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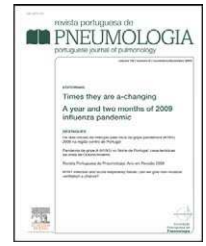

REVIEW

Physiotherapy in critically ill patients

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Abstract Prolonged stay in Intensive Care Unit (ICU) can cause muscle weakness, physical deconditioning, recurrent symptoms, mood alterations and poor quality of life.

Physiotherapy is probably the only treatment likely to increase in the short- and long-term care of the patients admitted to these units. Recovery of physical and respiratory functions, coming off mechanical ventilation, prevention of the effects of bed-rest and improvement in the health status are the clinical objectives of a physiotherapy program in medical and surgical areas. To manage these patients, integrated programs dealing with both whole-body physical therapy and pulmonary care are needed.

There is still limited scientific evidence to support such a comprehensive approach to all critically ill patients; therefore we need randomised studies with solid clinical short- and long-term outcome measures.

PALAVRAS-CHAVE
Reabilitação;
Ventilação mecânica;
Fisioterapia;
Desmame

Fisioterapia em pacientes gravemente doentes

Resumo Uma estadia prolongada na Unidade de Cuidados Intensivos (UCI) pode causar fraqueza muscular, descondicionamento físico, sintomas recorrentes, alterações de humor e má qualidade de vida.

A fisioterapia é, provavelmente, o único tratamento com potencial para aumentar nos cuidados a curto e longo prazo aos pacientes internados nestas unidades. A recuperação das funções físicas e respiratórias, retirar a ventilação mecânica, prevenção de efeitos do repouso na cama e melhoria do estado de saúde são objectivos clínicos de um programa de fisioterapia nas áreas médicas e cirúrgicas. Para tratar estes pacientes, são necessários programas integrados que englobem tanto a fisioterapia global como os cuidados respiratórios necessários.

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A evidência científica para apoiar esta abordagem abrangente para todos os doentes críticos é ainda limitada; portanto, são necessários estudos aleatorizados com medidas de resultados a curto e longo prazo.

Advances in the management of critically ill patients admitted to intensive (ICU) or respiratory intermediate intensive care units (RIICU) have improved hospital mortality and morbidity, leading to a growing population of patients with partial or complete dependence on mechanical ventilation and other ICU therapies.[1–3]

Clinical consequences of prolonged mechanical ventilation

Prolonged Hospital stay and difficulty with or lack of response to therapies can often cause severe complications such as muscle weakness, physical deconditioning, recurrent symptoms, mood alterations and poor quality of life.[4,5] Patients needing prolonged mechanical ventilation, may suffer from ''chronic critical illness'' involving myopathy related weakness, neuropathy, loss of lean body mass, increased adiposity, and anasarca.[4–6] This syndrome may contribute to low target organ hormone levels and impaired anabolism,[5,7] increased prevalence of difficult-to-eradicate infections,[8] coma or protracted or permanent delirium,[9] skin wounds, edema, incontinence, and prolonged immobility.[10,11]The role and workload of physical therapists in an ICU is different in different European countries,[12] but common to all is a growing need for physiotherapy programs in the short- and long-term care of patients admitted to ICUs or RIICU.[13–16] The recovery of physical and respiratory functions, discontinuation of mechanical ventilation, prevention of the effects of bed-rest and improvement in health status are proven clinical results of a physiotherapy program in these medical and surgical areas.[17–20]

The aims of any physical therapy program in critically ill patients is to apply advanced cost-effective therapeutic tools to decrease complications and the patient's ventilator-dependency and in this way decrease risks of complications associated with bed-rest, to improve residual function, to prevent the need for new hospitalisations and to improve the health status and quality of life. Physical therapy as a part of the overall care of patients undergoing cardiac, upper abdominal, and thoracic surgery, may prevent and treat respiratory complications such as secretion retention, atelectasis, and pneumonia by means of different techniques. Early physical therapy may prevent difficult weaning, limited mobility and ventilator dependency[21,22] (Table 1).

