



SPECIAL ARTICLE

# Multidisciplinary rehabilitation in ventilator-dependent patients: Call for action in specialized inpatient facilities



J. Winck<sup>a,\*</sup>, R. Camacho<sup>b</sup>, N. Ambrosino<sup>c</sup>

<sup>a</sup> Department of Pulmonology, Faculdade de Medicina, Universidade do Porto, Portugal & Linde Healthcare, Pullach, Germany

<sup>b</sup> REMEO Program, Colombia

<sup>c</sup> Weaning and Rehabilitation Unit, Auxilium Vitae Rehabilitation Center, Volterra, Italy

Received 18 March 2015; accepted 24 March 2015

Available online 8 May 2015

## KEYWORDS

Rehabilitation;  
Ventilator-dependent  
patients;  
Weaning facilities

**Abstract** The numbers of patients needing prolonged mechanical ventilation are growing. The rehabilitation programs to be implemented in specialized inpatient facilities are ill defined. There is a clear need to establish guidelines to define the optimal rehabilitation program in this setting. In this article we review the current evidence and propose some guidance.

© 2015 Sociedade Portuguesa de Pneumologia. Published by Elsevier España, S.L.U. All rights reserved.

## Introduction

According to the NAMDRC consensus conference, prolonged mechanical ventilation (PMV) defines patients who require at least 6 h of mechanical ventilation for >21 consecutive days.<sup>1</sup> Recent estimates indicate that in the US the numbers of PMV are expected to double by the year 2020, reaching more than 600,000 patients.<sup>2</sup>

The reasons for this are heterogeneous: a greater capacity of ICUs to assist severe respiratory failure; modulate systemic inflammatory response syndrome and severe sepsis in patients with a high prevalence of secondary neuromuscular dysfunction and severe physical deconditioning, all these at increasingly advanced ages. Another large group

of patients is represented by those suffering from severe injuries to the central nervous system or incurable and progressive neuromuscular diseases.

Currently we only have partial information about the functional outcomes and quality of life of these patients, who are now described as chronic critically ill patients.<sup>3</sup> Their life trajectories, during their stay at long-term acute care hospitals, or LTACs or after a successful ventilatory weaning, are yet to be described. Many will have severe, permanent cognitive and physical impairments and serious limitations due to their disability, which will obviously involve high psychosocial costs.<sup>4</sup>

Treating these patients in specific venues with strong rehabilitative focus is normally recommended, with the cost savings and higher ventilator weaning rates.<sup>5</sup>

PMV patients (also referred to as Chronically Critically Ill patients) are very demanding due to multiple systems

\* Corresponding author.

E-mail address: [jcwinck@mail.telepac.pt](mailto:jcwinck@mail.telepac.pt) (J. Winck).

and organs dysfunctions. Beyond prolonged dependence on mechanical ventilation, muscle, neuro-endocrine, skin and brain dysfunctions give way to a distinct and complex syndrome.<sup>3</sup>

Although liberation from the ventilator will be one of the most important interventions in this setting, there is more than one type of weaning.

### Psychological factors

Psychological factors (like depression or delirium) may hinder ventilator weaning.<sup>6</sup> Sleep deprivation or unrecognized sleep disorders may also interfere with weaning.<sup>7</sup> So measures to improve sleep and psychological disorders can impact other outcomes.<sup>8</sup> In fact educational interventions, counseling and stress management can decrease the risk of developing psychological disorders. Moreover, effective pharmacological treatment of anxiety and depression is also mandatory.

### Swallowing dysfunction

Oropharyngeal dysphagia (OPD) has been described in patients with PVM for three decades, and yet, has not received much attention in research addressing different subgroups of this diverse population.<sup>9,10</sup> Swallowing dysfunction is a common complication in chronic critically ill patients, which affects nearly half of the non-neurologic patients requiring percutaneous dilatational tracheostomy and almost all of those with neurologic involvement; it is well known to deteriorate outcomes, and delay the weaning and tracheostomy decannulation process.<sup>11</sup> A number of possible specific swallowing dysfunctional conditions arise in PMV patients; to mention a few, sarcopenic dysphagia, presbyphagia, neuromuscular dysfunction related dysphagia and even with some structural swallowing disorders.<sup>12</sup> Overall evaluation measures and treatment are based on experiments with different methodologies<sup>13,14</sup> but not on controlled studies which consider the unique pathophysiology of chronic critically ill patients.<sup>15</sup> It is worth mentioning the potential role of fiberoptic endoscopic evaluation of swallowing (FEES) as an objective tool to precisely classify and guide therapeutic interventions after prolonged intubation and in tracheostomy patients. In fact, FEES with sensory testing is improving the rehabilitation designs and protocols.<sup>16</sup>

