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Physiotherapy in Intensive Care*

Towards an Evidence-Based Practice

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Key words: critical care; evidence-based medicine; intensive care; physical therapy

Abbreviations: ABG = arterial blood gas; APACHE = acute physiology and chronic health evaluation; CPP = cerebral perfusion pressure; F_{IO_2} = fraction of inspired oxygen; ICP = intracranial pressure; MH = manual hyperinflation; $\dot{V}/\dot{Q}$ = ventilation/perfusion; V_T = tidal volume

In most hospitals in developed countries, physiotherapy is seen as an integral part of the management of patients in ICUs. The precise role that physiotherapists play in the ICU varies considerably from one unit to the next, depending on factors such as the country in which the ICU is located, local tradition, staffing levels, training, and expertise. The referral process is one example of this variation, whereby in some ICUs, physiotherapists assess all patients, whereas in other ICUs, patients are seen only after referral from medical staff.[1] The most common techniques used by physiotherapists in the ICU are positioning, mobilization, manual hyperinflation (MH), percussion, vibrations, suction, cough, and various breathing exercises.[1–7] Some physiotherapists routinely treat most, if not all, ICU patients with a combination of these techniques,[1] regardless of the patient's underlying pathophysiologic condition, with the intention of preventing pulmonary complications, whereas other physiotherapists use such techniques selectively when they believe they are specifically indicated.

As the cost associated with the management of ICU patients is very high, the requirement for all those who work in ICUs, including physiotherapists, to provide evidence-based practice is mandatory. The aim of this article is to review the evidence regarding the effectiveness of physiotherapy for patients in the ICU and thus provide a framework for evidence-based practice. Potential areas for future research are also discussed. This review is primarily concerned with the management of intubated, mechanically ventilated, adult patients. The role of physiotherapy for nonintubated patients, including those receiving noninvasive mechanical ventilation, and pediatric patients is beyond the scope of this review.

Initially, a description of the individual physiotherapy treatment techniques and their physiologic rationale will be provided. The literature review of the effectiveness of physiotherapy for intubated patients receiving mechanical ventilation in the ICU will then be discussed under the following headings: pulmonary function; hemodynamic and metabolic factors; the incidence of pulmonary complications; the clinical course of pulmonary conditions; overall outcome; and the effectiveness of the individual components of physiotherapy. Evidence concerning the effectiveness of continuous rotational therapy, which can be considered a type of physical therapy, will be reviewed in the treatment technique research section. In view of the large number of studies identified in some of these areas, details of each study will not be provided. Instead, selected studies that are considered to be landmark studies or characteristic of those conducted in the area will be described. Subsequent to the literature review, recommendations for evidence-based practice for physiotherapy in the ICU are considered under the following headings: prevention of pulmonary complications; treatment of pulmonary conditions and complications; short-term benefits; selection of individual treatment techniques; and monitoring required during physiotherapy.

To ensure that the major relevant articles were reviewed, literature searches were performed using a CD-ROM version of the databases MEDLINE and CINAHL (Cumulative Index to Nursing and Allied Health Literature) with appropriate subject headings and keywords, including physical therapy, intensive

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care, rehabilitation, postural drainage, MH, and breathing exercises. The reference lists of all articles were reviewed to identify other potentially relevant articles.

Treatment Techniques

Positioning

Positioning in this context describes the use of body position as a specific treatment technique. Positioning for ICU patients can be used with the physiologic aims of optimizing oxygen transport through its effects of improving ventilation/perfusion ($\dot{V}/\dot{Q}$) matching, increasing lung volumes, reducing the work of breathing, minimizing the work of the heart, and enhancing mucociliary clearance.[8–10] Rather than considering postural drainage as a separate technique, it is considered herein as one example of positioning which has the particular aim of increasing clearance of airway secretions with the assistance of gravity.

