Eduardo Ériko Tenório de França, Francimar Ferrari, Patrícia Fernandes, Renata Cavalcanti, Antonio Duarte, Bruno Prata Martinez, Esperidião Elias Aquim, Marta Cristina Paulete Damasceno

Physical therapy in critically ill adult patients: recommendations from the Brazilian Association of Intensive Care Medicine Department of Physical Therapy

Fisioterapia em pacientes críticos adultos: recomendações do Departamento de Fisioterapia da Associação de Medicina Intensiva Brasileira

Recommendations developed by the Department of Physical Therapy of Associação de Medicina Intensiva Brasileira (AMIB).

ABSTRACT

Complications from immobility in intensive care unit patients contribute to functional decline, increased healthcare costs, reduced quality of life and higher post-discharge mortality. Physical therapy focuses on promoting recovery and preserving function, and it may minimize the impact of these complications. A group of Brazilian Association of Intensive Care Medicine physical therapy experts developed this document that contains minimal physical therapy recommendations appropriate to the Brazilian real-world clinical situation. Prevention and treatment of atelectasis, procedures related to the removal of secretions and treatment of conditions related to physical deconditioning and functional decline are discussed. Equally important is the consideration that prescribing and executing activities, mobilizations and exercises are roles of the physical therapist, whose diagnosis should precede any intervention.

Keywords: Critical illness/rehabilitation; Critical care; Cooperative behavior

INTRODUCTION

The survival of critically ill patients has increased as a consequence of technological and scientific development and interdisciplinary cooperation. However, complications due to prolonged immobility in the intensive care unit (ICU) contribute to functional losses, increased healthcare costs and reduced post-discharge quality of life and survival. ICUs from Brazil and other countries have endeavored to find alternatives to face this challenge. Physical therapy, a science focused on promoting functional recovery and preservation, has a prominent role in this effort.[1-6]

This document is proposed to guide ICU physical therapy actions and is essentially focused on the diagnosis, prescription and execution of measures specific to the physical therapist. It is aimed to reflect the Brazilian real-world clinical situation and not to discuss ICU practices usually shared with the interdisciplinary team, such as mechanical ventilation and correlated procedures.

Often recommendations elicit resistance from some colleagues, who may feel that their professional autonomy is being restricted. However, these recommendations should be seen as supportive for the

Conflicts of interest: None.

Final version: August 2011.
Reviewed: February 2012.

Corresponding author:
Marta Cristina Paulete Damasceno
Rua Assungui, 310 - Vila Gumercindo
Zip Code: 04131-000 - São Paulo (SP), Brazil.
E-mail: martacpdamasceno@hotmail.com

decision-making process, as they can be adapted according to the professional's experience.[7] In summary, the recommendations are expected to improve the patient's care, supporting the healthcare professional's decisions and preserving the professional's autonomy.[8]

OBJECTIVES

To provide minimal recommendations applicable to the Brazilian real-world clinical situation on physical therapy in the intensive care unit specifically in three clinical areas:

1. Prevention and treatment of atelectasis.
2. Respiratory conditions related to removal of secretions.
3. Conditions related to physical deconditioning and functional decline.

A number of general aspects should be considered in addition to specific recommendations. Prescribing and executing activities, mobilizations and exercises are the physical therapist's specific roles. A physical therapy diagnosis should precede any intervention.

PULMONARY EXPANSION THERAPY

Recommendation: The physical therapist should identify and diagnose reduced pulmonary volume in patients at risk.

Therapeutic resources for pulmonary expansion or re-expansion in critically ill patients were developed in response to the need to prevent and treat reduced pulmonary volume. Alveolar collapse reduces lung volume and consequently reduces residual functional capacity (RFC). If not reversed, this situation can cause hypoxemia and increase the risk of pulmonary infections.[9]

Pulmonary collapse is frequent in patients with respiratory and neuromuscular diseases, in patients restricted to bed for long periods, in intubated mechanically ventilated patients and in patients after either thoracic or abdominal surgery. Therefore, expansion or re-expansion techniques may be effective both for prophylaxis and treatment of pulmonary collapse associated with some clinical conditions.

Recommendation: Respiratory exercises, also known as deep-breathing exercises and incentive spirometry, are indicated for collaborative patients who are able to generate large lung volumes (forced vital capacity (FVC) above 20 mL/kg) at risk of hypoventilation complications.

Pulmonary expansion therapy is especially aimed at increasing pulmonary volume by increasing the trans-pulmonary pressure gradient, either by reducing pleural pressure or increasing intra-alveolar pressure. Therefore, patients with spontaneous ventilation (SV) or mechanical ventilation (MV), either using their respiratory muscles or devices that create positive intra-alveolar pressure, can benefit from pulmonary expansion (Figure 1).

Pleural pressure is reduced by inspiratory muscle contraction. More potent muscle contractions generate higher trans-pulmonary pressures and, consequently, mobilize larger volumes of air. Respiratory exercises and incentive spirometry are included.[10]

Incentive spirometry uses sustained maximal inspiratory pressure to achieve large pulmonary volumes, requiring visual feedback devices to stimulate the patients to achieve the expected flows or volumes.[11,12]

Overend et al. reported that deep-breathing exercises and incentive spirometry prevent pulmonary complications in comparison to groups with no physical therapy intervention during the postoperative period after abdominal surgery.[13]

Controlled randomized trials report that respiratory exercises and incentive spirometry are equally effective in preventing pulmonary complications in patients after abdominal surgery.[9,14,15]

Recommendation: The use of devices to generate positive airway pressure is indicated to increase the inspiratory volume (manual hyperinflation, intermittent positive pressure breathing (IPPB) and ventilator hyperinflation) and increase the residual functional capacity (continuous positive airway pressure (CPAP), expiratory positive airway pressure (EPAP) and positive expiratory pressure (PEP)) in non-cooperative patients and cooperative patients with an FVC below 20 mL/kg.

Devices generating positive airway pressure can be used during the inspiratory phase, during the expiratory phase, or both. These include devices offering IPPB, EPAP, CPAP and Bi-level ventilation (offering two airway pressure levels).[16]

Clinical use of IPPB was first described by Motley in 1947,[17] with particular emphasis on increasing

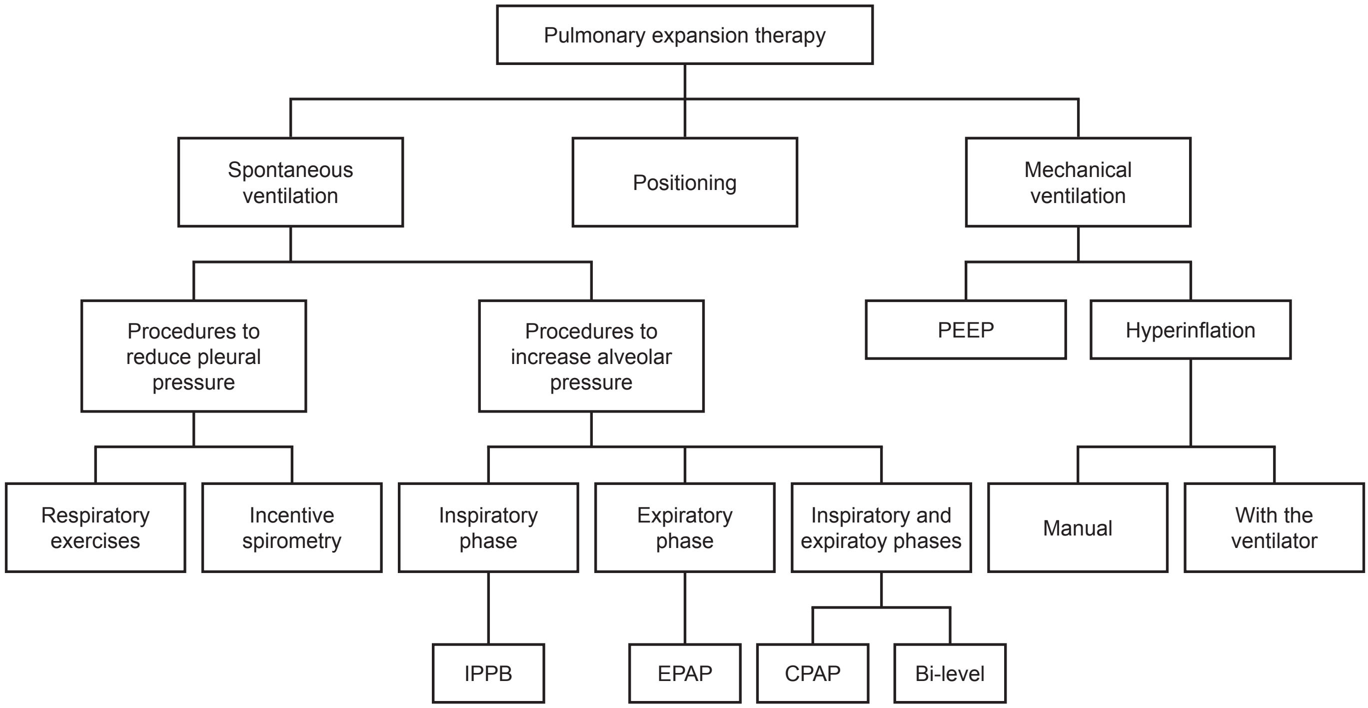

Figure 1 – Algorithm of pulmonary expansion therapy in spontaneous ventilation and mechanical ventilation intensive care unit patients.

