous Rotational Therapy refers to the use of specialised beds to continuously turn patients along the longitudinal axis up to an angle of 60° onto each side, with preset degree and speed of rotation. Rather than prevent, this treatment can reduce the risk of sequential airways
closure, and pulmonary atelectasis, reduce the incidence rate of lower respiratory tract infection, and pneumonia, duration of endotracheal intubation and length of hospital stay [23,29-33].

There is agreement on the use of early mobilisation also in unconscious or sedated patients [15,34]. This includes the use of semi-recumbent positioning with the goal of 45° head of the bed up and higher [14,35]; regular changes in postures beyond the standard every two hour turning regimen [36]; daily passive movement of all joints [37], (passive) bed cycling [38] and electrical stimulation as indicated [39].

Postures- Prone position has been shown to result so far in short-term gain in oxygenation, improvement of ventilation and perfusion mismatch and of the residual lung capacity [40-43]. Improvements in lung function and reduction of lung atelectasis rate have been also shown in patients with unilateral disease once positioned with the affected lung uppermost [44,45]. Despite their physiological rationale [18], these easy-to apply techniques are still not widely used and it is still unclear whether the reported improvements may be associated with similar changes of stronger clinical outcomes like mortality.
**Limb exercise and peripheral muscle training.** Passive, active assisted, or active resisted limb movements are aimed to maintain joint range of motion, to improve soft-tissue length and muscle strength, and to decrease the risk of thromboembolism [46]. Quadriceps strength and functional status showed no difference in patients where early mobilisation was added to standard chest physiotherapy compared to physiotherapy alone. However, the total walked distance, the isometric quadriceps force and the perceived functional well-being were significantly better in those patients who had been added with early mobilisation [38]. A gradual mobility protocol for both upper and lower limbs was then introduced. It was found to be feasible and safe and led to a decreased hospital length of stay in patients requiring mechanical ventilation [47]. In particular, addition of a supported arm training protocol was as effective in patients recently weaned from mechanical ventilation and admitted to a RIICU setting [48].

Muscle mass and ability to perform aerobic exercise decline with inactivity [49]. In critically ill and complex patients skeletal muscle training aims at improving strength, thus increasing the
patient's ability to recover his/her activities of daily life (ADL) [26], improving hospital stay and survival. In patients on long term mechanical ventilation and those difficult to wean, a tailored training program seems to be effective in speeding weaning time, and in improving hospital stay and survival [50].

Prolonged inactivity is more likely to cause skeletal muscle dysfunction and atrophy in antigravity muscles, with reduced capacity to perform aerobic exercise [51]. In severely disabled patients peripheral muscle training (lifting weights or pushing against a resistance with the limbs), produces specific gain in strength and recovery of ADL, although the evidence of effects after an episode of acute respiratory failure is not yet defined [52]. Figure 1 illustrates examples of active and passive peripheral muscle activities in bed-bounded critically ill patients.

**Neuromuscular electrical stimulation**— Neuromuscular electrical stimulation (NMES) can induce changes in muscle function without any form of ventilatory stress [53]. NMES can be easily performed in the ICU, applied to lower limb muscles of patients laying in bed. Nevertheless, to date, no clinical studies have yet completely demonstrated the additional effect of NMES on exercise
tolerance when compared with conventional training. Patients with COPD [54,55] or with congestive heart failure [56] are more likely to benefit; moreover, NMES has been also considered as a means to prevent the ICU neuromyopathy [57]. Although NMES may have a role, the timing of such an intervention is yet to be determined. An anabolic stimulus early on in critical illness may have little benefit, as shown by lack of NMES effect in patients with septic shock [58]. Nevertheless the severity of the acute illness appears also to have an important role as benefit of NMES has been shown in patients with sepsis without shock [59]. This is supported by the basic science literature. An anabolic stimulus at a time when mitochondrial dysfunction is present [60] may not be beneficial although survival appears to be associated with early activation of mitochondrial biogenesis [61], which could be stimulated by NMES.