Specific examples of positioning that may be used in the ICU setting include upright positioning to improve lung volumes and decrease the work of breathing in patients who are being weaned from mechanical ventilation; prone positioning to improve $\dot{V}/\dot{Q}$ matching, redistribute edema, and increase functional residual capacity for patients with ARDS; side lying with the affected lung uppermost to improve $\dot{V}/\dot{Q}$ matching for patients with unilateral lung disease; side lying with the affected lung uppermost to improve ventilation (via distending forces on the uppermost lung) and clearance of airway secretions for patients with acute lobar atelectasis.[5,11–22]

Mobilization

Mobilization techniques that may be used for intubated patients receiving mechanical ventilation in the ICU include active limb exercises, the patient actively moving or turning in bed, getting out of bed via mechanical lifting machines or slide board transfers, sitting on the edge of the bed, standing, standing transfers from bed to chair, and walking. The physiologic rationale for mobilization is that it will optimize oxygen transport by enhancing, for example, alveolar ventilation and $\dot{V}/\dot{Q}$ matching.[8,10] In addition, mobilization that involves being in the erect position will have the beneficial effects associated with the erect position as previously outlined. Mobilization can also provide a gravitational stimulus to maintain or restore normal fluid distribution in the body and to reduce the effects of immobility and bed rest.[8,10] In the longer term, mobilization aims to optimize work capacity and functional independence and to improve cardiopulmonary fitness.[8,10]

MH

MH involves disconnecting the patient from the ventilator and inflating the lungs with a large tidal volume (V_T) via a manual resuscitator bag. The technique is usually performed by delivering a slow deep inspiration, an inspiratory hold, and a quick release of the inflation bag to enhance expiratory flow rate.[4,7,9,23–25] MH is used with the aim of preventing pulmonary collapse, reexpanding collapsed alveoli, improving oxygenation and lung compliance, and increasing movement of pulmonary secretions toward the central airways.[4,5,7,23–27] It is likely that the additional V_T delivered with MH reaches the most compliant parts of the lungs and so expands normal rather than collapsed alveoli, although it may help reinflate collapsed alveoli by promoting airflow through collateral channels and the phenomenon of interdependence.[9,24]

It is important to differentiate between MH and manual hyperoxygenation, the latter being the delivery of high levels of oxygen, using a manual resuscitator bag, but with no attempt to increase V_T to the extent sought with MH. Manual hyperoxygenation is usually performed before and between suction passes, with the specific intention of preventing suction-induced hypoxemia.

Percussion and Vibrations

Percussion and vibrations are techniques that are believed to increase clearance of airway secretions by the transmission of an energy wave through the chest wall.[28] Percussion may be performed manually by clapping the chest wall over the affected area of the lung, using cupped hands.[28] Vibrations may be applied manually by vibrating, shaking, or compressing the chest wall during expiration. Both percussion and vibrations can also be performed using mechanical devices.[28]

Suction

Suction via an endotracheal tube or tracheostomy is used with the aim of removing secretions from the central airways and stimulating a cough.[2,3,5]

Limb Exercises

Limb exercises (passive, active assisted, or active resisted) may be performed with ICU patients with the aim of maintaining or improving joint range of motion, soft-tissue length, muscle strength, and function, and of decreasing the risk of thromboembolism.[2,9,29]

Continuous Rotational Therapy

Continuous rotational therapy refers to the use of specialized beds that continuously and slowly turn a patient along the longitudinal axis, up to an angle of 60° onto each side, with the degree and speed of rotation preprogrammed.[30,31] The therapy is achieved by the entire platform of the bed rotating (also known as kinetic therapy) or by the inflation and deflation of compartments in the mattress (also known as oscillating beds).[30,31] The rationale for the use of continuous rotational therapy is that it will prevent dependent airway closure, decreased compliance, atelectasis, pooling and stagnation of pulmonary secretions, and subsequent infection that are believed to result from prolonged immobility.[31]

Evidence Regarding Effectiveness of Physiotherapy in the ICU

The Effect of Physiotherapy on Pulmonary Function

Many studies have investigated the short-term effect of multimodality respiratory physiotherapy (*eg*, positioning, percussion, vibrations, MH, and suction) on the pulmonary function of intubated ICU patients receiving mechanical ventilation.[17,32–37]

Mackenzie and Shin,[32] in a study typical of those conducted in this area, examined the effect of a physiotherapy treatment (consisting of postural drainage, percussion, vibrations, and suction) administered to each of 19 patients receiving mechanical ventilation (12 men, 7 women; mean age, 32.4 years). All patients had respiratory failure after trauma that had occurred a mean of 4.4 days before the study.

