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Rehabilitation, weaning and physical therapy strategies in chronic critically ill patients

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ABSTRACT: In critically ill patients, a prolonged hospital stay, due to the initial acute insult and adverse side-effects of drug therapy, may cause severe late complications, such as 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 to improve their short- and even long-term care.

The purpose of this article is to review the currently available evidence on comprehensive rehabilitation programmes in critically ill patients, and describe the key components and techniques used, particularly in specialised ICUs.

Despite the literature suggesting 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 ICUs, further studies with solid clinical short- and long-term outcome measures are now welcomed.

KEYWORDS: **Mechanical ventilation, physiotherapy, rehabilitation, respiratory failure, weaning**

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Progress in treatment has markedly improved the survival of critically ill patients admitted to intensive care units (ICUs) or respiratory intermediate intensive care units (RIICUs). Increasing evidence, however, points to persisting physical disability in many survivors, associated with reduced quality of life, even years after the acute event [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 an increase in partial or complete dependence on mechanical ventilation.

CONSEQUENCES OF PROLONGED MECHANICAL VENTILATION

A long hospital stay and lack of response to or an 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 all ICU patients with sepsis, multiple organ failure or requiring prolonged mechanical ventilation and involves muscle weakness, neuropathy, loss of lean body mass, increased adiposity and anasarca [5–7]. This condition is also associated with 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 programmes in the short- and long-term care of patients admitted to ICUs or RIICUs [13–17]. The aims of these programmes in critically ill patients are: to apply advanced cost-effective therapeutic tools to decrease bed rest complications and patients' ventilator dependency; to improve residual function; to prevent the need for new hospitalisations; and to improve 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

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different techniques. Long-term outcomes include improvement in respiratory function, reduction in re-admission to hospital and overall improvement in 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 in ICU patients. Therefore, passive and active mobilisation may substantially contribute to the patient's recovery in the critical care area. Mobilisation is generally delivered progressively, increasing both intensity and duration of exercise.

Mobilisation

Early mobilisation is a feasible and safe intervention that is delivered after cardio-respiratory and neurological stabilisation [25–27]. This approach, together with specific muscle training, can improve functional outcomes and cognitive and respiratory conditions [26], and reduce 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 60° on each side, with pre-set degree and speed of rotation. Rather than prevention, this treatment can reduce the risk of sequential airway closure and pulmonary atelectasis, reduce the incidence rate of lower respiratory tract infection and pneumonia, and reduce the duration of endotracheal intubation and length of hospital stay [23, 30–32, 89, 90].

There is agreement on the use of early mobilisation in unconscious or sedated patients [15, 29]. This includes the use of semi-recumbent positioning with the aim being to have: the head of the bed positioned at $\geqslant 45^\circ$ [14, 33]; regular changes in postures beyond the standard 2-h turning regimen [34]; daily passive movement of all joints [91]; and (passive) bed cycling [41] and electrical stimulation as indicated [46].

TABLE 1 Rehabilitation-based activities and techniques in the intensive care unit

Activities and techniques	[Ref.]
Muscle weakness	
Passive and active-assisted mobilisation	[15, 23–29]
Continuous rotational therapy	[30–32]
Postures	[18, 33–40]
Active limb exercise	[41–43]
Peripheral muscle training	[44, 45]
Neuromuscular electrical stimulation	[46–55]
Respiratory muscle training	[56–60]
Airway secretions	
Manual hyperinflation	[61–66]
Percussion and vibrations	[67, 68]
In-exsufflation	[69–75]
Percussive ventilation	[76–81]
Weaning	
Therapist-driven protocols	[82–88]

Postures

Prone position has been shown to result in a short-term gain in oxygenation, and improvement of ventilation and perfusion mismatch and residual lung capacity [35–38]. Improvements in lung function and reduction of lung atelectasis rate have also been seen in patients with unilateral disease when positioned with the affected lung uppermost [39, 40]. 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 in stronger clinical outcomes, such as mortality.