Table 1 Physiotherapy techniques in the ICU.

Mobilisation
Postures
Passive limb exercise
Active limb exercise
Continuous rotational therapy
Muscle training
Respiratory muscle training
Peripheral muscle training
Neuromuscular electrical stimulation
Airway Secretions Management
Manual hyperinflation
Percussion and vibrations
In-exsufflation
Intrapulmonary percussive ventilation

Treatment of muscle weakness and related complications

Mobilisation

Prolonged immobility is a main cause of muscle weakness in patients admitted to ICU, conversely early physiotherapy has an important role in the recovery of these patients. Early physical activity is feasible and is a safe intervention following the initial cardio-respiratory and neurological stabilisation.[23,24] Early mobilisation and muscle training can improve functional outcomes, cognitive and respiratory conditions in these critically ill patients,[24] reducing the risks of venous stasis and deep vein thrombosis.[25] Postures, passive or active limb movements and Continuous Rotational Therapy (CRT) are considered the principal strategies to mobilise patients.

Postures

Prone position has been shown to result in short-term gain in oxygenation, in improvement of ventilation and perfusion mismatch and of the residual lung capacity.[26–29] Improvements in lung function and atelectasis have been also shown in patients with unilateral disease when positioned on their side, lying with the affected lung uppermost.[30,31] Despite their physiological rationale,[17] these easy techniques are still not widely used and it is still unclear whether the reported physiological improvements can be associated with improvements of stronger clinical outcomes like mortality.

Passive and active limb exercise

Passive, active assisted, or active resisted limb movements are aimed at maintaining the range of motion of the joints, at improving soft-tissue length and muscle strength, and decreasing the risk of thromboembolism.[32]

Fig. 1 Early bed cycling in ICU.

Quadriceps force and functional status was the same in patients undergoing the addition of early mobilisation to standard physiotherapy compared to standard physiotherapy alone. However, the total distance they walked, the isometric quadriceps force and the perceived functional well-being were significantly better with early mobilisation.[33] A gradual mobility protocol for both upper and lower limbs resulted in feasibility, safety and decreased hospital length of stay in acute patients requiring mechanical ventilation.[34] Supported arm training in addition to normal physiotherapy[35] gave similar positive results in patients recently weaned from mechanical ventilation in a RIICU (Fig. 1).

Continuous rotational therapy

This refers to specialised beds used to turn patients continuously along the longitudinal axis up to an angle of 60° onto each side, with preset degree and speed of rotation. This treatment can prevent sequential airways closure, and pulmonary atelectasis, reduce the incidence rate of lower respiratory tract infection and pneumonia, the duration of endotracheal intubation and the length of hospital stay.[36–40]

Muscle training

It is well known that muscle mass and its ability to perform aerobic exercise invariably declines with inactivity.[41] In critically complex patients, skeletal muscle training aims to strengthen, thus potentially increasing the patient's ability to perform Activities of Daily Life (ADL). In these patients, a tailored training program seems to be very effective in speeding weaning, in improving hospital survival, and in reducing risks associated to hospital-stay.[42]

Respiratory muscle training

Respiratory muscle weakness, imbalance between muscle strength and the load of the respiratory system and cardiovascular impairment are major determinants of weaning failure in ventilated patients. In ICU patients these factors and the excessive use of controlled mechanical ventilation, may lead to rapid diaphragmatic atrophy and dysfunction.[43] Nevertheless, the rationale for respiratory muscle training in ICU is still controversial. Indeed, the diaphragm of COPD patients is as valid as that of a healthy person in generating pressure at comparable lung volumes,[44] showing an adaptive change toward the slow-to-fast characteristics (resistance to fatigue) of the muscle fibres due to increased operational lung volume.[45]