The main components of a dysphagia rehabilitation program include oral health care, swallowing rehabilitative techniques, and food consistency modification. To the best of our knowledge there are no detailed studies or any evidence about the most effective strategies to improve the swallowing process in different non-invasive and invasive PMV scenarios. This role which has been suggested for FEES as an objective tool to precisely classify and guide therapeutic interventions after prolonged intubation and in tracheostomy patients should be considered.<sup>17</sup>

### Skin integrity

Skin integrity is an independent determinant of survival in patients requiring prolonged mechanical ventilation and is

a potentially modifiable factor.<sup>18</sup> The most important risk factors for development of pressure ulcers while in ICU are total score on Braden Scale, mobility, activity, sensory perception, moisture, friction/shear, nutrition, age, blood pressure, length of stay, APACHE II, vasopressor administration, and co-morbid conditions.<sup>19</sup> Where it is chronic, central neurological involvement and small fiber pathology (which explains chronic sensory impairment and pain in neuro-critical care survivors) are the main features.<sup>20</sup>

### Whole body rehabilitation (Fig. 1)

Increasing evidence supports early physiotherapy for the critically ill patient<sup>21,22</sup>.

RCT in ICU settings have already shown that early physical and occupational rehabilitation of mechanically ventilated patients translates into better weaning outcomes.<sup>23</sup>

In weaning facilities the studies evaluating the impact of rehabilitation in prolonged mechanical ventilated patients



**Figure 1** A ventilator-dependent tracheostomized patient walking with assistance from the staff.

**Table 1** Summary of retrospective/prospective/RCT in weaning facilities.

Article	Number of patients	Diagnosis	Design	Intervention	Outcome	Frequency of exercise sessions	Results
Martin <sup>24</sup> *	49	Pneumonia, CHF, ARDS	Retrospective	Whole body Rehab, IMT	Weaning success, FIM, MRC	5days/wk 30–60 min (1–2 sessions/day)	↑ limbs strength; ability to sit to stand and supine to sit; FIM Mortality 12% Weaning rate 98%
Chiang <sup>25</sup> **	39	Chronic lung disease, Post-op, ALI	RCT	Whole body Rehab, Diaphragmatic breathing	Barthel Index, FIM, ventilator free time, P <sub>i</sub> max, P <sub>e</sub> max, Dynamometer	5 days/wk for 6 wks	↑ limbs strength; P <sub>i</sub> max, P <sub>e</sub> max FIM, BI Ventilator free time Mortality 17.6% Weaning rate 47%
Chen <sup>26</sup> **	34	Chronic lung disease, Post-op, ALI	RCT	Whole body Rehab, Diaphragmatic breathing	1-year Survival FIM	5days/wk for 6 wks + 1day/wk for 6 wks	↑ FIM, survival Mortality 30% Weaning rate (at 1 year) 36%
Clini <sup>30</sup> *	77	COPD, Post-Op	Prospective	Whole body Rehab (including pedaling and weights holding)	ADL, survival weaning success	6days/wk for 15 sessions	↑ ADL Mortality 13% Weaning rate 74%
Chen <sup>27</sup> **	27	COPD/Chronic Lung Disease, CHF, SCI, Pneumonia	RCT	Whole body Rehab, Cardiopulmonary endurance exercise	Pulmonary mechanics, Barthel Index, FIM, weaning success, mortality	10 exercise training sessions	↑ VT, RSBI, FIM Mortality 0% Weaning rate 75%
Montagnini <sup>28</sup>	56	COPD, NMD, Trauma, CHF, Post-op	Retrospective	Whole body Rehab (including bed-side cycle ergometer)	FIM	6 days/wk	↑ FIM Dyspnea (MRC) PaO <sub>2</sub> /FiO <sub>2</sub> ↓ PaCO <sub>2</sub>
Vitacca <sup>29</sup> *	240	COPD, ARF, Neurological diseases, Post-op	Prospective	Whole body Rehab (including electrical stimulation)	Barthel Index, Gussago Nursing Scale, survival, weaning success	6 days/wk 1 h/day (in 1 or 2 30 min sessions)	↑ BI, GNS, DPAP PaO <sub>2</sub> /FiO <sub>2</sub> ↓ PaCO <sub>2</sub> ↓ Borg Mortality 13.8% Weaning rate 47%