PEEP - positive expiratory end pressure; IPPB - intermittent positive pressure breathing; EPAP - expiratory positive airway pressure; CPAP - continuous positive airway pressure.

tidal volume and consequently increasing minute volume, thereby optimizing gas exchange.[18,19] Ever since, IPPB has been widely used by physical therapists for SV patients, but its use is considered controversial and inconsistent.[20] This technique may be used both for intubated and non-intubated patients and consists in producing positive airway pressure during inspiration. It can be performed using volume, pressure, time and flow ventilators or with a manual hyperinflator (ambu).[21]

EPAP treatment consists in generating positive airway pressure during expiration only. EPAP devices produce expiratory flow resistance, such as spring-loaded valves, which may be connected to masks, mouthpieces or directly to the patient's artificial airway (AAW). The resulting PEEP promotes increased pulmonary volume and alveolar recruiting.[22]

CPAP is obtained with a flow generator and can be used for SV patients without AAW. CPAP consists of PEEP associated with airway inspiratory flow.[23] The benefits from CPAP are widely described in the literature and are directly related to increased alveolar pressure and RFC. Consequently, these benefits promote the recruitment of previously collapsed alveoli.[24-26]

Bi-level ventilation is a non-invasive ventilation mode characterized by the use of two different positive pressure levels, one during the inspiratory and one during the expiratory phase, generating increased pulmonary volume. Inspiratory phase pressure is always higher than that during expiration, allowing trans-pulmonary pressure to be increased even if the patient does not cooperate at all.[27-29]

Bi-level and CPAP are currently used for pulmonary expansion, but bi-level should be the first choice, as it offers two different pressure levels. CPAP is not able to increase alveolar ventilation; therefore, with hypercapnia, non-invasive two-pressure-level ventilation should be preferred.[29-32]

In patients with AAW, hyperinflation, either manual or using a ventilator, promotes the expansion of collapsed pulmonary units by increasing the airflow to atelectatic areas via collateral pathways, the alveolar interdependence mechanism and the renewal of alveolar surfactant. In addition, collateral ventilation to obstructed alveolar units favors the displacement of pulmonary secretions from the peripheral to central airways, promoting atelectasis expansion.[33-36] Offering larger pulmonary volumes may increase trans-pulmonary pressure and favor alveolar expansion and airway desobstruction.

Manual hyperinflation (MH) performed with a manual bag consists of consecutive slow and deep breaths, increasing the inspired volume, and is either followed or not by an inspiratory pause and quick pressure release.[37,38] Short-term MH can improve pulmonary compliance and resolve atelectasis.[39-45]

Even so, hyperinflation using a mechanical ventilator allows for increased positive inspiratory pressure with controlled pressure levels, incorporating the beneficial effects of PEEP and avoiding the untoward effects of disconnection from the mechanical ventilator.[46]

The use of PEEP for pulmonary expansion is well described in the literature and is directly related to its improvements of gas exchange and ventilation mechanics given its ability to generate increased pulmonary volume and alveolar recruiting, which increase RFC. For this aim, increasing PEEP in MV patients is a valuable resource.[22]

Considering physiological principles and respiratory mechanics, the positioning should be always chosen carefully. Pulmonary expansion is favored by regional ventilation differences, especially in non-dependent regions. A more negative pleural pressure allows alveoli from non-dependent regions to have a larger volume and increased stability in comparison with dependent-region alveoli. This relationship should be considered during the use of pulmonary expansion resources, either with MV or SV, to optimize results.[46,47]

BRONCHIAL HYGIENE THERAPY

Recommendation: The indication of bronchial hygiene therapy should be based on functional diagnosis, the impact of secretion retention on the pulmonary function, the patient's difficulty in expectorating, the patient's level of cooperation and the patient's performance status, allowing the professional to choose the most effective and less harmful method to optimize operational costs and fit the patient's preference.

Critically ill ICU patients have a range of medical diagnoses, but they frequently develop similar conditions requiring physical therapy assistance.[48] MV patients have increased bronchial secretion retention risks that are related to the functional impact of the underlying disease or the therapeutic intervention, either alone or in combination. These issues include tracheal intubation, which is related to impairment of the mucociliary system,[49-51] rheological changes of mucus;[52] immobilization due to being restricted to bed;[51-53] overall weakness leading to ineffective coughing;[54] and fluid restriction that may contribute to increased mucus viscosity.[55]

Bronchial hygiene therapy (BHT) is a set of interventions to promote or support the removal of a patient's airway secretions. In the setting of intensive care, these measures have been applied to SV and MV patients.[56] Several aspects should be considered for its indication: a) functional diagnosis, b) the impact on pulmonary function, c) difficulty of expectoration, d) the patient's level of cooperation and performance status, e) the most effective and less harmful intervention, f) the operational cost and g) the patient's preference.[57]

Recommendation: Choosing bronchial hygiene therapy should be based on the intervention's mode of action and indication: increasing inspiratory volume (positioning, manual hyperinflation, mobilization and respiratory exercises), increasing expiratory flow (positioning, manual hyperinflation, mobilization, coughing, huffing and respiratory exercises), oscillation (percussion, vibration and high-frequency oral oscillation) and increasing RFC (positioning, CPAP, EPAP and PEP).

The possible BHT interventions are stratified in this guideline considering MV patients (Figure 2) and SV patients (Figure 3). Intervention groups were adapted from Gosselink et al. and selected according to the mechanism of action and indication, i.e., a) increasing inspiratory volume, b) increasing expiratory flow, c) using oscillation techniques and d) using RFC-increasing techniques (Table 1).[52]

Positioning and mobilization are first-line interventions and should be coordinated with all other interventions. These techniques are safe and affordable and affect muscle strength, ventilation distribution, mucociliary clearance, oxygenation and RFC regionalization, which protects against alveolar hyperdistension.

Measures are recommended that increase inspiratory volume in patients with an inability

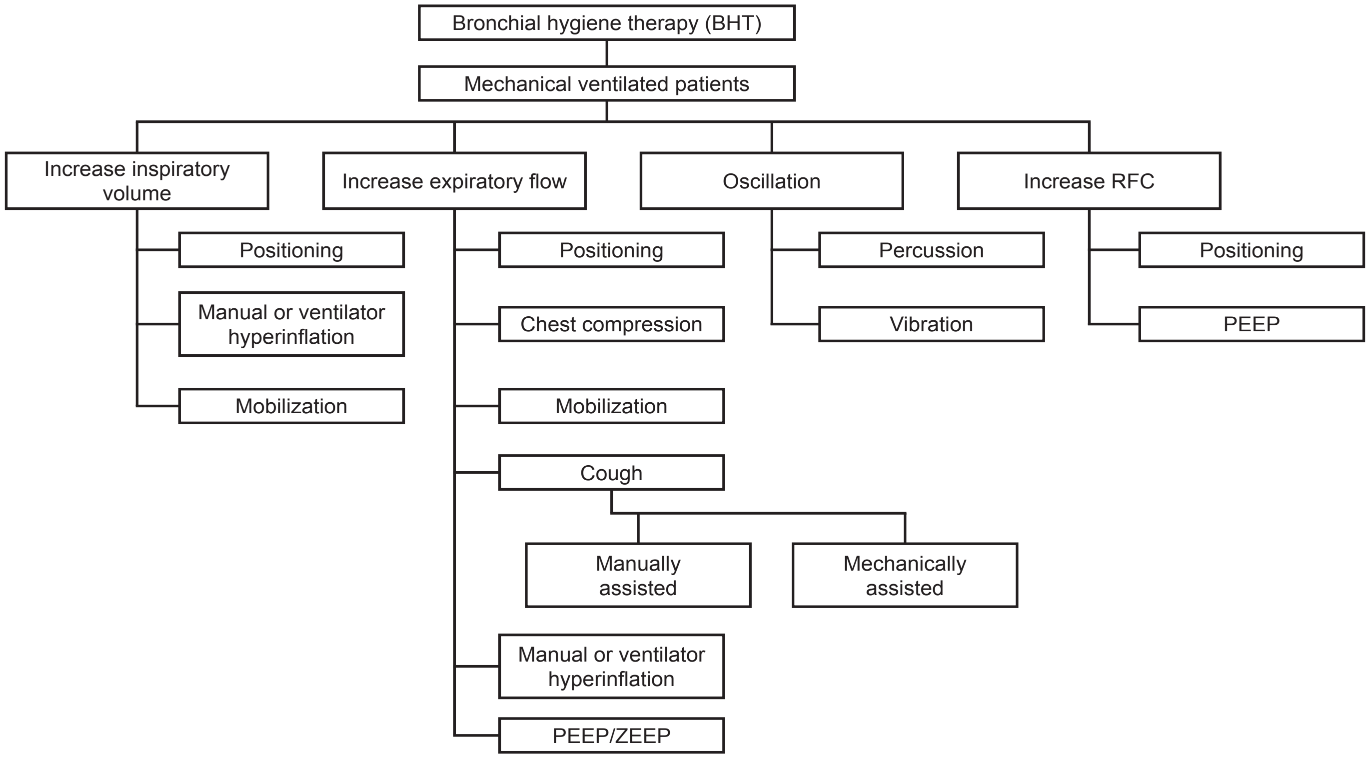

Figure 2 – Algorithm of bronchial hygiene therapy in mechanically ventilated intensive care unit patients.
RFC - residual functional capacity; PEEP - positive end-expiratory pressure; ZEEP - zero end-expiratory pressure.