Various respiratory variables were measured before and up to 2 h after treatment. It was not noted who recorded these measurements. No significant changes were found in arterial blood gas (ABG) measurements, but intrapulmonary shunt significantly decreased by a mean of 20% immediately after physiotherapy (from a mean of 16.4 to 13.2%), and there was a significant increase in total lung compliance of 14% 2 h after physiotherapy (from a mean of 29 to 33 mL/cm H_2O).

Other studies have also demonstrated significant improvements after physiotherapy in lung compliance, ABG values, and intrapulmonary shunt.[17,35,37] These improvements were usually of short duration, but improvement lasting up to 2 h after treatment has been reported.[35] However, other studies have reported no significant changes in pulmonary function after multimodality physiotherapy.[33,34,36] In virtually all of these studies, measurements were taken before and after physiotherapy, without the inclusion of a control group that received no intervention or another treatment group to enable comparison of outcomes. This may be an important omission, as Sasse et al,[38] who measured ABGs for a 1-h period in 28 ICU patients, with all facets of management being held constant during this period, found that the mean intraindividual variation was 6% for the $Pa{O_2}$ and 5% for the $Pa{CO_2}$. Thus, there is a substantial spontaneous variability for ABG values, which should be taken into account when interpreting such data.

The Effect of Physiotherapy on Hemodynamic and Metabolic Factors

The hemodynamic and metabolic effects of multimodality respiratory physiotherapy for intubated ICU patients receiving mechanical ventilation have been extensively investigated.[4,39–48] The hemodynamic effects associated with physiotherapy were comprehensively reviewed by Paratz.[9]

In an example of the studies conducted in this area, Cohen et al[47] evaluated the hemodynamic and metabolic effects of respiratory physiotherapy for 32 patients receiving mechanical ventilation (18 men, 14 women; mean age, 62.0 years). All but two patients were studied in the postoperative period, and all patients were hemodynamically stable and receiving ventilation using the synchronized intermittent mandatory ventilation mode. Patients were divided into two groups, each containing 16 patients. All patients, who were receiving physiotherapy treatment as part of their routine care, received two physiotherapy treatments in randomized order—one treatment was preceded by administration of propofol and the other treatment was preceded by administration of a placebo drug. The dosage of propofol administered before treatment varied between the two groups—one group received 0.75 mg/kg, and the other group, 0.35 mg/kg. The physiotherapy treatment consisted of percussion in alternate side-lying positions, followed by suction in the supine position. Hemodynamic and metabolic variables were recorded during an initial baseline rest period, immediately after the physiotherapy treatment, and during a rest period after treatment. It was not noted who collected these data or whether they were blinded to the study. Significant and at times dramatic increases in heart rate, systolic and mean BP, cardiac output, oxygen consumption, carbon dioxide production, and $Pa{CO_2}$ were found during the physiotherapy treatment. The administration of propofol before the treatment decreased or prevented these hemodynamic and metabolic responses. As an example of the metabolic effects seen, oxygen consumption increased by approximately 70% over baseline values during the physiotherapy treatments preceded by the placebo drug (from a mean of 236 to 404 mL/min), compared with an increase of 19% for patients given the higher dose of propofol (from a mean of 233 to 277 mL/min) and 43% for patients given the lower dose of propofol before treatment (from a mean of 243 to 348 mL/min).

Other authors have documented similar significant detrimental hemodynamic and metabolic responses to multimodality physiotherapy.[4,39–46,48] In general, these detrimental effects were noted during physiotherapy and up to half an hour after treatment, and were reduced or prevented by the prior administration of sedative medications, such as propofol or fentanyl.[41,44,47]

Horiuchi et al[48] further investigated the cause for the increased metabolic and hemodynamic responses during physiotherapy by studying seven patients receiving mechanical ventilation after major vascular or abdominal surgery (no other patient details were provided). These patients all received two standardized physiotherapy treatments (consisting of percussion in alternate side-lying positions, followed by suction in the supine position), with the first treatment preceded by midazolam and the second treatment preceded by vecuronium. They found that the administration of vecuronium suppressed the increased metabolic demands that were seen during the physiotherapy treatment preceded by midazolam, whereas the hemodynamic responses were not altered by the administration of vecuronium. Thus, they hypothesized that the increased metabolic demand during multimodality physiotherapy is an exercise-like response resulting from increased muscular activity, whereas the increased hemodynamic responses are most likely caused by a stresslike response associated with an increased sympathetic output.