CHF, chronic heart failure; FIM, functional independence measure; IMT, inspiratory muscle training; BI, barthel index; Post-op, post-operative; ALI, acute lung injury; SCI, spinal cord injury; NMD, neuromuscular disorders; ARF, acute respiratory Failure.

\* Excluded NMD.

\*\* Excluded neurological disorders.

(Table 1) show positive results, from increase in limb strength<sup>24,25</sup> to improvement in functional measures like FIM,<sup>24–28</sup> respiratory muscle strength<sup>25</sup> and mechanics.<sup>27</sup> A RCT study has also shown a significant survival benefit in the rehabilitation group.<sup>26</sup> In these studies mortality ranges from 12%<sup>24</sup> to 30%<sup>25</sup> and weaning rate from 47%<sup>29</sup> to 98%.<sup>24</sup> The studies include also very different subgroups of patients from chronic respiratory diseases<sup>25–30</sup> to post-operative and acute lung injuries.<sup>24–26</sup> Only one

study includes neuromuscular patients.<sup>28</sup> Even in RCT, rehabilitation programs are not uniform, with some studies proposing 6-week long programs<sup>25,26</sup> while others proposing shorter times<sup>27,30</sup>; some include specific inspiratory muscle training,<sup>24</sup> a few others formal cardiopulmonary endurance exercise<sup>27</sup> and the others use electrical stimulation.<sup>29</sup>

Type of intervention, frequency, duration and intensity based on Denehy et al.<sup>31</sup> and Hanekom et al.<sup>32</sup> is proposed in Table 2.

**Table 2** Type of intervention, frequency, duration and intensity.

Frequency of exercise sessions	15 min/day (if <4h spontaneous breathing) 2 × 15 min/day (if >4h spontaneous breathing)	
Type of exercise	Marching in place Moving from sitting to standing Arm and leg active and active resistance movements	Based on <sup>34</sup> Active range of motion exercises for all major joints, bed mobility exercises (e.g. lateral rolling, supine to sit), dangling at the edge of the bed, postural retraining, balance exercises (e.g. reaching in and out of the base support, challenges to elicit "righting" reflexes), training in ADL (eating or simulated eating, grooming, bathing, dressing, and toileting), transfer from seated to a standing position and from bed to chair or commode, standing exercises such as reaching in and out of the base of support, mini-squats, marching, and ambulation (with or without assistive devices)
Intensity	Target modified Borg Scale score 3–5	

### Aims of multidisciplinary (interdisciplinary or trans-disciplinary) rehabilitation

To improve survival, diminish co-morbidities, decrease ventilator dependence, improve functional status and health related quality of life, decrease hospital re-admissions, decrease length of stay in long-term care, favor return to work and social re-integration and reduce the amount of ineffective care. Caution must be taken about potential contraindications (Table 3).

### Evidence-based multidisciplinary rehabilitative interventions

There has been a growing interest in different rehabilitative strategies to treat PMV patients. However most of the published studies covered non-randomized clinical trials.

In Table 4 we review some of the most interesting topics involved in these interventions. Cognitive training

has been tested among post-ICU survivors and preliminary data are encouraging<sup>33</sup> and a new RCT is being designed.<sup>34</sup> A prospective non-randomized study has also shown that early intra-ICU clinical psychologist intervention may help critically ill trauma patients recover from post-traumatic stress disorder.<sup>8</sup>

As mentioned before no RCT so far has analyzed swallowing dysfunction management.