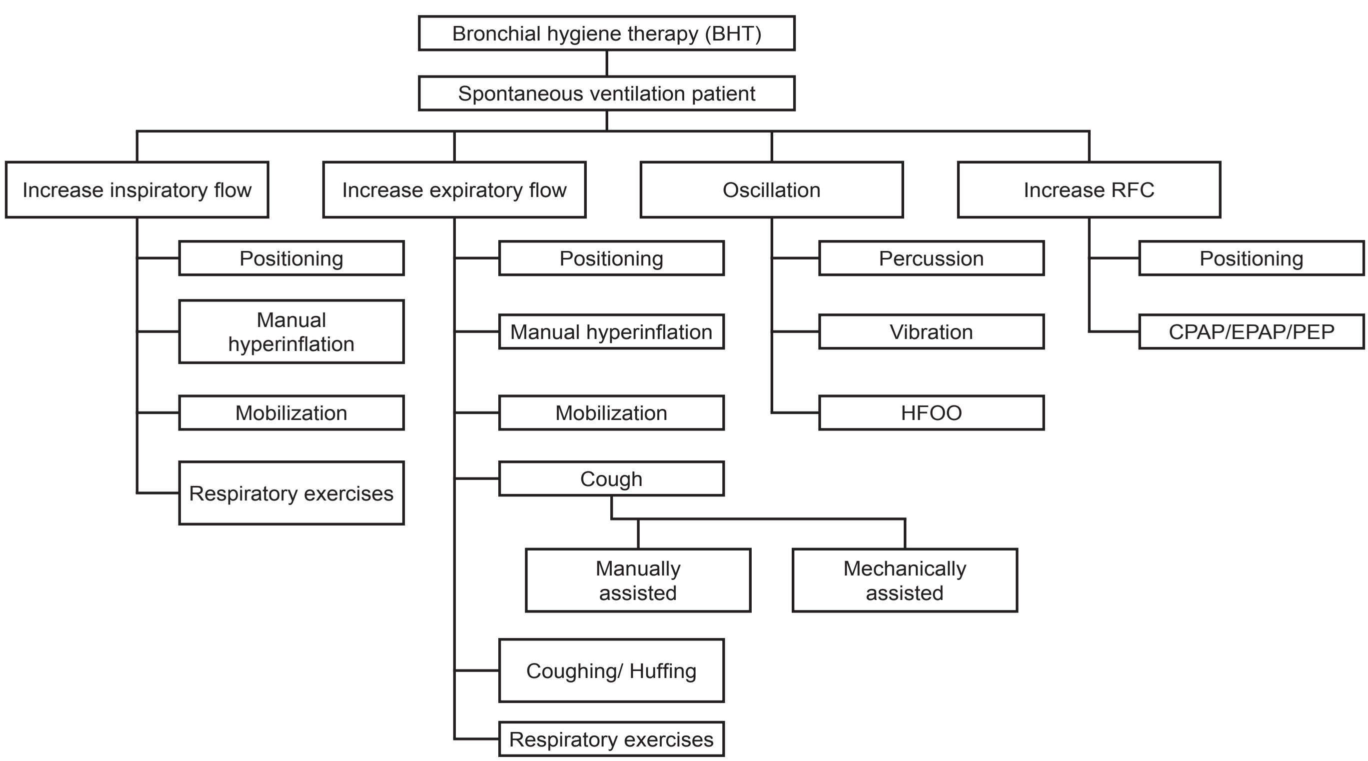

Figure 3 – Algorithm of bronchial hygiene therapy in spontaneous ventilation intensive care unit patients.
SV - spontaneous ventilation; RFC - residual functional capacity; CPAP - continue positive airway pressure; EPAP - expiratory positive airway pressure; PEP – positive expiratory pressure; HFOO – high frequency oral oscillation.

Table 1 – Relationship between the resources used for pulmonary expansion and bronchial hygiene therapy with the patient's forced vital capacity and cooperation

PET and BHT	Cooperative FVC > 20 ml / kg	Cooperative FVC 20 -10 ml/Kg	Cooperative FVC < 10ml / kg	Non-cooperative
Increased inspiratory volume	Positioning Mobilization MSI Respiratory exercise	Positioning Mobilization MSI Manual hyperinflation Ventilator hyperinflation	Positioning Manual hyperinflation Ventilator hyperinflation	Positioning Manual hyperinflation Ventilator hyperinflation
Increased expiratory flow	Positioning Coughing/Huffing	Positioning TMA/TMecA/TEA Manual hyperinflation Ventilator hyperinflation	Positioning TMA/TMecA/TEA Manual hyperinflation Ventilator hyperinflation PEEP/ZEEP	Positioning TMA/TMecA/TEA Manual hyperinflation Ventilator hyperinflation PEEP/ZEEP
Oscillation	Percussion Vibration HFOO	Percussion Vibration HFOO	Percussion Vibration	Percussion Vibration
Increased FRC	Positioning Respiratory exercise	Positioning CPAP/EPAP/PEP	Positioning PEEP	Positioning CPAP/EPAP/PEEP

PET - pulmonary expansion therapy; BHT - bronchial hygiene therapy; FVC - forced vital capacity; MSI - maximal sustained inspiration; CMA - cough manually assisted; CMecA - cough mechanically assisted; CEA - cough electrically assisted; PEEP - positive end-expiratory pressure ; ZEEP - zero end-expiratory pressure; HFOO - high frequency oral oscilation; CPAP - continuous positive airway pressure; EPAP - expiratory positive airway pressure; PEP - positive expiratory pressure.

to generate appropriate pulmonary expansion for effective coughing,[48,51,57] as are measures that promote increased expiratory flow related to expiratory muscle dysfunction.[48,51,54,56,57]

Oscillations should be used to increase airflow and mucus interaction, which modifies secretion viscosity by changing intra-thoracic pressures.[58-61]

Resources promoting increased RFC are recommended for air trapping prevention and therapy, early airway closure prevention, atelectasis prevention and therapy, and optimization of bronchodilators during BHT.[62]

BHT recommendations are shown in table 1. Aspects related to cooperation and motivation,[48,57] as well as recent data correlating the interventions' performance and FVC, were considered.[63]

NEUROMUSCULAR DYSFUNCTION, MUSCLE TRAINING AND EARLY MOBILIZATION

Recommendation: For cooperative patients, the Medical Research Council (MRC) score, which is used to assess peripheral muscle strength, should be used to assess the risk of functional decline.

Technical and scientific progress in intensive care medicine has significantly impacted the critically ill patient's survival, consequently increasing the time of exposure to causative factors of neuromuscular weakness and impacting the physical functioning and quality of life after discharge from the hospital.[64,65]

Among these causative factors are prolonged mechanical ventilation, restriction to bed and clinical conditions such as sepsis, systemic inflammatory response syndrome (SIRS), nutrition deficit and exposure to pharmacological agents, such as neuromuscular blockers and corticosteroids, that may adversely impact the functional status and result in prolonged tracheal intubation and hospital stay.[66,67] Figure 4 shows the mechanisms and consequences of muscle weakness in critically ill patients.[68] These factors may also increase the likelihood of polyneuropathy, which has serious consequences on the musculoskeletal system.[69] The association of prolonged MV with the effects of immobility results in muscle fiber loss, leading to significant loss of respiratory and peripheral muscle strength. Therefore, the duration of immobility will determine the contractile dysfunction severity, due to intrinsic muscle changes.[70,71]

Recognizing and diagnosing ICU-acquired neuromuscular dysfunction may be difficult

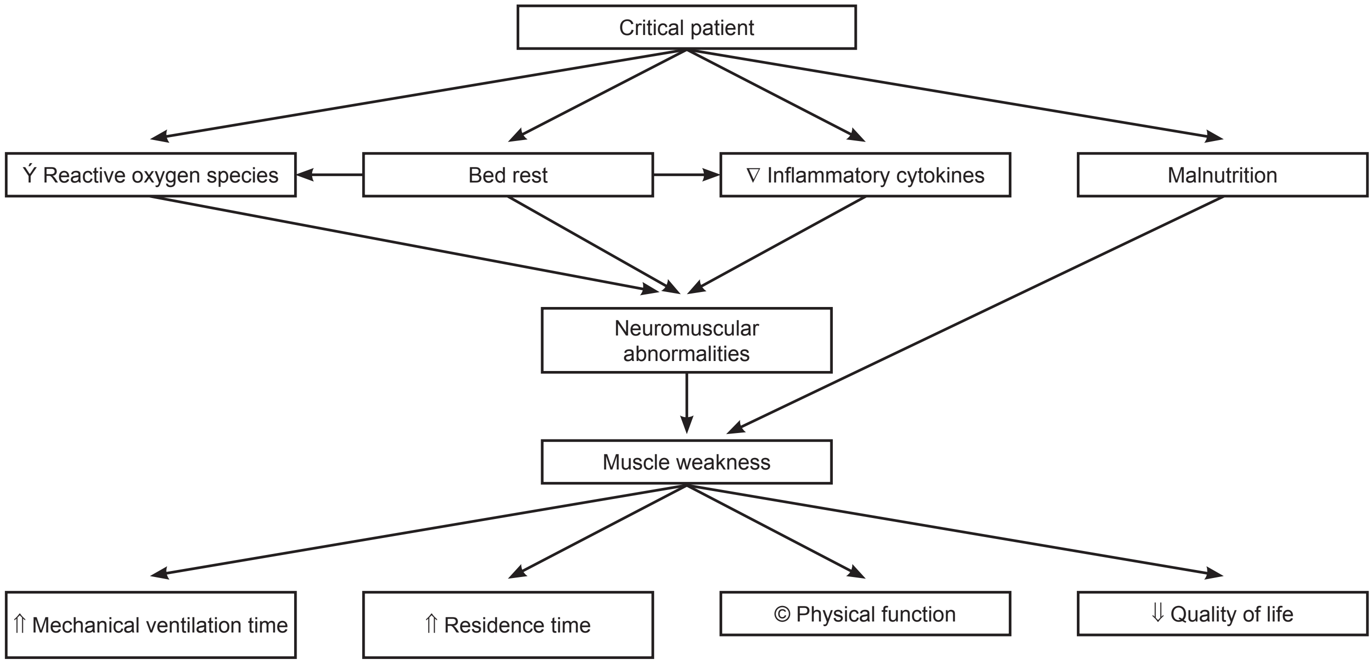

Figure 4 – Mechanisms and consequences of muscle weakness in critically ill patients.
Translated from: Truong AD, Fan E, Brower RG, Needham DM. Needham. Bench-to-bedside review:mobilizing patients in the intensive care unit--from pathophysiology to clinical trials. Critital Care. 2009;13(4):216.

in MV patients who are sedated and unable to cooperate with the assessment tests. Muscle weakness is diffuse and asymmetrical, involving both peripheral and respiratory muscles, with variable involvement of deep tendinous reflexes and sensitive innervation.