Cardiac arrhythmias have been documented during respiratory physiotherapy in a study involving 72 critically ill ICU patients (42 men, 30 women; mean age, 58.6 years).[42] Patients included in this study had a variety of medical conditions, including pneumonia (44 patients), abdominal surgery (19 patients), and acute cardiac conditions (20 patients). Although it would seem that not all patients were intubated, the exact number of patients intubated and receiving mechanical ventilation, and their mode of ventilation, were not reported. A standardized physiotherapy treatment comprising postural drainage and percussion was performed on all patients. All patients had been referred for physiotherapy by a physician, but the specific indications for this treatment were not described. No cardiac arrhythmias were seen for 46 patients (63.9%), minor arrhythmias were seen for 18 patients (25.0%), and major arrhythmias were seen for 8 patients (11.1%). Most patients with minor arrhythmias had an increased frequency of premature atrial contractions (eight patients) or less than six premature ventricular contractions per minute (six patients). The most common major arrhythmia reported was the occurrence of more than six premature ventricular contractions per minute (six patients). None of the cardiac arrhythmias seen were life threatening, and in all cases, the arrhythmia resolved spontaneously or on resumption of the upright position or cessation of treatment. It was noted that cardiac arrhythmias were more common in older patients and those with acute cardiac disorders.

Multimodality physiotherapy has also been shown to increase intracranial pressure (ICP) significantly, although cerebral perfusion pressure (CPP) is usually maintained at adequate levels.[43,49–52] The magnitude of the mean increase in ICP seen in these studies was < 10 mm Hg, with the exception of the study by Ersson et al[52] in which mean ICP increased by > 30 mm Hg during suction and manual "bag squeezing." In those studies in which BP, ICP, and CPP were measured, the increases in ICP were accompanied by increases in BP, therefore resulting in < 10 mm Hg mean change in CPP.[43,52]

As the physiotherapy treatments applied in the majority of the studies investigating the effect of physiotherapy on hemodynamic and metabolic variables used combinations of techniques, such as positioning, percussion, vibrations, MH, and suction, it is not possible to attribute any decrements in function to a particular technique. There were also methodologic concerns with most studies. The majority studied patients with heterogeneous respiratory problems, comparative treatment or control groups were not used in most studies, patient numbers were generally small, and the rationale for physiotherapy intervention and treatment selection was often not provided or questionable.

The Effect of Physiotherapy on the Incidence of Pulmonary Complications

In some hospitals, physiotherapy is performed routinely on all intubated ICU patients receiving mechanical ventilation, with the aim of decreasing the incidence of pulmonary complications (*eg*, nosocomial pneumonia, bronchopulmonary infection, atelectasis). To my knowledge, the only published report investigating the effectiveness of physiotherapy in preventing pulmonary complications for intubated patients receiving mechanical ventilation is by Ntoumenopoulos et al.[53] In this key study, 46 patients who were receiving mechanical ventilation after trauma were randomly allocated to a group that received standard nursing care (which comprised at least two hourly turns and suction) plus physiotherapy, or standard nursing care alone. The physiotherapy consisted of twice-daily postural drainage, MH, and suction. Outcome measurements included ABG analyses, the incidence of nosocomial pneumonia, days receiving mechanical ventilation, and length of stay in the ICU. Nosocomial pneumonia was diagnosed by consultant or registrar medical staff who were blind to the patients' groups, and defined as the presence of a new pulmonary infiltrate on chest radiograph, together with at least three of the following: temperature $> 38°C$, WBC count $> 11,000$ cells/μL, purulent sputum with bacteria on Gram's stain, and positive sputum culture. The reliability of medical staff involved in the diagnosis of pneumonia was not investigated. If patients developed nosocomial pneumonia, they were withdrawn from the study and provided with appropriate physiotherapy. Because of a delay in the final diagnosis of nosocomial pneumonia (while awaiting Gram's stain or sputum cultures), some patients were withdrawn from the study owing to the clinical suspicion of pneumonia.