Disruption of sleep is very common in mechanically ventilated patients. In an observational study Koldobskyi et al. have shown that specific facilities (like LTAC's) maintain the patients' circadian rhythm compared to the ICU environment.<sup>35</sup>

In a recent meta-analysis, examining three trials involving a heterogeneous group of patients, inspiratory muscle training was found to significantly increase inspiratory muscle strength in adults undergoing mechanical ventilation.<sup>36</sup> Further research is needed including more homogeneous PMV populations and analyzing more relevant outcomes.

Concerning airway secretion management, Gonçalves et al. showed in a RCT that adding mechanical

**Table 3** Contraindications of physical therapy in PMV.

Hemodynamic instability (in this case the patient should be discharged to an ICU)
Non-controlled behavioral disorders (in this case also the patient should be discharged)
Severe anemia (less than Hgb 7 g/dl) or thrombocytopenia (Platelets <40–50.000/dl). In Hemato-oncologic patients levels between 20 and 30.000 can be accepted
HR <60 or >110/min (or >30 bpm above resting predicted HR); also consider underlying cardiac disease
Mean ABP <65 mmHg or >200 mmHg
Sepsis or persistent fever (>38 °C) (in fever of central cause or while fever cause is being investigated, between fever peaks, consider lower intensity/passive interventions)
End-stage patients included in palliative care

Abbreviations: ICU, intensive care unit; Hgb, hemoglobin; HR, heart rate; ABP, arterial blood pressure.

**Table 4** Evidence-based multidisciplinary rehabilitative interventions.

Cognitive rehabilitation	8,33,34
Feeding/nutrition and swallowing	NA
Sleep	35
Respiratory – respiratory muscle training	36 37 38,39
Secretion management; Weaning/decannulation protocols	
Physical therapy – limb exercises, exercise training, neuromuscular electrical stimulation	See Table 1
Co-morbidities management (e.g. CHF, DM, COPD),	NA
Skin care	NA

Abbreviations: CHF, chronic heart failure; DM, diabetes mellitus; COPD, chronic obstructive pulmonary disease.



**Table 5** Members of the team and roles.

Core team: MD, Nurse, RT
MD: Serve as a coordinator
Nurse: Liaise with RT/PT as required
Speech pathologist: Liaise with RT/PT as required to evaluate swallowing
Occupational therapist, psychologist, nutritionist/dietitian, social worker involved as required

in-exsufflation improved extubation outcomes, increasing the efficacy of NIV post-extubation.<sup>37</sup>

There are few RCT in the context of weaning tracheostomized patients. Hernandez showed that deflating the tracheal cuff in tracheostomized patients shortens weaning, reduces respiratory infections, and probably improves swallowing.<sup>38</sup> Jubran et al. in patients requiring PMV, showed that unassisted breathing through a tracheostomy (compared with pressure support) resulted in shorter median weaning time.<sup>39</sup>

Verceles et al. have shown that in patients under PMV, higher comorbidity burden is associated with increased risk of transfer to acute care.<sup>40</sup> In fact, in a retrospective study, Schulman et al. suggest that tighter glycemic control was associated with better outcomes in CCI patients. Prospective studies addressing the importance of co-morbidities treatment optimization are warranted in this setting.<sup>41</sup>

## Members of the team and roles (Table 5)

Teamwork has been shown to improve outcomes. In fact medical ICU nurses' reports of collaboration were associated positively with patient outcomes.<sup>42</sup>

The core team is normally the *medical doctor*, the *nurse* and the *respiratory therapist* (or *specialized physiotherapist*); the sense of interdependence exists between each other to ensure workflow is efficient, effective and coordinated.<sup>43</sup> Daily multidisciplinary rounds integrate the different knowledge to promote the clinical goals and formulate a plan of interventions. Coordination between professionals is essential to make a personalized and integrated therapeutic plan.

The *speech pathologist* has a very important role not only to facilitate speech in patients with tracheostomy but also to evaluate swallowing.<sup>44</sup>

Due to the high resource use and costs involved in supporting ventilator-dependent patients, *social workers* are indispensable to assure effective integration of health, social, education and employment services and voluntary and independent sectors when pertinent.<sup>45</sup> It also plays a fundamental role avoiding any possible discrimination that may rise from the disability surrounding PMV. Frequent communication with the family with discussion about realistic versus futile goals is also an important goal.