In sedated patients, muscle strength may be assessed by evaluating the patient's ability to raise a limb in response to painful stimuli. For cooperative patients, the MRC score (used for peripheral muscle assessment) is quite reproducible and has a high predictive value, as reported by several neuromuscular assessment studies in critically ill patients.[67,72,73]

Recommendation: Knowing the functional status before ICU admission is fundamental for physical therapy planning.

Another relevant issue to be assessed in critically ill patients is their functional independence before ICU admission, which can be determined using Barthel's scale and the Functional Independence Measure (FIM) scale to quantify the functional loss during the hospitalization and better plan the physical therapy.[73-75]

Respiratory muscle dysfunction should be systematically assessed by serial measurements of inspiratory (Pimax) and expiratory muscle (Pemax)–generated pressures, in addition to measuring the maximal voluntary air mobilization volume using vital capacity (VC).

Recommendation: Respiratory muscle dysfunction should be identified by systematic serial assessment of inspiratory (Pimax) and expiratory muscle (Pemax)–generated pressures, in addition to measuring the maximal voluntary air mobilization volume using vital capacity (VC) in cooperative patients.

In addition to immobility, which causes disuse muscle atrophy, ICU-acquired muscle weakness may be caused by the critically ill patient's myopathy or polyneuropathy. As an alternative for the prevention and treatment of these neuromuscular diseases, physical therapy has been recommended as an early mobilization of critically ill patient programs. However, the literature on the uniform use of physical therapy mobilization protocols in critically ill patients is scarce. More studies are required that assess its effects on pulmonary function, mechanical ventilation weaning, quality of life, and ICU and hospital length of stay.

Respiratory muscle training (RMT)

Recommendation: Mechanically ventilated patients should be tested daily for spontaneous breathing. RMT should be used in patients subject to muscle weakness and as adjuvant for patients who fail to wean from the ventilator.

Respiratory muscle weakness is common after prolonged MV, and its pathogenesis is similar to peripheral muscle weakness. Respiratory muscle weakness and, in particular, the imbalance between muscle strength and the respiratory system load are two of the major issues responsible for failed weaning. RMT can be performed using a range of devices with springs and holes that pose restrictive inspiration loads. RMT can also be performed using the ventilator sensitivity or by providing intermittent spontaneous breathing or minimal ventilation support.(76)

Two meta-analyses provide consistent evidence that RMT with specific linear load devices promotes significant respiratory muscle strength and endurance gains, improved perception of effort, increased 6-minute walk-test distance and higher quality of life in patients with chronic obstructive pulmonary disease (COPD) and respiratory muscle weakness.(77,78) Similar benefits are shown for this device in several other clinical conditions.(79-83)

RMT is also used in clinical practice to accelerate MV weaning by increasing respiratory muscle strength and endurance in MV-dependent patients. However, only four case-series reports are available that show the benefits of these devices in gaining inspiratory muscle strength, increasing spontaneous breathing time and promoting MV weaning.(83-86)

A retrospective study by Martin et al. assessed the benefit of RMT in association with a full-body physical therapy program. They identified improved peripheral and respiratory muscle strength and a substantially improved weaning. The training regimen included RMT twice daily with 1/3 of Pimax load in 49 patients who were able to breath spontaneously for more than two hours.(87)

The use of the ventilator sensitivity for RMT was described in only a single randomized controlled trial, which used sensitivity set to 20% of Pimax and increased it to 40% if tolerated. No inspiratory muscle strength improvement was identified in that study, and weaning time and re-intubation were not impacted by this technique.(88)

Recently Martin et al., in a randomized clinical trial with 69 patients who failed to wean, have shown that the group undergoing RMT had respiratory muscle strength gains and improved ventilator weaning compared with the control group. RMT was performed in four series of six to ten, five times a week, at the highest tolerated daily increased pressure level.(89)

Using low ventilation support levels or spontaneous breathing periods has been widely used in clinical practice to mitigate ventilator-induced muscle dysfunction, as well as for respiratory muscle endurance training.(90) Aliverti et al. (2006) assessed nine patients with different support pressure levels and observed that those with lower levels had a more homogeneous respiratory muscle recruitment.(91) Futier et al. (2008), in an experimental trial in rats, have shown that support pressure was effective to prevent proteolysis and inhibit protein synthesis, without changing the risk of oxidative injuries from controlled MV.(92) Although promising, this practice has no consistent support from human studies.

Girard et al., in a randomized clinical trial with 336 patients, have shown that the group undergoing spontaneous breathing tests associated with daily sedation withdrawal had more ventilator-free days (14.7 versus 11.6 days; $p = 0.02$), a shorter ICU stay (9.1 versus 12.9 days; $p = 0.01$) and a shorter hospital stay (14.9 versus 19.2; $p = 0.04$) compared with the control group that underwent only sedation withdrawal.(93)

Functional positioning

Recommendation: Functional positioning is a first-line technique that should be part of any treatment plan.

Functional positioning can be either passive or active and used for stimulating the musculoskeletal system, providing benefit for autonomic control, improving alertness and promoting vestibular stimulation, in addition to easing the anti-gravity posture response. It can be used to prevent muscle contractures and lymphatic edema and to minimize the effects of prolonged restriction to bed.(51,94) It is the physical therapist's duty to educate all professionals involved in the care of critically ill patients on how to perform this type of care and to highlight its relevance (it is as valuable as mobilization and is a basis for other physical therapy interventions).

Electric neuromuscular stimulation

Recommendation: Electric neuromuscular stimulation (ENMS) is a resource available for use in critically ill patients who are incapable of voluntary muscle contractions.

ENMS is frequently used by physical therapists in patients who are unable to voluntarily contract muscles, such those during the acute phase of disease. This technique improves muscle function through the use of low-voltage stimulation of peripheral motor nerves, providing passive muscle contraction and increasing oxidative muscle capacity. This technique may represent an alternative to mild physical training.(51,67,94) ENMS has been consistently associated with improved muscle mass, strength and endurance in patients with a range of clinical conditions who present with muscle weakness due to disuse or deficient muscle innervation.(95,96) In combination with physical exercise programs, ENMS significantly improves muscle strength in comparison with exercise alone.(97,98)

In chronic critically ill patients, such as patients with congestive heart failure and chronic respiratory failure, and particularly in patients with COPD, ENMS has been used safely and effectively, improving peripheral muscle strength, functional status and quality of life.(99)

Recommendation: ENMS should be used in COPD or chronic patients to stimulate voluntary muscle contraction and improve functional performance.

Zanotti et al. conducted a randomized clinical trial in MV-dependent COPD patients and observed that patients treated with both ENMS and mobilization had improved muscle strength and a shorter time for transference from bed to chair in comparison with patients who were only mobilized.(100)

However, the best forms of ENMS treatment in terms of the electrical current are still to be determined. Morphologic studies correlating improved exercise tolerance and muscle changes following ENMS versus conventional exercise should be conducted in critically ill patients, particularly in patients who develop critical illness neuromuscular disease.

Criteria and safety mechanisms for early critically ill patient mobilization

Recommendation: Monitoring during and after exercise is mandatory. Cardiovascular and respiratory variables should be monitored in addition to the consciousness level.

Early mobilization in critically ill patients was historically used for functional recovery in World War II victims. Currently, deep sedation and bed rest are routinely used in most mechanically ventilated patients. However, a new trend for the management of MV patients is apparent, which includes reducing deep sedation and starting functional physical training as early as possible.(66,101)

The European Respiratory Society and European Society of Intensive Care Medicine taskforce has recently proposed a hierarchy of ICU mobilization based on an exercise intensity sequence: decubitus change and functional positioning, passive mobilization, assisted-active and active exertion, cycloergonometry in bed, sitting in the bed, orthostatism, static walking, transferring from bed to chair, chair exertion and walking. Additionally, the task force recommended that the physical therapist be the healthcare professional responsible for implementing and managing the mobilization program.(52) This treatment sequence reflects specific training for future functional tasks.