There has been a debate in recent literature about the potential role of Inspiratory Muscle Training as a component of pulmonary rehabilitation in severely disabled COPD and in neuromuscular patients,[46,47] which is aimed at improving their strength and reducing the load perception of the respiratory system. Studies on ICU ventilatory-dependent COPD patients have also shown that respiratory muscles training may be associated with a favourable weaning outcome.[48,49]

Peripheral muscle training

Prolonged inactivity is more likely to cause skeletal muscle dysfunction and atrophy in antigravity muscles, with reduced capacity to perform aerobic exercise.[41,50] In severely disabled patients peripheral muscle training (both passive and active training lifting weights or pushing against a resistance with the limbs), produces specific gain of strength and recovery of ADL, although the evidence of effects after an episode of acute respiratory failure is not specified.[51] We have found that selective arm training added to the benefits (exercise tolerance and perception of dyspnoea) of standard physiotherapy.[35]

Neuromuscular electrical stimulation

Neuromuscular electrical stimulation (NMES) can induce changes in muscle function without any form of ventilatory stress in severely ill patients who are unable to perform any activity.[52] However, no clinical studies have yet clearly demonstrated the additional effect of NMES on exercise tolerance when compared with conventional training. NMES can be easily used in the ICU, applied to lower limb muscles of patients lying in bed. Patients with COPD[53,54] or with congestive heart failure[55] are more likely to benefit. NMES has been also considered as a means of preventing ICU polyneuromyopathy, a frequent complication in the critically ill patients.[56]

Airway secretions

Increase of bronchial secretions (either due to muco-ciliary dysfunction or to muscular weakness) may affect respiratory flow and increase the risk of nosocomial pneumonia.[8] Chest physiotherapy should prevent such complications by improving ventilation and gas exchange, and by reducing airway resistance and the work of breathing.[15] Several manually assisted techniques (manual hyperinflation, percussions/vibrations) and mechanical devices (in-exsufflator) are often applied to facilitate removal of excess of mucus (Table 1).

Manual hyperinflation

This respiratory technique is aimed at preventing pulmonary collapse (or re-expanding collapsed alveoli), improving oxygenation and lung compliance, and facilitating the movement of secretions toward the central airways.[57] Manual hyperinflation does not have a standard practice; the possible physiological side effects of delivered air volume, flow rates and airway pressure must be carefully considered, especially in patients under mechanical ventilation.[58–60] Increase in air volume with this technique can be obtained both manually or with assisted mechanical ventilation, each producing similar benefits in clearing excessive mucus.[61,62]

Percussion and vibrations

Manual percussion and vibrations (clapping a selected area and then compressing the chest during the expiratory phase) are commonly used to increase airway clearance and are often associated with postural drainage. Currently, in critical ventilated patients with a normal cough competence, increase of mucus clearance is achieved without a significant change of blood gases and lung compliance.[15,63,64]

In-exsufflation

The mechanical in-exsufflator promotes removal of excessive mucus by inflating the airways with a large air volume that rapidly is exsufflated by a negative pressure, thus simulating the physiological mechanism of cough.[65–67] The safety and the clinical advantage (avoidance of tracheostomy and/or endotracheal intubation) of this device when compared with conventional chest physiotherapy in hospitalised neuromuscular patients with recent upper respiratory tract infection has been shown.[68,69] The usefulness of these techniques in allowing for extubation in patients judged as needing tracheostomy has been recently outlined.[70]

Intrapulmonary percussive ventilation

Intrapulmonary Percussive Ventilation creates a percussive effect in the airways thus facilitating mucus clearance through direct high-frequency oscillatory ventilation which is able to help the alveolar recruitment.[71] This effect has been successfully shown during both acute and chronic phases in patients with respiratory distress,[72] neuromuscular disease,[73] and pulmonary atelectasis with or without consolidation.[74] In hospitalised COPD patients with respiratory acidosis, this technique has been shown to prevent the deterioration of the acute episode, thus avoiding endo-tracheal intubation.[75] In tracheostomised patients recently weaned from mechanical ventilation the addition of Intrapulmonary Percussive Ventilation to standard chest physiotherapy was associated with an improvement of oxygenation and expiratory muscle performance thus leading to a substantial reduction in the risk of pneumonia.[76]