## Evaluation of efficacy

The traditional severity-of-illness scoring systems like the SOFA (Sepsis-related organ failure Assessment) score or the APACHE III were developed in the acute Intensive care Unit (ICU) population.<sup>46</sup> These systems were not established or

validated using populations of patients under PMV (or also referred to as Chronically Critically Ill patients), as a result caution should be used when interpreting such data.<sup>47</sup>

Therefore the development of adequately performing severity-of-illness measures appropriate to this patient population is highly needed.

In the absence of newer multidimensional tools, the majority of authors use the Functional Independence Measure (FIM) to evaluate the efficacy of a rehabilitation program.<sup>24,25,27,28</sup> They evaluate the functional status of the patient at admission, after half the length of the program, at the end of the program and at discharge. If the results are not improving significantly the program/interventions should be adjusted on a regular basis, decreasing/increasing or maintaining intensity based on the eventual resolution of contraindications/significant improvement/deterioration/plateauing. To make this choice the Minimal Detectable Change (MDC) or Minimal Clinically Important Difference (MCID) of the disability scoring system being used should be considered.<sup>48</sup> For stroke patients the MCID for total FIM score was 22 points.<sup>48</sup> In studies including PMV patients the improvement in total FIM score ranged from 11<sup>25</sup> at 6 weeks to 44 points at 1 year.<sup>26</sup>

Eventually after >1 month of structured multidisciplinary approach, consider transferring the patient to another setting (home or nursing home) if no improvement is gained.

## Challenges

In one facility with more than 30 patients with heterogeneous diagnosis, the logistics of tailored therapeutic interventions can be very complex, from timing and chronobiology to coordination. To maintain a constant flow of interventions a highly flexible team is needed.

The role of the family/non-professional caregivers to support and assist in the rehabilitation program can have a role in improving functional outcomes and potentiate team interventions.

It is possible that some subgroups of PMV/CCI benefit more from whole body rehabilitation than others. A challenge for the future will be identifying which subgroups of PMV/CCI benefit most from these programs.

## Conclusions

Until now, post-ICU patients have not had a recognized rehabilitation program and the care process is still fragmented. There is a clear need to establish guidelines to define the optimal rehabilitation program in this setting. Integrated, multidisciplinary rehabilitation programs for ventilator-dependent chronic critically ill patients should be urgently defined. Randomized studies for this situation are welcomed.

## Ethical disclosures

**Protection of human and animal subjects.** The authors declare that no experiments were performed on humans or animals for this study.

**Confidentiality of data.** The authors declare that they have followed the protocols of their work center on the publication of patient data.

**Right to privacy and informed consent.** The authors have obtained the written informed consent of the patients or subjects mentioned in the article. The corresponding author is in possession of this document.

## Conflicts of interest

The authors have no conflicts of interest to declare.