Several studies have shown that these activities are safe and feasible and should be started as early as possible, i.e., immediately after major physiological disorders, such as uncontrolled shock, are stabilized. A well-trained and motivated team is fundamental in safely and effectively developing these activities.(52,66,101)

Monitoring is mandatory both during and after exertion, and the assessment of cardiovascular (heart rate and blood pressure) and respiratory variables (respiratory muscle pattern, synchronism with the ventilator if MV, peripheral oxygen saturation and respiratory rate) is recommended. Additionally, the consciousness level should be assessed, as should sedative and vasoactive drug doses.(101,102) Hemodynamically unstable patients requiring high oxygen inspired fractions (FiO_2) and ventilation support are not recommended for more aggressive mobilization activities.(52,66,102)

Critically ill patients' physiological status may widely fluctuate during the day. Additionally, sedation, intermittent hemodialysis and assessments and preparations for MV weaning may make physical exertion difficult, requiring individualized planning that is as flexible as possible and is based on the patient's physiological status at the time of the activity (Figure 5).(66)

Knowing the patient's cardiorespiratory reserve, neurological and musculoskeletal status and functional independence before admission

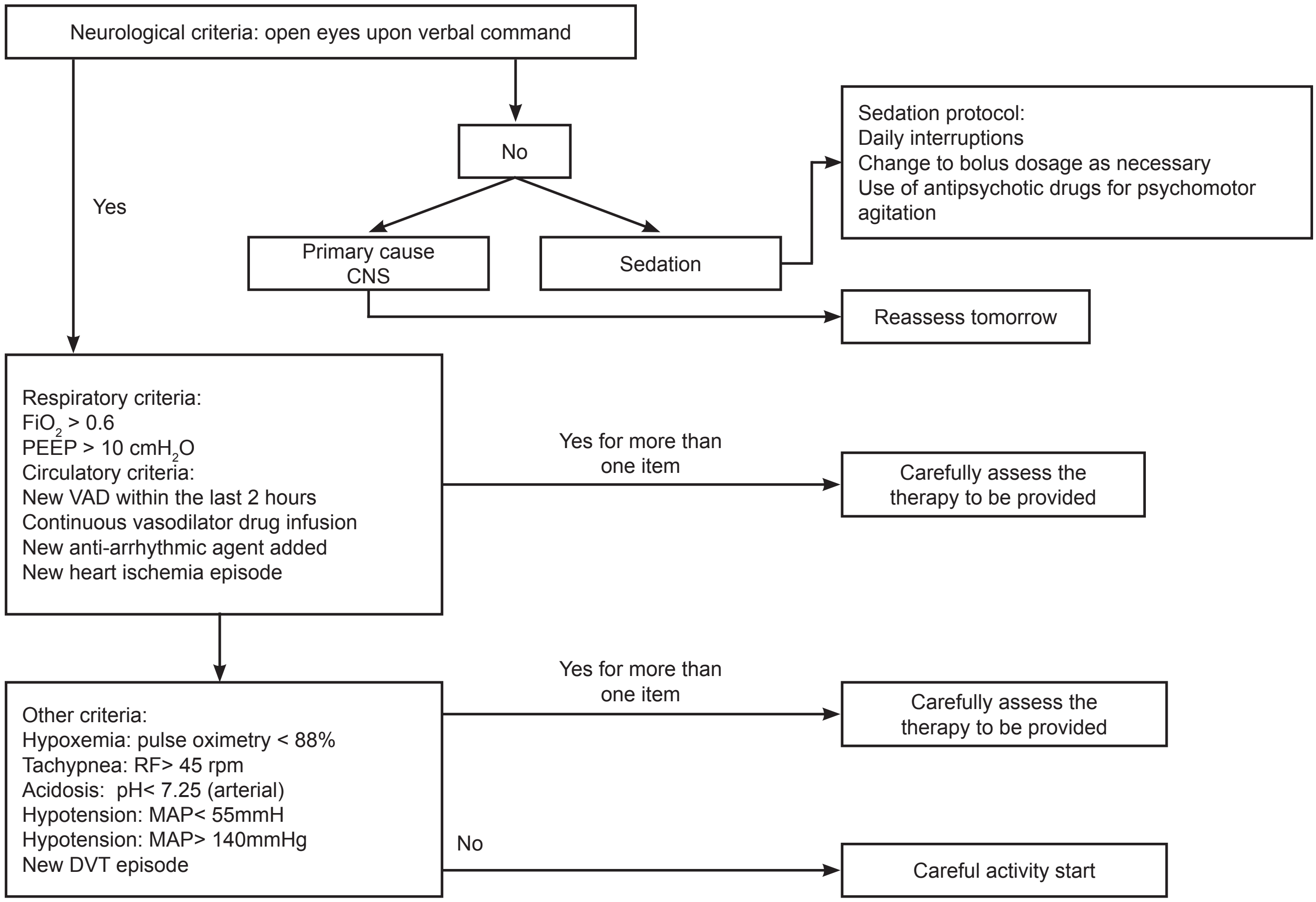

Figure 5 – Algorithm for assessment of critically ill patients candidate for training.

Translated from: Korupolu R, Gifford JM, Needham DM. Early mobilization of critically ill patients: reducing neuromuscular complications after intensive care. Contemp Crit Care. 2009;6(9):1-12.

CNS – central nervous system; FiO_2 – inspired oxygen fraction; PEEP - positive expiratory end pressure; VAD - vasoactive drug ; RF - respiratory frequency ; MAP – mean arterial pressure; DVT – deep vein thrombosis.

to the ICU is essential to maximize the safety and effectiveness of the intensity level of the physical therapy.[63,76,91] The Borg scale is an effective tool for assessing exertion intensity and perception of effort during mobilization in patients with a good cognitive condition.[52]

Increasing FiO_2 and ventilator support may offer better cardiorespiratory reserve, allowing patients to more safely perform the exercises with improved physiological response.[103] For spontaneously breathing patients, supplementary oxygen and non-invasive ventilation techniques can improve cardiopulmonary function at rest, and additionally, it can reduce the cardiorespiratory stress and potentiate physical exertion benefits in chronic heart and lung disease patients.[104,105] In clinical practice, this approach has been extrapolated for critically ill patients, although no studies have investigated its effectiveness in this population.[106]

Passive mobilization and physical training

Recommendation: The physical therapist is the healthcare professional responsible for implementing and managing the critically ill patient's mobilization program.

Although immobility in bed is associated with musculoskeletal dysfunction, no consistent evidence is found in the literature on the effectiveness of limb mobilization for maintaining an articular range of motion and/or improving muscle strength.[107]

The most important advantage of limb mobilization over conventional muscle training is lower respiratory stress during passive muscle activity. Therefore, it is more tolerable than aerobic exertion in severely deconditioned patients and chronic critically ill patients, although this benefit reflects less muscle mass involvement.[108]

Although passive mobilization alone increases oxygen consumption by up to 15% in critically ill patients, with significant increases in metabolic and hemodynamic variables,[108] it should be started early in the critically ill patient's care, even during the acute phase. This is particularly true in patients unable to move spontaneously. During this phase, passive mobilization aims to maintain joint range of motion and prevent muscle shortening, pressure ulcers, pulmonary thromboembolism and loss of muscle strength by reducing muscle proteolysis.

Griffiths et al. have shown three hours of continuous passive mobilization daily, by use of an appropriate cycloergometer, reduced fiber atrophy and protein loss in comparison with passive stretching for five minutes twice daily.[109]

Chiang et al. assessed the effects of physical training in 32 prolonged-MV patients undergoing strength and endurance training, transference from bed to chair and from chair to standing with diaphragmatic exercises and observed improvements in limb strength, functional independence and Barthel score, resulting in MV weaning for nine patients.[110] Bailey et al. (2007), using a protocol of sitting in the bed and sitting in a chair in association with walking, observed that this routine was safe in MV patients and that it provided improved functional status and prevention of neuromuscular complications.[111]

In a controlled clinical trial, Morris et al. identified an early systematic mobilization protocol that promoted reduced length of stay and reduced ICU and hospital costs compared with patients undergoing usual care. The protocol was considered safe and easy to apply.[112] The group undergoing early mobilization left the bed earlier (5 vs 11 days), had a shorter stay in the ICU (5.5 vs 6.9 days) and had a shorter stay in the hospital (11.2 vs 14.5 days).

In another controlled trial, Malkoç et al. assessed 510 patients for the effects of physical therapy on mechanical ventilation time and ICU length of stay. The patients undergoing physical therapy, consisting of respiratory physical therapy, bed exercises and mobilization (n=227), remained under MV an average of six days less and stayed an average of 10 days less in the ICU in comparison with the control group (n=233), which received no physical therapy.[113]

Schweickert et al. conducted a controlled randomized trial on a group of patients undergoing mobilization and exercises during daily sedation withdrawals. In the intervention group, 59% of the patients regained functional independence by hospital discharge. In the control group, functional independence was observed for only 35% of the patients. MV-free time was longer for the intervention group in comparison with the control group.[74]

Physical training is increasingly acknowledged as an important aspect of care in critically ill patients who require prolonged MV because it improves pulmonary function, muscle strength and functional independence, which accelerates the recovery process and reduces MV time and ICU length of stay.[52,66,94,114] Physical therapy mobilization protocols range from lower metabolic–impact exercises, such as passive mobilization, to transferences and upper and lower limb exercises using ergometers.[52,94,112]

Currently, no standardized guidelines are available for physical reconditioning in critically ill patients. However, such guidelines would be valuable because these patients have increased mortality rates, reduced quality of life and higher healthcare expenses compared with other ICU patients.

Figure 6 shows a proposed work flow to establish progressive mobilization in critically ill patients. This protocol establishes five activity levels, starting with passive upper and lower limb mobilization. Progression to the next level depends on the patient's consciousness level. When the patient is conscious, active limb mobilization is started (Level 2). Next, if they are able to move their upper limbs against gravity, assisted transference to sit up in the bed is performed, and body control and balance exercises are started. In this level (Level 3), if the patient has sufficient upper limb muscle strength (MRC > 4) for elbow flexion and anterior shoulder flexion, aerobic and/or counter-resisted exertion is started. In this progression, if the patient is able to perform hip flexion and knee extension against gravity, active transference to a chair is indicated (Level 4). Finally, if the patient is able to perform hip flexion and knee extension against gravity, active transference to a chair and assisted walking commence (Level 5).