Conclusion

Due to the increasing number of ICU admissions and the global risk of complications and mortality over the following years,[3,77] comprehensive programs including physiotherapy should be implemented to speed-up the patients' functional recovery and to prevent the complications of prolonged immobilisation especially in ventilator-dependent or difficult- to wean patients.[18,78] To manage the multiple and complex problems of these patients, integrated programs dealing with both whole-body physical therapy and pulmonary care are needed.[13,14]

There is still limited scientific evidence to support such a comprehensive approach to all critically ill patients; therefore we need randomised studies with solid clinical short- and long-term outcome measures.

Conflicts of interest

The authors have no conflicts of interest to declare.

References

1. Epstein SK. Size of the problem, what constitutes prolonged mechanical ventilation, natural history, epidemiology. In: Ambrosino N, Goldstein RS, editors. *Ventilatory support in chronic respiratory failure*. New York, USA: Informa Publisher; 2008. p. 39–57.
2. Milberg JA, Davis DR, Steinberg KP, Hudson LD. Improved survival of patients with acute respiratory distress syndrome (ARDS). JAMA. 1995;273:306–9.
3. Herridge MS, Tansey CM, Matté A, Tomlinson G, Diaz-Granados N, Cooper A, et al. Functional disability 5 years after acute respiratory distress syndrome. N Engl J Med. 2011;364:1293–304.
4. Nelson JE, Cox CE, Hope AA, Carson SS. Concise clinical review: chronic critical illness. Am J Respir Crit Care Med. 2010;182:446–54.
5. Ambrosino N, Gabbrielli L. The difficult-to-wean patient. Expert Rev Respir Med. 2010;4:685–92.
6. Hollander JM, Mechanick JI. Nutrition support and the chronic critical illness syndrome. Nutr Clin Pract. 2006;21:587–604.
7. Van den Berghe G, de Zegher F, Veldhuis JD, Wouters P, Gouwy S, Stockman W, et al. Thyrotrophin and prolactin release in prolonged critical illness: dynamics of spontaneous secretion and effects of growth hormones ecretagogues. Clin Endocrinol. 1997;47:599–612.
8. Kalb TH, Lorin S. Infection in the chronically critically ill: unique risk profile in a newly defined population. Crit Care Clin. 2002;18:529–52.
9. Nelson JE, Tandon N, Mercado AF, Camhi SL, Ely EW, Morrison RS. Brain dysfunction: another burden for the chronically critically ill. Arch Intern Med. 2006;166:1993–9.
10. Carasa M, Polycarpe M. Caring for the chronically critically ill patient: establishing a wound-healing program in a respiratory care unit. Am J Surg. 2004;188:18–21.
11. De Jonghe B, Bastuji-Garin S, Durand MC, Malissin I, Rodrigues P, Cerf C, et al. Respiratory weakness is associated with limb weakness and delayed weaning in critical illness. Crit Care Med. 2007;35:2007–15.
12. Norrenberg M, Vincent JL. A profile of European intensive care unit physiotherapists. Intensive Care Med. 2000;26:988–94.
13. 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;34:1188—99.