## References

- MacIntyre NR, Epstein SK, Carson S, Scheinhorn D, Christopher K, Muldoon S. Management of patients requiring prolonged mechanical ventilation: report of a NAMDRC consensus conference. *Chest*. 2005;128:3937–54.
- Zilberberg MD, de Wit M, Pirone JR, Shorr AF. Growth in adult prolonged acute mechanical ventilation: implications for healthcare delivery. *Crit Care Med*. 2008;36:1451–5.
- Nelson JE, Cox CE, Hope AA, Carson SS. Chronic critical illness. *Am J Respir Crit Care Med*. 2010;182:446–54.
- Cox CE, Martinu T, Sathy SJ, Clay AS, Chia J, Gray AL, et al. Expectations and outcomes of prolonged mechanical ventilation. *Crit Care Med*. 2009;37:2888–94 [quiz 2904].
- Simonds AK. Streamlining weaning: protocols and weaning units. *Thorax*. 2005;60:175–82.
- Jubran A, Lawm G, Kelly J, Duffner LA, Gungor G, Collins EG, et al. Depressive disorders during weaning from prolonged mechanical ventilation. *Intens Care Med*. 2010;36:828–35.
- Diaz-Abad M, Verceles AC, Brown JE, Scharf SM. Sleep-disordered breathing may be under-recognized in patients who wean from prolonged mechanical ventilation. *Respir Care*. 2012;57:229–37.
- Peris A, Bonizzoli M, Iozzelli D, Migliaccio ML, Zagli G, Bacchereti A, et al. Early intra-intensive care unit psychological intervention promotes recovery from post traumatic stress disorders, anxiety and depression symptoms in critically ill patients. *Crit Care*. 2011;15:R41.
- Tolep K, Getch CL, Criner GJ. Swallowing dysfunction in patients receiving prolonged mechanical ventilation. *Chest*. 1996;109:167–72.
- DeVita MA, Spierer-Rundback L. Swallowing disorders in patients with prolonged orotracheal intubation or tracheostomy tubes. *Crit Care Med*. 1990;18:1328–30.
- Romero CM, Marambio A, Larrondo J, Walker K, Lira MT, Tobar E, et al. Swallowing dysfunction in nonneurologic critically ill patients who require percutaneous dilatational tracheostomy. *Chest*. 2010;137:1278–82.
- Wakabayashi H. Transdisciplinary approach for sarcopenia. *Sarcopenic Dysphagia*. *Clin Calcium*. 2014;24:1509–17.
- Goldsmith T. Evaluation and treatment of swallowing disorders following endotracheal intubation and tracheostomy. *Int Anesthesiol Clin*. 2000;38:219–42.
- Fernandez-Carmona A, Penas-Maldonado L, Yuste-Osorio E, Diaz-Redondo A. Exploration and approach to artificial airway dysphagia. *Med Intensiva*. 2012;36:423–33.
- Mirzakhani H, Williams JN, Mello J, Joseph S, Meyer MJ, Waak K, et al. Muscle weakness predicts pharyngeal dysfunction and symptomatic aspiration in long-term ventilated patients. *Anesthesiology*. 2013;119:389–97.
- Zielske J, Bohne S, Axer H, Brunkhorst FM, Guntinas-Lichius O. Dysphagia management of acute and long-term critically ill intensive care patients. *Med Klin Intensivmed Notfmed*. 2014;109:516–25.
- Ajemian MS, Nirmul GB, Anderson MT, Zirlen DM, Kwasnik EM. Routine fiberoptic endoscopic evaluation of swallowing following prolonged intubation: implications for management. *Arch Surg*. 2001;136:434–7.
- Aboussouan LS, Lattin CD, Kline JL. Determinants of long-term mortality after prolonged mechanical ventilation. *Lung*. 2008;186:299–306.
- Cox J. Predictors of pressure ulcers in adult critical care patients. *Am J Crit Care*. 2011;20:364–75.
- Latronico N, Filosto M, Fagoni N, Gheza L, Guarneri B, Todeschini A, et al. Small nerve fiber pathology in critical illness. *PLoS ONE*. 2013;8:e75696.
- Clini E, Ambrosino N. Early physiotherapy in the respiratory intensive care unit. *Respir Med*. 2005;99:1096–104.
- Ambrosino N, Venturelli E, Vaghegini G, Clini E. Rehabilitation, weaning and physical therapy strategies in chronic critically ill patients. *Eur Respir J*. 2012;39:487–92.
- 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;373:1874–82.
- 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;33:2259–65.
- 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;86:1271–81.
- Chen S, Su CL, Wu YT, Wang LY, Wu CP, Wu HD, et al. Physical training is beneficial to functional status and survival in patients with prolonged mechanical ventilation. *J Formos Med Assoc*. 2011;110:572–9.
- Chen YH, Lin HL, Hsiao HF, Chou LT, Kao KC, Huang CC, et al. Effects of exercise training on pulmonary mechanics and functional status in patients with prolonged mechanical ventilation. *Respir Care*. 2012;57:727–34.
- Montagnani G, Vaghegini G, Panait Vlad E, Berrighi D, Pantani L, Ambrosino N. Use of the functional independence measure in people for whom weaning from mechanical ventilation is difficult. *Phys Ther*. 2011;91:1109–15.
- Vitacca M, Paneroni M, Peroni R, Barbano L, Dodaj V, Piaggi G, et al. Effects of a multidisciplinary care program on disability, autonomy, and nursing needs in subjects recovering from acute respiratory failure in a chronic ventilator facility. *Respir Care*. 2014;59:1863–71.
- Clini EM, Crisafulli E, Antoni FD, Beneventi C, Trianni L, Costi S, et al. Functional recovery following physical training in tracheotomized and chronically ventilated patients. *Respir Care*. 2011;56:306–13.
- Denehy L, Skinner EH, Edbrooke L, Haines K, Warrillow S, Hawthorne G, et al. Exercise rehabilitation for patients with critical illness: a randomized controlled trial with 12 months of follow-up. *Crit Care*. 2013;17:R156.
- Hanekom S, Gosselink R, Dean E, van Aswegen H, Roos R, Ambrosino N, et al. The development of a clinical management algorithm for early physical activity and mobilization of critically ill patients: synthesis of evidence and expert opinion and its translation into practice. *Clin Rehabil*. 2011;25:771–87.
- Jackson JC, Ely EW, Morey MC, Anderson VM, Denne LB, Clune J, et al. Cognitive and physical rehabilitation of intensive care unit survivors: results of the RETURN randomized controlled pilot investigation. *Crit Care Med*. 2012;40:1088–97.
- Brummel NE, Jackson JC, Girard TD, Pandharipande PP, Schiro E, Work B, et al. A combined early cognitive and physical rehabilitation program for people who are critically ill: the activity and cognitive therapy in the intensive care unit (ACT-ICU) trial. *Phys Ther*. 2012;92:1580–92.