Limb exercise and peripheral muscle training

The aims of passive, active-assisted or active-resisted limb movements are to: maintain joint range of motion; improve soft-tissue length and muscle strength; and decrease the risk of thromboembolism [92]. Quadriceps strength and functional status showed no difference in patients where early mobilisation was added to standard chest physiotherapy compared with physiotherapy alone. However, the total walked distance, the isometric quadriceps force and the perceived functional well-being were significantly better in those patients with early mobilisation [41]. 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 length of hospital stay in patients requiring mechanical ventilation [42]. In particular, addition of a supported arm-training protocol was effective in patients recently weaned from mechanical ventilation and admitted to an RIICU [43].

Muscle mass and the ability to perform aerobic exercise declines with inactivity [93]. In critically ill and complex patients, skeletal muscle training aims at improving strength, thus, increasing the patient's ability to recover activities of daily life [26], improving hospital stay and survival. In patients on long-term mechanical ventilation and those who are difficult-to-wean, a tailored training programme seems to be effective in speeding up weaning time and improving hospital stay and survival [44].

Prolonged inactivity is more likely to cause skeletal muscle dysfunction and atrophy in anti-gravity muscles, with reduced capacity to perform aerobic exercise [94]. In severely disabled patients, peripheral muscle training (lifting weights or pushing against a resistance with the limbs) produces a specific gain in strength and recovery of activities of daily life, although evidence of effects after an episode of acute respiratory failure has not yet been defined [45]. Figure 1 illustrates examples of active and passive peripheral muscle activities in bed-bound critically ill patients.

Neuromuscular electrical stimulation

Neuromuscular electrical stimulation (NMES) can induce changes in muscle function without any form of ventilatory stress [47]. NMES can be easily performed in the ICU and applied to the lower limb muscles of patients lying in bed. Nevertheless, to date, no clinical studies have completely demonstrated the additional effect of NMES on exercise tolerance when compared with conventional training. Patients with chronic obstructive pulmonary disease (COPD) [48, 49] or congestive heart failure [50] are more likely to benefit; moreover, NMES has also been considered as a means to prevent the ICU neuromyopathy [51]. Although NMES may have a role, the timing of such an

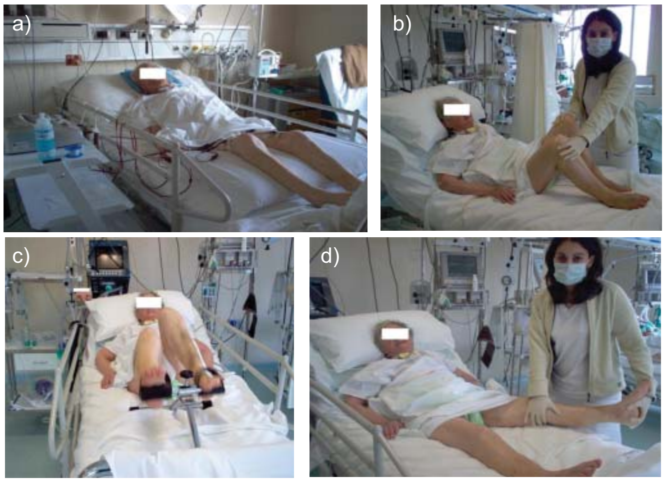

FIGURE 1. Examples of a) passive, b, d) active-assisted and c) active peripheral muscle activities in bed-bound critically ill patients.

intervention has yet to be determined. An anabolic stimulus early on in critical illness may have little benefit, as shown by the lack of NMES effect in patients with septic shock [52]. Nevertheless the severity of the acute illness also appears to have an important role, as the benefit of NMES has been shown in patients with sepsis without shock [53]. This is supported by the basic scientific literature. An anabolic stimulus at a time when mitochondrial dysfunction is present [54] may not be beneficial, although survival appears to be associated with early activation of mitochondrial biogenesis [55], 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 [95]. 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 effective as that of normal subjects in generating pressure at comparable lung volumes [96]. 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 [97]. Recent literature debates the potential role of inspiratory muscle training as a component of pulmonary rehabilitation in severely disabled COPD and neuromuscular disease patients [56, 57], aimed at improving their strength and reducing the respiratory system load perception. Notwithstanding, studies in ventilator dependent COPD patients have shown that respiratory muscle training may be associated with a favourable weaning outcome [58–60].