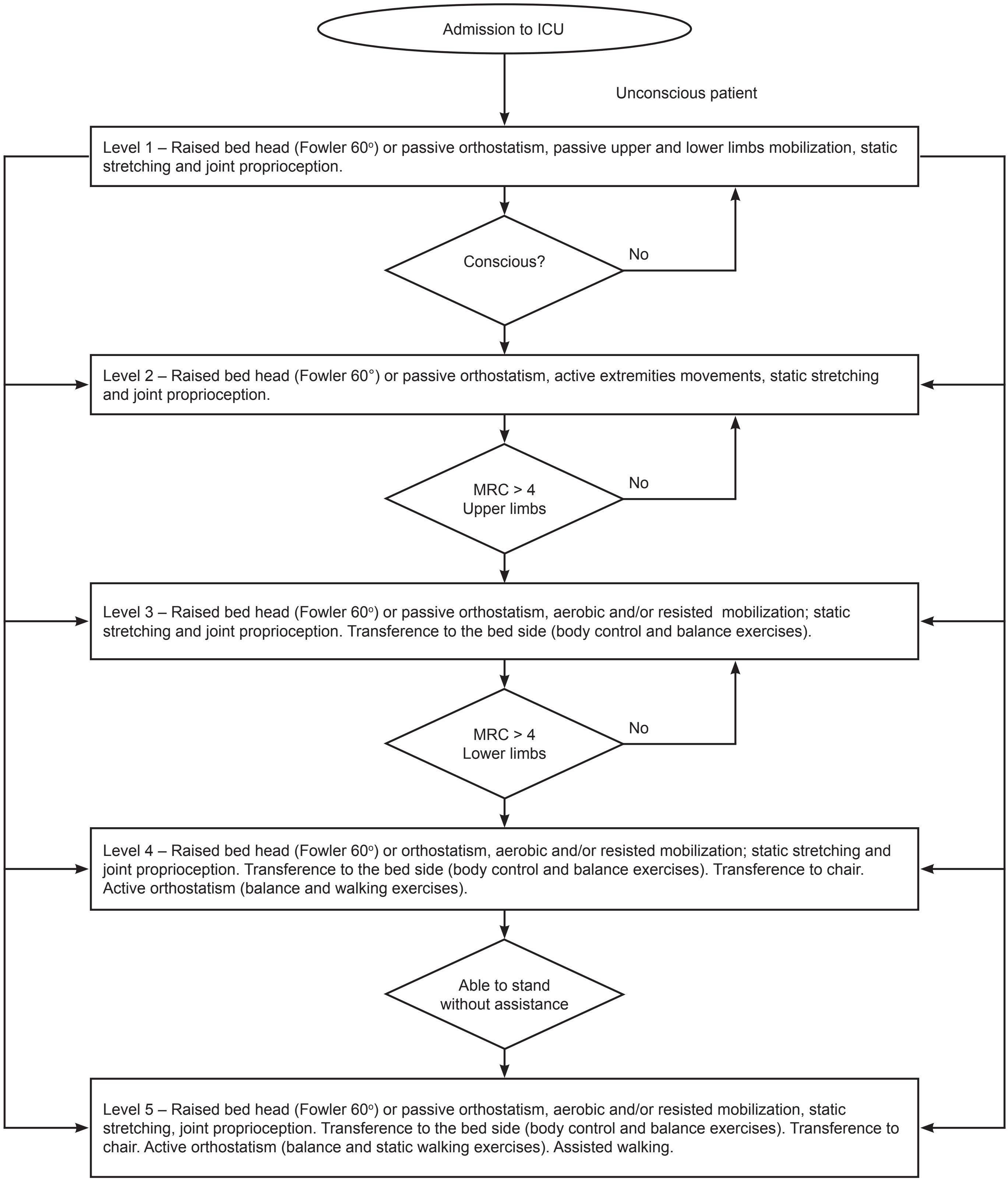

Figure 6 – Proposed flow chart for progressive mobilization of critically ill patients.
ICU – intensive care unit; MRC – Medical Research Council.

CONCLUSION

Physical therapy in critically ill patients progressively requires physical therapists prove that they have a role on these patients' management. In most ICUs, physical therapy is seen as integral part of the interdisciplinary team, but the cost-effectiveness of this extensive intervention needs to be examined. For this purpose, more randomized clinical trials are necessary.

In addition to the physical therapist's role in treating airway obstruction and retention of secretion, other aspects, related to pulmonary expansion, muscle dysfunction, mobilization and muscle training, were considered in this review. All of the described procedures should be under the exclusive purview of qualified physical therapists.

The lack of systematic reviews on resources for pulmonary expansion, removal of secretions and interventions for functional rehabilitation was acknowledged by the taskforce, given that most of the recommendations lack scientific evidence. Therefore, investigations of ICU physical therapy interventions should be related to mechanical ventilation time, ICU length of stay, ICU readmission, quality of life and physical function measures. However, these randomized controlled clinical trials are extremely expensive and difficult to implement due to the different physical therapy practices and variable degrees of autonomy in different ICUs.

Finally, it is necessary to standardize the resources for the clinical decision-making process and to clarify the ICU physical therapist's job description. ICU patients have a range of issues, which change quickly in response to the disease course and medical intervention. Instead of a standardized treatment, approaches to variable conditions may provide practical principles that can guide the physical therapist's action while prescribing interventions customized to each ICU patient's needs.

RESUMO

A incidência de complicações decorrentes dos efeitos deletérios da imobilidade na unidade de terapia intensiva contribui para o declínio funcional, aumento dos custos assistenciais, redução da qualidade de vida e mortalidade pós-alta. A fisioterapia é uma ciência capaz de promover a recuperação e preservação da funcionalidade, podendo minimizar estas complicações. Para nortear as condutas fisioterapêuticas nas unidades de terapia intensiva, um grupo de especialistas reunidos pela Associação de Medicina Intensiva Brasileira (AMIB), desenvolveu recomendações mínimas aplicáveis à realidade brasileira. Prevenção e tratamento de atelectasias, condições respiratórias relacionadas à remoção de secreção e condições relacionadas a falta de condicionamento físico e declínio funcional foram as três áreas discutidas. Além destas recomendações específicas, outro aspecto importante foi a consideração de que a prescrição e execução de atividades, mobilizações e exercícios físicos são do domínio específico do fisioterapeuta e o seu diagnóstico deve preceder qualquer intervenção.

Descritores: Estado terminal/reabilitação; Cuidados críticos; Comportamento cooperativo

REFERENCES

1. Azeredo CAC. Fisioterapia respiratória. Rio de Janeiro: Panamed; 1984.
2. Malkoç M, Karadibak D, Yildirim Y. The effect of physiotherapy on ventilatory dependency and the length of stay in an intensive care unit. Int J Rehabil Res.2009;32(1):85-8.
3. Stiller K. Physiotherapy in intensive care: towards and evidence-based practice. Chest. 2000;118(6):1801-13. Review.
4. Ciesla ND. Chest physical therapy for patients in the intensive care unit. Phys Ther. 1996;76(6):609-25.
5. Buhop KL. Pulmonary rehabilitation in the intensive care unit. In: Fishman AP, editor. Pulmonary rehabilitation. New York: Marcel & Dekker;1996. p. 725-38.
6. Desai SV, Law TJ, Needham DM.Long-term complications of critical care. Crit Care Med. 2011;39(2):371-9. Review.
7. Evidence-Based Medicine Working Group. Evidence-based medicine. A new approach to teaching the practice of medicine. JAMA. 1992;268(17):2420-5.
8. Haycox A, Bagust A, Walley T. Clinical guidelines - the hidden costs. BMJ. 1999;318(7180):391-3.
9. Marini JJ, Pierson DJ, Hudson LD. Acute lobar atelectasis: a prospective comparison of fiberoptic bronchoscopy and respiratory therapy. Am Rev Respir Dis. 1979;119(6):971-8.
10. Thomas JA, McIntosh JM. Are incentive spirometry, intermittent positive pressure breathing, and deep breathing exercises effective in the prevention of postoperative pulmonary complications after upper abdominal surgery? A systematic overview and meta-analysis. Phys Ther. 1994;74(1):3-10; discussion 10-6.
11. Fagevik Olsén M, Hahn I, Nordgren S, Lönroth H, Lundholm K. Randomized controlled trial of prophylactic chest physiotherapy in major abdominal surgery. Br J Surg. 1997;84(11):1535-8.
12. Chumillas S, Ponce JL, Delgado F, Viciano V, Mateu M. Prevention of postoperative pulmonary complications