The profiles of the two groups on entry into the study were similar and not significantly different with respect to data such as age (mean, 40.1 years), APACHE (acute physiology and chronic health evaluation) II score (mean, 13.2), and injury severity score (mean, 26.6). Of the 22 patients in the group that received physiotherapy and standard nursing care, 4 patients (18.2%) were withdrawn because of a suspicion of nosocomial pneumonia, with 3 of these patients (13.6%) subsequently receiving a diagnosis of nosocomial pneumonia. For the 24 patients in the group who received standard nursing care alone, 8 patients (33.3%) were withdrawn because of a suspicion of nosocomial pneumonia, with the diagnosis of nosocomial pneumonia confirmed for 4 of these patients (16.7%). There were no statistically significant differences between the two groups in either the number of patients withdrawn from the study on the suspicion of nosocomial pneumonia or the number of patients with a final diagnosis of pneumonia. Similarly, no significant differences were seen between groups in ABG values, the length of time receiving mechanical ventilation (mean, 6.1 days physiotherapy group; 5.2 days control group), length of ICU stay (mean, 7.4 days physiotherapy group; 6.8 days control group), or mortality rate in the ICU (0 for both groups). As identified by the authors, the small sample size was a limitation of the study that may have led to a type II error.

The Effect of Physiotherapy on the Clinical Course of Pulmonary Conditions

The management of pulmonary conditions commonly found in intubated ICU patients receiving mechanical ventilation (*eg*, pneumonia, bronchopulmonary infection, atelectasis, acute exacerbation of chronic pulmonary disease, ARDS) often includes physiotherapy. However, the effect of physiotherapy on the clinical course of such conditions has been studied only for acute lobar atelectasis.[17,54–57]

Marini et al,[54] in a landmark study, investigated 31 patients (23 men, 8 women; mean age, 50.5 years) with acute lobar atelectasis diagnosed by chest radiograph. There were a variety of primary diagnoses, with postoperative conditions and neurologic problems the most common. Patients were intubated and received mechanical ventilation for 43% and 36% of treatments, respectively. Patients were randomly allocated to a group that received initial fiberoptic bronchoscopy followed by physiotherapy or a group that received physiotherapy alone. Physiotherapy consisted of postural drainage, percussion, vibrations, MH or deep breathing, suction, or coughing, and was given at 4-h intervals for 48 h. Two examiners blinded to the patients' treatment groups assessed the percentage resolution of atelectasis as seen on chest radiograph after the first treatment and at 24 h and 48 h. Intraexaminer and interexaminer reliability was not assessed. No significant difference was seen between the two groups in the rate of resolution of atelectasis at any stage, nor were there significant differences between the groups in ABG values.

Fourrier et al[57] investigated 26 patients with acute lobar atelectasis (no other patient details were provided) who were randomly allocated to receive either a single episode of bronchoscopy or a single treatment of physiotherapy (positioning in side lying, vibrations, and suction). Chest radiographs were taken initially and at 1 h, 6 h, and 24 h after treatment, and reviewed by two examiners who were blind to the patients' allocated groups. It was not noted whether intraexaminer or interexaminer reliability was assessed. During the 24-h follow-up period, they found that complete resolution of atelectasis was seen on chest radiograph for 67% of patients who received physiotherapy compared with 29% of patients who received bronchoscopy ($p = 0.05$).

Other studies have also shown that physiotherapy, incorporating techniques such as positioning, MH, and suction, is an effective treatment for acute lobar atelectasis.[17,55,56]

The Effect of Physiotherapy on Overall Outcome

With the exception of the study by Ntoumenopoulos et al,[53] as outlined previously, the ability of physiotherapy to facilitate weaning, shorten the length of stay in the ICU or hospital, or decrease morbidity and mortality has not been reported.