Respiratory muscle training- Weakness of the respiratory muscle mass, imbalance between respiratory muscle strength and load of the respiratory system, and cardiovascular impairment, are major determinants of weaning failure in ventilated individuals. In ICU patients these factors and the excessive use (especially in the past) of controlled mechanical ventilation, may rapidly lead to
diaphragmatic dysfunction [62]. Nevertheless, the rationale of respiratory muscle training in critically ill patients is still controversial and is not part of mainstream practice in many institutions. Indeed, the diaphragm of patients with COPD, is as valid as that of normals in generating pressure at comparable lung volumes [63]. An adaptive change toward the slow-to-fast characteristics (resistance to fatigue) of the muscle fibres due to increased operational lung volume has been shown [64]. Recent literature debates the potential role of Inspiratory Muscle Training as a component of pulmonary rehabilitation in severely disabled COPD and in neuromuscular patients [65,66], aimed at improving their strength and at reducing the respiratory system load perception. Notwithstanding, studies in ventilatory-dependent COPD patients showed that respiratory muscles training may be associated with a favourable weaning outcome [67-69].

**Management of airway secretions**

Increased retention of bronchial secretion as a result of mucociliary dysfunction and reduced cough function as a result of inspiratory and expiratory muscle weakness cause an increased risk
of nosocomial pneumonia [9]. Chest physiotherapy should prevent such complications by improving ventilation and gas exchange, and by reducing airway resistance and work of breathing [16]. Several manually assisted techniques (manual hyperinflation, percussions/vibrations) and mechanical devices are often applied to facilitate the movement of mucus excess (see in Table 1).

**Manual Hyperinflation**- This technique is aimed at preventing pulmonary collapse (or re-expanding collapsed alveoli), improving oxygenation and lung compliance, and facilitating the movement of secretions toward the central airways [70]. The guidelines for the application of manual hyperinflation vary across units. The possible physiological side effects of delivered air volume, flow rates and airway pressure must be carefully considered especially in patients under mechanical ventilation [71-73]. Increase in air volume with this technique can be obtained both manually or with assisted mechanical ventilation, each producing similar benefit in clearing excessive mucus [74,75].

**Percussion and Vibrations.** Manual clapping over a selected area of the chest wall and vibration that involves compression of
the chest during the expiratory phase of ventilation are common techniques used to increase airway clearance by shifting secretions from the periphery towards the central airways. The techniques may be applied along with the use of gravity by positioning the patients to assist with drainage of secretions. Currently, in critical ventilated patients with a normal cough competence, increase of mucus clearance is described without a significant change of blood gases and lung compliance [16,76,77].

**In-Exsufflation**—This is the most popular mechanically assisted technique adopted to promote removal of excessive mucus in neuromuscular disease [78]. In-exsufflation is also referred to as the cough assist and is usually limited to patients with neuromuscular and skeletal conditions, who have a weak cough (<250 L/min flow). It acts by inflating the airways with a large air volume that rapidly is exsufflated by negative pressure, thus simulating the physiological mechanism of cough [79-81]. The safety and the clinical advantage (avoidance or delay of tracheostomy and/or endotracheal intubation) of this device when compared with conventional chest physiotherapy has been shown in hospitalised neuromuscular patients with recent upper respiratory
tract infection [82,83]. The usefulness of this technique in allowing for extubation in patients judged as needing tracheostomy has been recently outlined [84].

**Intrapulmonary Percussive Ventilation (IPV)**- This mechanical device creates a percussive effect in the airways thus facilitating mucus clearance through a direct high-frequency oscillatory ventilation able to help the alveolar recruitment [85]. Positive effects from this technique have been shown during both acute or chronic phases in patients with respiratory distress [86], neuromuscular diseases [87], and pulmonary atelectasis [88]. In hospitalised COPD patients with respiratory acidosis, this technique has been also shown to prevent the deterioration of the acute episode, thus avoiding endotracheal intubation [89]. In tracheostomised patients recently weaned from mechanical ventilation the addition of IPV to usual chest physiotherapy was associated with improvement of oxygenation and expiratory muscle performance also leading to a substantial reduction in the risk of late onset pneumonia [90].