through respiratory rehabilitation: a controlled clinical study. Arch Phys Med Rehabil. 1998;79(1):5-9.
13. Overend TJ, Anderson CM, Lucy SD, Bhatia C, Jonsson BI, Timmermans C. The effect of incentive spirometry on postoperative pulmonary complications: a systematic review. Chest. 2001;120(3):971-8. Review.
14. Hall JC, Tarala R, Harris J, Tapper J, Christiansen K. Incentive spirometry versus routine chest physiotherapy for prevention of pulmonary complications after abdominal surgery. Lancet. 1991;337(8747):953-6.
15. Hall JC, Tarala RA, Tapper J, Hall JL. Prevention of respiratory complications after abdominal surgery: a randomised clinical trial. BMJ. 1996;312(7024):148-52; discussion 152-3.
16. Denehy L, Berney S. The use of positive pressure devices by physiotherapists. Eur Respir J. 2001;17(4):821-9.
17. Motley HL, Werko L, et al. Observations on the clinical use of intermittent positive pressure. J Aviat Med. 1947;18(5):417-35.
18. Emmanuel GE, Smith WM, Briscoe WA. The effect of intermittent positive pressure breathing and voluntary hyperventilation upon the distribution of ventilation and pulmonary blood flow to the lung in chronic obstructive lung disease. J Clin Invest. 1966;45(7):1221-33.
19. Torres G, Lyons HA, Emerson P. The effects of intermittent positive pressure breathing on the interpulmonary distribution of inspired air. Am J Med. 1960;29:946-54.
20. Webber BA, Pryor JA. Physiotherapy skills: techniques and adjuncts. In: Pryor JA, Prasad SA, editors. Physiotherapy for respiratory and cardiac problems. London: Churchill Livingstone; 1993. p. 112-72.
21. AARC clinical practice guideline. Intermittent positive pressure breathing. American Association for Respiratory Care. Respir Care. 1993;38(11):1189-95.
22. Peruzzi W. The current status of PEEP. Respir Care. 1996;41:273-9.
23. Fu C, Caruso P, Lucatto JJ, de Paula Schettino GP, de Souza R, Carvalho CR. Comparison of two flow generators with a noninvasive ventilator to deliver continuous positive airway pressure: a test lung study. Intensive Care Med. 2005;31(11):1587-91.
24. Putensen C, Hörmann C, Baum M, Lingnau W. Comparison of mask and nasal continuous positive airway pressure after extubation and mechanical ventilation. Crit Care Med. 1993;21(3):357-62.
25. Kesten S, Rebuck AS. Ventilatory effects of nasal continuous positive airway pressure. Eur Respir J. 1990;3(5):498-501.
26. Andersen JB, Olesen KP, Eikard B, Jansen E, Quist J. Periodic continuous positive airway pressure, CPAP, by mask in the treatment of atelectasis. Eur J Respir Dis. 1980;61:20-5.
27. Paratz J, Lipman J, McAuliffe M. Effect of manual hyperinflation on hemodynamics, gas exchange, and respiratory mechanics in ventilated patients. Intensive Care Med. 2002;17(6):317-24.
28. Simonds AK. Equipment. In: Simonds AK, editor. Non-invasive respiratory support. London: Chapman & Hall Medical; 1996. p.16-37.
29. Ellis ER, Bye PT, Bruderer JW, Sullivan CE. Treatment of respiratory failure during sleep in patients with neuromuscular disease. Positive-pressure ventilation through a nose mask. Am Rev Respir Dis. 1987;135(1):148-52.
30. Piper A, Willson G. Nocturnal nasal ventilatory support in the management of daytime hipercapnic respiratory failure. Aust J Physiother. 1996;42(1):17-29.
31. Gust R, Gottschalk A, Schmidt H, Böttiger BW, Böhrer H, Martin E. Effects of continuous (CPAP) and bi-level positive airway pressure (BiPAP) on extravascular lung water after extubation of the trachea in patients following coronary artery bypass grafting. Intensive Care Med. 1996;22(12):1345-50.
32. Matte P, Jacquet L, Van Dyck M, Goenen M. Effects of conventional physiotherapy, continuous positive airway pressure and non-invasive ventilatory support with bilevel positive airway pressure after coronary artery bypass grafting. Acta Anaesthesiol Scand. 2000;44(1):75-81.
33. Pasquina P, Merlani P, Granier JM, Ricou B. Continuous positive airway pressure versus noninvasive pressure support ventilation to treat atelectasis after cardiac surgery. Anesth Analg. 2004;99(4):1001-8, table of contents.
34. Martin RJ, Rogers RM, Gray BA. Mechanical aids to lung expansion. The physiologic basis for the use of mechanical aids lung expansion. Am Rev Respir Dis. 1980;122(5 Pt 2):105-7.
35. Menkes HA, Traystman RJ. Collateral ventilation. Am Rev Respir Dis. 1977;116(2):287-309.
36. Williams JV, Tierney DF, Parker HR. Surface forces in the lung, atelectasis, and transpulmonary pressure. J Appl Physiol. 1966;21(3):819-27.
37. Andersen JB, Qvist J, Kann T. Recruiting collapsed lung through collateral channels with positive end-expiratory pressure. Scand J Respir Dis. 1979;60(5):260-6.
38. Clement AJ, Hübsch SK. Chest physiotherapy by the 'bag squeezing' method: a guide to technique. Physiotherapy. 1968;54(10):355-9.
39. Hack I, Katz A, Eales C. Airway pressure changes during bag squeezing. S Afr J Physiother. 1980;36:97-9.
40. Opie LH, Spalding JM. Chest physiotherapy during intermittent positive- pressure respiration. Lancet. 1958;2(7048):671-4.
41. Unoki T, Mizutani T, Toyooka H. Effects of expiratory rib cage compression and/or prone position on oxygenation and ventilation in mechanically ventilated rabbits with induced atelectasis. Respir Care. 2003;48(8):754-62
42. Ciesla ND. Chest physical therapy for patients in the intensive care unit. Phys Ther. 1996;76(6):609-25.
43. Unoki T, Mizutani T, Toyooka H. Effects of expiratory rib cage compression combined endotracheal suctioning

on gas exchange in mechanically ventilated rabbits with induced atelectasis. Respir Care. 2004;49(8):896-901
44. Lachmann B. Open up the lung and keep the lung open. Intensive Care Med. 1992;18(6):319-21.
45. Bond DM, McAloon J, Froese AB. Sustained inflations improve respiratory compliance during high-frequency oscillatory ventilation but not during large tidal volume positive-pressure ventilation in rabbits. Crit Care Med. 1994;22(8):1269-77.
46. Pelosi P, Goldner M, McKibben A, Adams A, Eccher G, Gaironi P, et al. Recruitment and derecruitment during acute respiratory failure: an experimental study. Am J Respir Crit Care Med. 2001;164(1):122-30.
47. Tucker B, Jenkins S. The effect of breathing exercises with body positioning on regional lung ventilation. Aust J Physiother. 1996;42(3):219-27.
48. Ciesla ND. Chest physical therapy for patients in the intensive care unit. Phys Ther, 1996;76(6):609- 25.
49. Zadai CC. Physical therapy for the acutely ill medical patient. Phys Ther. 1981;61(12):1746-54.
50. Sackner MA, Hirsch J, Epstein S. Effect of cuffed endotracheal tubes on tracheal mucous velocity. Chest. 1975;68(6):774-7.
51. Safdar N, Crnich CJ, Maki DG. The pathogenesis of ventilator-associated pneumonia: its relevance to developing effective strategies for prevention. Respir Care. 2005;50(6):725-39; discussion 739-41.
52. Gosselink R, Bott J, Johnson M, Dean E, Nava S, Norrenberg M, et al. Physiotherapy for adult patients with critical illness: recommendations of the European Respiratory Society and European Society of Intensive Care Medicine Task Force on Physiotherapy for Critically Ill Patients. Intensive Care Med. 2008;34(7):1188-99.
53. Palmer LB, Smaldone GC, Simon SR, O'Riordan TG, Cuccia A. Aerosolized antibiotics in mechanically ventilated patients: delivery and response. Crit Care Med. 1998;26(1):31-9.
54. Ray JF 3rd, Yost L, Moallem S, Sanoudos GM, Villamena P, Paredes RM, Clauss RH. Immobility, hypoxemia, and pulmonary arteriovenous shunting. Arch Surg. 1974;109(4):537-41.
55. Schweickert WD, Hall J. ICU-acquired weakness. Chest. 2007;131(5):1541-9.
56. Branson RD. Secretion management in the mechanically ventilated patient. Respir Care. 2007;52(10):1328-42; discussion 1342-7.
57. Fink JB. Positive pressure techniques for airway clearance. Respir Care. 2002;47(7):786-96.
58. Hess DR. Secretion clearance techniques: absence of proof or proof of absence? Respir Care. 2002;47(7):757-8.
59. Pryor JA. Physiotherapy for airway clearance in adults. Eur Respir J. 1999;14(6):1418-24.
60. Tomkiewicz RP, Biviji A, King M. Effects of oscillating air flow on the rheological properties and clearability of mucous gel simulants. Biorheology. 1994;31(5):511-20.
61. King M, Phillips DM, Gross D, Vartian V, Chang HK, Zidulka A. Enhanced tracheal mucus clearance with high frequency chest wall compression. Am Rev Respir Dis. 1983;128(3):511-5.
62. Flower KA, Eden RI, Lomax L, Mann NM, Burgess J. New mechanical aid to physiotherapy in cystic fibrosis. Br Med J. 1979;2(6191):630-1.
63. AARC clinical practice guideline. Use of positive airway pressure adjuncts to bronchial hygiene therapy. American Association for Respiratory Care. Respir Care. 1993;38(5):516-21.
64. Toussaint M, Boitano LJ, Gathot V, Steens M, Soudon P. Limits of effective cough-augmentation techniques in patients with neuromuscular disease. Respir Care. 2009;54(3):359-66.
65. Amato MB, Barbas CC, Medeiros DM, Magaldi RB, Schettino GP, Lorenzi-Filho G, et al. Effect of a protective-ventilation strategy on mortality in the acute respiratory distress syndrome. N Engl J Med. 1998;338(6):347-54.
66. Korupolu R, Gifford JM, Needham DM. Early mobilization of critically ill patients: reducing neuromuscular complications after intensive care. Contemp Crit Care. 2009;6(9):1-11.
67. Nava S, Piaggi G, De Mattia E, Carlucci A. Muscle retraining in the ICU patients. Minerva Anestesiol. 2002;68(5):341-5.
68. Truong AD, Fan E, Brower RG, Needham DM. Bench-to-bedside review: mobilizing patients in the intensive care unit--from pathophysiology to clinical trials. Crit Care. 2009;13(4):216.
69. De Jonghe B, Bastuji-Garin S, Durand MC, Malissin I, Rodrigues P, Cerf C, Outin H, Sharshar T; Groupe de Réflexion et d'Etude des Neuromyopathies en Réanimation. Respiratory weakness is associated with limb weakness and delayed weaning in critical illness. Crit Care Med. 2007;35(9):2007-15.
70. De Jonghe B, Sharshar T, Lefaucheur JP, Authier FJ, Durand-Zaleski I, Boussarsar M, Cerf C, Renaud E, Mesrati F, Carlet J, Raphaël JC, Outin H, Bastuji-Garin S; Groupe de Réflexion et d'Etude des Neuromyopathies en Réanimation Paresis acquired in the intensive care unit: a prospective multicenter study. JAMA. 2002;288(22):2859-67.
71. Leijten FS, Harinck-de-Weerd JE, Poortvliet DC, de Weerd AW. The role of polyneuropathy in motor convalescence after prolonged mechanical ventilation. JAMA. 1995;275(15):1221-5.
72. Bednarík J, Vondracek P, Dusek L, Moravcova E, Cundrle I. Risk factors for critical illness polyneuromyopathy. J Neurol. 2005;252(3):343-51.
73. Burtin C, Clerckx B, Robbeets C, Ferdinande P, Langer D, Troosters T, et al. Early exercise in critically ill patients enhances short-term functional recovery. Crit Care Med. 2009;37(9):2499-505.