14. 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;(April) [Epub ahead of print].
15. Stiller K. Physiotherapy in intensive care. Towards an evidence-based practice. Chest. 2000;118:1801—13.
16. Scala R, Corrado A, Confalonieri M, Marchese S, Ambrosino N. Increased number and expertise of Italian respiratory high-dependency care units: the second national survey. Respir Care. 2011;(April).
17. Novoa N, Ballesteros E, Jiménez MF, Aranda JL, Varela G. Chest physiotherapy revisited: evaluation of its influence on the pulmonary morbidity after pulmonary resection. Eur J Cardiothorac Surg. 2011;40(Jul (1)):130—4.
18. Carpenè N, Vagheggini G, Panait E, Gabbrielli L, Ambrosino N. A proposal of a new model for long-term weaning: respiratory intensive care unit and weaning center. Respir Med. 2010;104(October):1505—11.
19. Montagnani G, Vagheggini G, Panait Vlad E, Berrighi D, Pantani L, Ambrosino N. Use of the functional independence measure following a weaning program from mechanical ventilation in difficult to wean patients. Phys Ther. 2011;91(Jul (7)):1109—15.
20. Ambrosino N, Gabbrielli L. Physiotherapy in the perioperative period. Best Pract Res Clin Anaesthesiol. 2010;24:283—9.
21. Clini E, Ambrosino N. Early physiotherapy in the respiratory intensive care unit. Respir Med. 2005;99:1096—104.
22. Pohlman MC, Schweickert WD, Pohlman AS, Nigos C, Pawlik AJ, Esbrook CL, et al. Feasibility of physical and occupational therapy beginning from initiation of mechanical ventilation. Crit Care Med. 2010;38:2089—94.
23. 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;36:1119—24.
24. 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.
25. Partsch H. Bed rest versus ambulation in the initial treatment of patients with proximal deep vein thrombosis. Curr Opin Pulm Med. 2002;8:389—93.
26. Gattinoni L, Tognoni G, Pesenti A, Taccone P, Mascheroni D, Labarta V, et al. Effect of prone positioning on the survival of patients with acute respiratory failure. N Engl J Med. 2001;345:568—73.
27. Mure M, Martling C-R, Lindahl SGE. Dramatic effect on oxygenation in patients with severe acute lung insufficiency treated in the prone position. Crit Care Med. 1997;25: 1539—44.
28. Jolliet P, Bulpa P, Chevrolet JC. Effects of the prone position on gas exchange and hemodynamics in severe acute respiratory distress syndrome. Crit Care Med. 1998;26:1539—44.
29. Chatte G, Sab JM, Dubois JM, Sirodot M, Gaussorgues P, Robert D. Prone positioning in mechanically ventilated patients with severe acute respiratory failure. Am J Respir Crit Care Med. 1997;155:473—8.
30. Gillespie DJ, Rehder K. Body position and ventilation-perfusion relationships in unilateral pulmonary disease. Chest. 1987;91:75—9.
31. Stiller K, Jenkins S, Grant R. Acute lobar atelectasis: a comparison of five physiotherapy regimens. Physiother Theory Pract. 1996;12:197—209.
32. Koch SM, Fogarty S, Signorino C, Parmley L, Mehlhorn U. Effect of passive range motion on intracranial pressure in neurosurgical patients. J Crit Care. 1996;11:176—9.