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 and percussions/vibrations) and mechanical devices are often applied to facilitate the movement of excess mucus (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 [61]. 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 on mechanical ventilation [62–64]. An increase in air volume with this technique can be obtained both manually or with assisted mechanical ventilation, with each producing similar benefits in clearing excessive mucus [65, 66].

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 airways 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 normal cough competence, increase of mucus clearance is described without a significant change of blood gases and lung compliance [16, 67, 68].

In-exsufflation

This is the most popular mechanically assisted technique adopted to promote removal of excessive mucus in neuromuscular disease [69]. In-exsufflation is also referred to as cough assist and is usually limited to patients with neuromuscular and skeletal conditions who have a weak cough (flow rate $<250\ L \cdot min^{-1}$). It acts by inflating the airways with a large volume of air that is rapidly exsufflated by negative pressure, thus simulating the physiological mechanism of cough [70–72]. The safety and 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 [73, 74]. The usefulness of this technique in allowing for extubation in patients judged as needing tracheostomy has been recently reported [75].

Intrapulmonary percussive ventilation

This mechanical device creates a percussive effect in the airways, thus facilitating mucus clearance through direct high-frequency oscillatory ventilation that is able to help the alveolar recruitment [76]. Positive effects from this technique have been shown during both acute and chronic phases in patients with respiratory distress [77], neuromuscular diseases [78] and pulmonary atelectasis [79]. In hospitalised COPD patients with respiratory acidosis, this technique has also been shown to prevent the deterioration of the acute episode, thus avoiding endotracheal intubation [80]. In tracheostomised patients recently weaned from mechanical ventilation, the addition of intermittent percussive ventilation 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 [81].

WEANING

COPD patients can have substantial difficulties in completing the weaning process due to the pulmonary/thoracic (imbalance between capacity of and load on respiratory system) and systemic involvement of their chronic disease [98]. 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 [6, 99]. For these patients, difficult/prolonged weaning requires a rehabilitation-based, specific process aimed at restoring the individual's independence from the ventilator.

Therapist-driven protocols

Despite studies being inconclusive in determining whether decreasing pressure support or T-piece tube trials are the best method to speed up the weaning process [82, 100], recent trials have underlined the role of a standardised protocol (the so-called therapist-driven protocol; TDP) to resume the patient's spontaneous breathing more easily. TDPs represent ICU staff consensus summarised into a daily care plan (algorithm), essentially based on reporting day by day changes in patient to ventilator interactions (*e.g.* the change of the ventilatory setting) [83]. The role of professional expertise in guiding this process is crucial.

At present there are no definitive results regarding the application of TDP as a fixed protocol-based procedure to discontinue mechanical ventilation [84], the use of this care plan has been proven to be effective when applied to the weaning process in the critical care area. SAURA *et al.* [85] prospectively studied 51 patients weaned using the TDP and found that they required less mechanical ventilation and spent less time in hospital compared with retrospective controls. These results were confirmed by a randomised controlled study by ELY *et al.* [86] who demonstrated that the use of TDP for weaning reduces costs and clinical complications compared to conventional ventilation. Overall, the clinical experience in this field seems to confirm positive results regarding the weaning process. In fact, when using TDP, a weaning success rate of ~60% was reported in complex and difficult-to-wean patients [87, 88]. 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 in different countries [100–103].

CONCLUSION

Due to an increasing number of ICU admissions worldwide, which all carry a risk of subsequent complications and mortality over the following years [3, 104], comprehensive programmes 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 programmes dealing with both whole-body physical therapy and pulmonary care are needed [14, 15]. To date, the application of both techniques and strategies is more likely to be dedicated to those critically ill patients who are specifically admitted to an RIICU. Indeed, there is still limited scientific evidence to support such a comprehensive approach to all critically ill patients. Therefore, despite the ethical difficulties experienced with randomised control trials and other reasons which make studies undertaken in ICUs challenging, we need randomised studies with solid clinical short- and long-term outcome measures.

STATEMENT OF INTEREST

None declared.

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