35. Koldobskiy D, Diaz-Abad M, Scharf SM, Brown J, Verceles AC. Long-term acute care patients weaning from prolonged mechanical ventilation maintain circadian rhythm. *Respir Care*. 2014;59:518–24.
36. Moodie L, Reeve J, Elkins M. Inspiratory muscle training increases inspiratory muscle strength in patients weaning from mechanical ventilation: a systematic review. *J Physiother*. 2011;57:213–21.
37. Goncalves MR, Honrado T, Winck JC, Paiva JA. Effects of mechanical insufflation–exsufflation in preventing respiratory failure after extubation: a randomized controlled trial. *Crit Care*. 2012;16:R48.
38. Hernandez G, Pedrosa A, Ortiz R, Cruz Accuaroni Mdel M, Cuena R, Vaquero Collado C, et al. The effects of increasing effective airway diameter on weaning from mechanical ventilation in tracheostomized patients: a randomized controlled trial. *Intens Care Med*. 2013;39:1063–70.
39. Jubran A, Grant BJ, Duffner LA, Collins EG, Lanuza DM, Hoffman LA, et al. Effect of pressure support vs unassisted breathing through a tracheostomy collar on weaning duration in patients requiring prolonged mechanical ventilation: a randomized trial. *J Am Med Assoc*. 2013;309:671–7.
40. Verceles AC, Lechner EJ, Halpin D, Scharf SM. The association between comorbid illness, colonization status, and acute hospitalization in patients receiving prolonged mechanical ventilation. *Respir Care*. 2013;58:250–6.
41. Schulman RC, Moshier EL, Rho L, Casey MF, Godbold JH, Mechanick JI. Association of glycemic control parameters with clinical outcomes in chronic critical illness. *Endocr Pract*. 2014;20:884–93.
42. Baggs JG, Schmitt MH, Mushlin AI, Mitchell PH, Eldredge DH, Oakes D, et al. Association between nurse-physician collaboration and patient outcomes in three intensive care units. *Crit Care Med*. 1999;27:1991–8.
43. Bailey PP, Miller RR III, Clemmer TP. Culture of early mobility in mechanically ventilated patients. *Crit Care Med*. 2009;37:S429–35.
44. Hess DR. Facilitating speech in the patient with a tracheostomy. *Respir Care*. 2005;50:519–25.
45. Noyes J, Godfrey C, Beecham J. Resource use and service costs for ventilator-dependent children and young people in the UK. *Health Soc Care Community*. 2006;14:508–22.
46. Vincent JL, Moreno R. Clinical review: scoring systems in the critically ill. *Crit Care*. 2010;14:207.
47. Carson SS, Bach PB. Predicting mortality in patients suffering from prolonged critical illness: an assessment of four severity-of-illness measures. *Chest*. 2001;120:928–33.
48. Beninato M, Gill-Body KM, Salles S, Stark PC, Black-Schaffer RM, Stein J. Determination of the minimal clinically important difference in the FIM instrument in patients with stroke. *Arch Phys Med Rehabil*. 2006;87:32–9.