33. 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;37:2499—505.
34. 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;36:2238—43.
35. Porta R, Vitacca M, Gilè LS, Clini E, Bianchi L, Zanotti E, et al. Supported arm training in patients recently weaned from mechanical ventilation. Chest. 2005;128:2511—20.
36. Raoof S, Chowdhrey N, Raoof S, Feuerman M, King A, Sriraman R, et al. Effect of combined kinetic therapy and percussion therapy on the resolution of atelectasis in critically ill patients. Chest. 1999;7:1658—66.
37. deBoisblanc BP, Castro M, Everret B, Grender J, Walker CD, Summer WR. Effect of air-supported, continuous, postural oscillation on the risk of early ICU pneumonia in non-traumatic critical illness. Chest. 1993;103:1543—7.
38. Gentilello L, Thompson DA, Tonnesen AS, Hernandez D, Kapadia AS, Allen SJ, et al. Effect of a rotating bed on the incidence of pulmonary complications in critically ill patients. Crit Care Med. 1988;16:783—6.
39. Fink MP, Helsmoortel CM, Stein KL, Lee PC, Cohn SM. The efficacy of an oscillating bed in the prevention of lower respiratory tract infection in critically ill victims of blunt trauma. Chest. 1990;97:132—7.
40. Kirschenbaum L, Azzi E, Sfeir T, Tietjen P, Astiz M. Effect of continuous rotational therapy on the prevalence of ventilator-associated pneumonia in patients requiring long-term ventilatory care. Crit Care Med. 2002;30:1983—6.
41. Bloomfield SA. Changes in musculoskeletal structure and function with prolonged bed rest. Med Sci Sport Exerc. 1997;29:197—206.
42. 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.
43. Le Bourdelles G, Viires N, Boczkowski J, Seta N, Pavlovic D, Aubier M. Effects of mechanical ventilation on diaphragmatic contractile properties in rats. Am J Respir Crit Care Med. 1994;149:1539—44.
44. Similowski T, Yan S, Gauthier AP, Macklem PT, Bellemare F. Contractile properties of the human diaphragm during chronic hyperinflation. N Engl J Med. 1991;325:917—23.
45. Levine S, Kaiser L, Leferovich J, Tikunov B. Cellular adaptations in the diaphragm in chronic obstructive pulmonary disease. N Engl J Med. 1997;337:1799—806.
46. Gosselink R, De Vos J, van den Heuvel SP, Segers J, Decramer M, Kwakkel G. Impact of inspiratory muscle training in patients with COPD: what is the evidence? Eur Respir J. 2011;32:416—25.
47. American Thoracic Society. Respiratory care of the patient with Duchenne muscular dystrophy: ATS consensus statement. Am J Respi Crit Care Med. 2004;170:456—65.
48. Martin AD, Davenport PD, Franceschi AC, Harman E. Use of inspiratory muscle strength training to facilitate ventilator weaning. Chest. 2002;122:192—6.
49. Aldrich TK, Karpel JP, Uhrlass RM, Sparapani MA, Eramo D, Ferranti R. Weaning from mechanical ventilation: adjunctive use of inspiratory muscle training. Crit Care Med. 1989;17: 14—14.
50. Coyle EF, Martin 3rd WH, Bloomfield SA, Lowry OH, Holloszy JO. Effects of detraining on response to sub maximal exercise. J Appl Physiol. 1985;59:853—9.