**Weaning**
COPD patients can have substantial difficulties to accomplish the weaning process, due to the pulmonary/thoracic (imbalance between capacity of and load on respiratory system) and systemic involvement of their chronic disease. Among the systemic factors, immobility (even by neuromuscular blocking agents), muscle de-conditioning (with muscle disuse atrophy), systemic use of corticosteroids, malnutrition and gas exchange abnormalities are common obstacles to weaning in critically ill patients. For these patients, the “difficult/prolonged weaning” requires a rehabilitation-based specific process aimed at restoring the individual’s independence from the ventilator.

**Therapist Driven Protocols** - Despite studies have been inconclusive in determining whether decreasing pressure support or T-piece tube trials is the best method to speed up the weaning process, trials in recent years have underlined the role of a standardized protocol (the so called therapist driven protocol, TDP) to resume more easily the patient’s spontaneous breathing. Therapist driven protocols represent ICU staff consensus summarised into a daily care plan (algorithm), essentially based on
reporting changes in patient to ventilator interactions as recordable at each step (e.g. the change of the ventilatory setting) [95]. The role of professional expertise in guiding this process is crucial.

Despite no definitive results exist regarding the application of TDP as a fixed protocol-based procedure to discontinue mechanical ventilation [96], the use of this care plane has proven to be effective when applied to the weaning process in the critical care area. Saura et al. [97], prospectively studied 51 patients weaned by a TDP who resulted in less days under mechanical ventilation and in hospital when compared with retrospective controls. These results were confirmed by a randomised controlled study by Ely and colleagues [98] who demonstrated that the use of TDP for weaning is able to reduce costs and clinical complications due to conventional ventilation. Overall, the clinical experience in this field seems to confirm good results regarding weaning process: in fact, when using a TDP, a weaning success rate of about 60% is reported in complex and difficult-to-wean patients [99,100]. Finally, increasing periods of spontaneous breathing (T-piece) trials or decreasing levels of pressure support were found to be equally effective during TDP in tracheostomised and difficult-to-wean COPD patients [101]. Despite the evidence, recent surveys have shown
that TDPs are unevenly or infrequently adopted in ICUs across different countries [100-103].

**Conclusion**

Due to increasing number of ICU admissions worldwide which all carry a risk of subsequent complications and mortality over the following years [3,104], comprehensive programs including physiotherapy should be implemented to speed-up the patients’ functional recovery and to prevent the complications of prolonged immobilisation especially in ventilator-dependent or difficult-to-wean patients [19,104]. To manage the multiple and complex problems of these patients, integrated programs dealing with both whole-body physical therapy and pulmonary care are needed [14,15].

To date, application of both techniques and strategies here reviewed is more likely to be dedicated to those critically ill patients who are specifically admitted to a RIICU. Indeed, there is still a limited scientific evidence to support such a comprehensive approach to all the critically ill patients. Therefore, despite the ethical difficulties experienced with randomised control trials and other reasons which make studies undertaken in ICU challenging
we need randomised studies with solid clinical short- and long-term outcome measures.
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Legend

Figure 1. Examples of passive, active-assisted and active peripheral muscle activities in bed-bounded critically ill patients.
Table 1. Rehabilitation-based activities and techniques in the ICU

<table>
<thead>
<tr>
<th><strong>Muscle Weakness</strong></th>
<th>Passive and active-assisted mobilisation [15,23-28,34]</th>
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<tr>
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<td>Continuous rotational therapy [31-33]</td>
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<td>Peripheral muscle training [50,52]</td>
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<td><strong>Airway Secretions</strong></td>
<td>Manual Hyperinflation [70-75]</td>
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<td>Percussion and Vibrations [76,77]</td>
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*Note*: Numbers in square brackets refer to the bibliography list.