74. Schweickert WD, Pohlman MC, Pohlman AS, Nigos C, Pawlik AJ, Esbrook CL, et al. Early physical and occupational therapy in mechanically ventilated, critically ill patients: a randomised controlled trial. Lancet. 2009;373(9678):1874-82.
75. Oliveira AB, Martinez BP, Gomes Neto MG. Impacto do internamento em uma unidade de terapia intensiva na independência funcional. Rev Bras Ter Intensiva. 2010;Suplemento:S95.
76. Geddes EL, Reid WD, Crowe J, O'Brien K, Brooks D. Inspiratory muscle training in adults with chronic obstructive pulmonary disease: a systematic review. Respir Med. 2005;99(11):1440-58. Review.
77. Lötters F, van Tol B, Kwakkel G, Gosselink R. Effects of controlled inspiratory muscle training in patients with COPD: a meta-analysis. Eur Respir J. 2002;20(3):570-6.
78. Weiner P, Magadle M, Massarwa F, Beckerman M, Berar-Yanay N. Influence of gender and inspiratory muscle training on the perception of dyspnea in patients with asthma. Chest. 2002;122(1):197-201.
79. Finder JD, Birnkrant D, Carl J, Farber HJ, Gozal D, Iannaccone ST, Kovesi T, Kravitz RM, Panitch H, Schramm C, Schroth M, Sharma G, Sievers L, Silvestri JM, Sterni L; American Thoracic Society. Respiratory care of the patient with Duchenne muscular dystrophy: ATS consensus statement. Am J Respir Crit Care Med. 2004;170(4):456-65.
80. Dall'Ago P, Chiappa GR, Guths H, Stein R, Ribeiro JP. Inspiratory muscle training in patients with heart failure and inspiratory muscle weakness: a randomized trial. J Am Coll Cardiol. 2006;47(4):757-63.
81. Weiner P, Azgad Y, Weiner M. Inspiratory muscle training during treatment with corticosteroids in humans. Chest. 1995;107(4):1041-4.
82. Hulzebos H, Helders PJ, Favié NJ, De Bie RA, Brutel de la Riviere A, Van Meeteren NL. Preoperative intensive inspiratory muscle training to prevent postoperative pulmonary complications in high-risk patients undergoing CABG surgery: a randomized clinical trial. JAMA. 2006;296(15):1851-7.
83. Aldrich TK, Uhrlass RM. Weaning from mechanical ventilation: successful use of modified inspiratory resistive training in muscular dystrophy. Crit Care Med. 1987;15(3):247-9.
84. Belman MJ. Respiratory failure treated by ventilatory muscle training(VMT). A report of two cases. Eur J Respir Dis. 1981;62(6):391-5.
85. Sprague SS, Hopkins PD. Use of inspiratory strength training to wean six patients who were ventilator-dependent. Phys Ther. 2003;83(2):171-81.
86. Martin AD, Davenport PD, Franceschi AC, Harman E. Use of inspiratory muscle strength training to facilitate ventilator weaning: a series of 10 consecutive patients. Chest. 2002;122(1):192-6.
87. Martin UJ, Hincapie L, Nimchuk M, Gaughan J, Criner GJ. Impact of whole-body rehabilitation in patients receiving chronic mechanical ventilation. Crit Care Med. 2005;33(10):2259-65.
88. Caruso P, Denari SD, Ruiz SA, Bernal KG, Manfrin GM, Friedrich C, Deheinzelin D. Inspiratory muscle training is ineffective in mechanically ventilated critically ill patients. Clinics (Sao Paulo). 2005;60(6):479-84.
89. Martin AD, Smith BK, Davenport PD, Harman E, Gonzalez-Rothi RJ, Baz M, et al. Inspiratory muscle strength training improves weaning outcome in failure to wean patients: a randomized trial. Crit Care. 2011;15(2):R84.
90. Jerre G, Silva TJ, Beraldo MA. III Consenso Brasileiro de Ventilação Mecânica. Fisioterapia no paciente sob ventilação mecânica. J Bras Pneumol. 2007;33(Suppl 2):S142-50.
91. Aliverti A, Carlesso E, Dellacà R, Pelosi P, Chiumello D, Pedotti A, Gattinoni L. Chest wall mechanics during pressure support ventilation. Crit Care. 2006;10(2):R54.
92. Futier E, Constantin JM, Combaret L, Mosoni L, Roszyk L, Sapin V, et al. Pressure support ventilation attenuates ventilator-induced protein modifications in the diaphragm. Crit Care. 2008;12(5):R116.
93. Girard TD, Kress JP, Fuchs BD, Thomason JW, Schweickert WD, Pun BT, et al. Efficacy and safety of a paired sedation and ventilator weaning protocol for mechanically ventilated patients in intensive care (Awakening and Breathing Controlled trial): a randomised controlled trial. Lancet. 2008;371(9607):126-34.
94. Clini E, Ambrosino N. Early physiotherapy in the respiratory intensive care unit. Respir Med. 2005;99(9):1096-104.
95. Lake DA. Neuromuscular electrical stimulation. An overview and its application in the treatment of sports injuries. Sports Med. 1992;13(5):320-36.
96. Glaser RM. Functional neuromuscular stimulation. Exercise conditioning of spinal cord injured patients. Int J Sports Med. 1994;15(3):142-8.
97. Bax L, Staes F, Verhagen A. Does neuromuscular electrical stimulation strengthen the quadriceps femoris? A systematic review of randomised controlled trials. Sports Med. 2005;35(3):191-212.
98. Currier DP, Mann R. Muscular strength development by electrical stimulation in healthy individuals. Phys Ther. 1983;63(6):915-21.
99. Sillen MJ, Speksnijder CM, Eterman RM, Janssen PP, Wagers SS, Wouters EF, et al - Effects of neuromuscular electrical stimulation of muscles of ambulation in patients with chronic heart failure or COPD: a systematic review of the English-language literature. Chest. 2009;136(1):44-61.
100. Zanotti E, Felicetti G, Maini M, Fracchia C. Peripheral muscle strength training in bed-bound patients with COPD receiving mechanical ventilation: effect of electrical stimulation. Chest. 2003;124(1):292-6.

101. Stiller K, Phillips A. Safety aspects of mobilising acutely ill in patients. Physiother Theory Pract. 2003;19(4):239-57.
102. Denehy L, Berney S. Physiotherapy in the intensive care unit. Phys Ther Rev. 2006;11(1):49-56.
103. Emtner M, Porszasz J, Burns M, Somfay A, Casaburi R. Benefits of supplemental oxygen in exercise training in nonhypoxemic chronic obstructive pulmonary disease patients. Am J Respir Crit Care Med. 2003;168(9):1034-42.
104. van't Hul A, Gosselink R, Hollander P, Postmus P, Kwakkel G. Training with inspiratory pressure support in patients with severe COPD. Eur Respir J. 2006;27(1):65-72.
105. Borghi-Silva A, Sampaio LMM, Toledo A, Pincelli MP, Costa D. Efeitos agudos da aplicação do BiPAP sobre a tolerância ao exercício físico em pacientes com doença pulmonar obstrutiva crônica (DPOC). Rev Bras Fisioter. 2005;9(3):273-80.
106. Vitacca M, Bianchi L, Sarvà M, Paneroni M, Balbi B. Physiological responses to arm exercise in difficult to wean patients with chronic obstructive pulmonary disease. Intensive Care Med. 2006;32(8):1159-66.
107. Clavet H, Hébert PC, Fergusson D, Doucette S, Trudel G. Joint contracture following prolonged stay in the intensive care unit. CMAJ. 2008;178(6):691-7.
108. Norrenberg M, De Backer D, Moraine JJ. Oxygen consumption can increase during passive leg mobilization. Intensive Care Med. 1995;21(Suppl):S177.
109. Griffiths RD, Palmer TE, Helliwell T, MacLennan P, MacMillan RR. Effect of passive stretching on the wasting of muscle in the critically ill. Nutrition. 1995;11(5):428-32.
110. Chiang LL, Wang LY, Wu CP, Wu HD, Wu YT. Effects of physical training on functional status in patients with prolonged mechanical ventilation. Phys Ther. 2006;86(9):1271-81.
111. Bailey P, Thomsen GE, Spuhler VJ, Blair R, Jewkes J, Bezdjian L, et al. Early activity is feasible and safe in respiratory failure patients. Crit Care Med. 2007;35(1):139-45.
112. Morris PE, Goad A, Thompson C, Taylor K, Harry B, Passmore L, et al. Early intensive care unit mobility therapy in the treatment of acute respiratory failure. Crit Care Med. 2008;36(8):2238-43.
113. Malkoç M , Karadibak D, Yildirim Y. The effect of physiotherapy on ventilatory dependency and the length of stay in an intensive care unit. Int J Rehabil Res. 2009;32(1):85-8.
114. Thomsen GE, Snow GL, Rodriguez L, Hopkins RO. Patients with respiratory failure increase ambulation after transfer to an intensive care unit where early activity is a priority. Crit Care Med. 2008;36(4):1119-24.