51. Nava S. Rehabilitation of patients admitted to a respiratory intensive care unit. Arch Phys Med Rehabil. 1998;79:849–54.
52. Ambrosino N, Strambi S. New strategies to improve exercise tolerance in chronic obstructive pulmonary disease. Eur Resp J. 2004;24:313–22.
53. 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;124:2992–6.
54. Vivodtzev I, Pépin JL, Vottero G, Mayer V, Porsin B, Lévy P, et al. Improvement in quadriceps strength and dyspnea in daily tasks after 1 month of electrical stimulation in severely deconditioned and malnourished COPD. Chest. 2006;129:1540–8.
55. Nuhr MJ, Pette D, Berger R, Quittan M, Crevenna R, Huelsman M, et al. Beneficial effects of chronic low-frequency stimulation of thigh muscle in patients with advanced chronic heart failure. Eur Heart J. 2004;25:136–43.
56. Routsi C, Gerovasili V, Vasileiadis I, Karatzanos E, Pitsolis T, Tripodaki E, et al. Electrical muscle stimulation prevents critical illness polyneuromyopathy: a randomized parallel intervention trial. Crit Care. 2010;14:R74.
57. Denehy L. The use of manual hyperinflation in airway clearance. Eur Respir J. 1999;14:958–65.
58. Clarke RC, Kelly BE, Convery PN, Fee JP. Ventilatory characteristics in mechanically ventilated patients during manual hyperventilation for chest physiotherapy. Anesthesia. 1999;54:936–40.
59. Singer M, Vermaat J, Hall G, Latter G, Patel M. Hemodynamic effects of manual hyperinflation in critically ill mechanically ventilated patients. Chest. 1994;106:1182–7.
60. Turki M, Young MP, Wagers SS, Bates JH. Peak pressures during manual ventilation. Respir Care. 2005;50:340–4.
61. Maa SH, Hung TJ, Hsu KH, Hsieh YI, Wang KY, Wang CH, et al. Manual hyperinflation improves alveolar recruitment in difficult-to-wean patients. Chest. 2005;128:2714–21.
62. Stiller K, Geake T, Taylor J, Grant R, Hall B. Acute lobar atelectasis: a comparison of two chest physiotherapy regimens. Chest. 1990;98:1336–40.
63. Ntoumenopoulos G, Presneill JJ, McElholum M, Cade JF. Chest Physiotherapy for the prevention of ventilator-associated pneumonia. Intensive Care Med. 2002;28:850–6.
64. Eales CJ, Barker M, Cubberley NJ. Evaluation of a single chest physiotherapy treatment to post-operative, mechanically ventilated cardiac surgery patients. Physiother Theory Pract. 1995;11:23–8.
65. Bach JR. Mechanical insufflation-exsufflation: a comparison of peak expiratory flows with manually assisted and unassisted coughing techniques. Chest. 1993;104:1553–62.
66. Bach JR. Update and perspective on noninvasive respiratory muscle aids: part 2.The expiratory aids. Chest. 1994;105:1538–44.
67. Winck JC, Gonçalves MR, Lourenço C, Viana P, Almeida J, Bach JR. Effects of mechanical insufflation-exsufflation on respiratory parameters for patients with chronic airway secretion encumbrance. Chest. 2004;126: 774–80.
68. Vianello A, Corrado A, Arcaro G, Gallan F, Ori C, Minuzzo M, et al. Mechanical insufflation-exsufflation improves outcomes for neuromuscular disease patients with respiratory tract infections. Am J Phys Med Rehabil. 2005;84(February): 83–8.
69. Branson RD. Secretion management in the mechanically ventilated patient. Respir Care. 2007;52:1328–47.
70. Bach JR, Gonçalves MR, Hamdani I, Winck JC. Extubation of patients with neuromuscular weakness: a new management paradigm. Chest. 2010;137:1033–9.
71. Salim A, Martin M. High frequency percussive ventilation. Crit Care Med. 2005;33:S241–5.
72. Velmahos GC, Chan LS, Tatevossian R, Cornwell 3rd EE, Dougherty WR, Escudero J, et al. High-frequency percussive ventilation improves oxygenation in patients with ARDS. Chest. 1999;116:440–6.
73. Crescimanno G, Marrone O. High frequency chest wall oscillation plus mechanical in-exsufflation in Duchenne muscular dystrophy with respiratory complications related to pandemic Influenza A/H1N1. Rev Port Pneumol. 2010;16: 912–6.
74. Tsuruta R, Kasaoka S, Okabayashi K, Maekawa T. Efficacy and safety of intrapulmonary percussive ventilation superimposed on conventional ventilation in obese patients with compression atelectasis. J Crit Care. 2006;2:328–32.
75. Vargas F, Boyer A, Bui HN, Guenard H, Gruson D, Hilbert G. Effect of intrapulmonary percussive ventilation on expiratory flow limitation in chronic obstructive pulmonary disease patients. J Crit Care. 2009;24:212–9.
76. Clini EM, Antoni FD, Vitacca M, Crisafulli E, Paneroni M, Chezzi-Silva S, et al. Intrapulmonary percussive ventilation in tracheostomized patients: a randomized controlled trial. Intensive Care Med. 2006;32:1994–2001.
77. Stoller JK, Xu M, Mascha E, Rice R. Long term outcomes for patient discharged from a long term hospital-based weaning unit. Chest. 2003;124:1892–9.
78. 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.