The Effectiveness of the Individual Components of Physiotherapy

Positioning: Although the physiologic rationale for the use of positioning with critically ill patients is sound, there are limited published data to support its efficacy in the clinical setting. Prone positioning has been shown to result in short-term improvements in oxygenation for 57 to 92% of patients with severe acute respiratory failure or ARDS.[15,16,18–21] As an example of the improvements seen, Chatte et al,[18] investigating 32 patients receiving mechanical ventilation (24 men, 8 women; mean age, 55.9 years) with severe acute respiratory failure (PaO_2 to fraction of inspired oxygen [FIO_2] ratio < 150) that was not caused by left ventricular failure or atelectasis, found that the mean PaO_2/FIO_2 ratio significantly increased from a baseline value (supine) of 103 to 158 after 1 h in the prone position and to 159 after 4 h prone. Improvements in lung function have also been documented for patients with unilateral lung disease when they are positioned in side lying with the affected lung uppermost.[11–14] Ibanez et al[11] studied 10 patients (7 men, 3 women; mean age, 33.5 years) who were receiving mechanical ventilation because of acute respiratory failure and whose chest radiograph findings predominantly showed unilateral disease. They found that the PaO_2/FIO_2 ratio significantly increased from 112 when patients were positioned in side lying with the affected lung dependent, to 189 when in side lying with the affected lung uppermost.

It is not known whether these improvements in pulmonary function result in faster recovery or improved outcome for patients with severe acute respiratory failure, ARDS, or unilateral lung disease.

Stiller et al,[17] in a study that compared various combinations of physiotherapy techniques for 35 patients with acute lobar atelectasis, found that positioning patients in side lying with the affected lung uppermost and the head of the bed flat enhanced the resolution of acute lobar atelectasis, as seen on chest radiograph, when added to a treatment of MH and suction. The use of traditional postural drainage positions did not further add to the efficacy of this treatment.

An additional consideration regarding the use of positioning is its effect on gastroesophageal reflux and subsequent pulmonary aspiration and nosocomial pneumonia. Torres et al[58] investigated 19 patients (13 men, 6 women; mean age, 60 years) who were receiving mechanical ventilation for acute respiratory failure. They showed that the supine position (compared with the 45° head-up position), and the length of time in the supine position, are potential risk factors for the pulmonary aspiration of gastric contents for patients receiving mechanical ventilation. Similar findings were reported in studies by Ibanez et al[59] and Orozco-Levi et al,[60] in which, in comparison with the supine position, the semirecumbent position (45° head up) essentially prevented pulmonary aspiration[60] while decreasing (but not preventing) gastroesophageal reflux for patients receiving mechanical ventilation who have a nasogastric tube.[59,60]

Mobilization: Dean and Ross[8] and Dean[10] proposed that mobilization should be used as a primary means of enhancing oxygen transport in patients with acute pulmonary disease, including patients in the ICU. Although there is unequivocal evidence that prolonged bed rest results in deconditioning, to my knowledge, there are no published data involving intubated patients receiving mechanical ventilation that investigate the effect of mobilization on pulmonary function, the resolution of pulmonary disease, weaning from mechanical ventilation, or the length of ICU stay.

MH: Despite the many theoretical aims of MH, there are few definitive studies to support its routine use. Furthermore, the published research is often difficult to interpret, as various combinations of machine hyperinflation and MH, with and without changes in the F_{IO_2}, have been compared. However, improvements in lung compliance and oxygenation for up to 2 h after treatment have been noted after MH.[35,37,61] Jones et al,[35] for example, found that total static compliance significantly increased by 16% immediately after MH (from a mean of approximately 34 to 40 mL/cm H_2O) for 20 patients (15 men, 5 women; mean age, 48.7 years) who were receiving mechanical ventilation for respiratory failure. Other authors, however, have reported no significant change in oxygenation or compliance with MH.[33,36] The effect of MH on longer-term outcomes, such as the resolution of pulmonary disease and the prevention of pulmonary complications, has not been studied (to my knowledge).

It is known that MH has the potential to result in high airway pressures and overdistension of normal alveoli and may also cause significant hemodynamic changes (*eg*, decrease in cardiac output), partially as a result of the large fluctuations in intrathoracic pressure it may cause.[4,5,9,61] MH has also been shown to increase ICP and mean arterial pressure significantly for neurosurgical patients.[43] The mean increases seen in ICP and mean arterial pressure were < 5 mm Hg, and CPP was not altered significantly.[43] The actual application of the technique of MH by both physiotherapists and nursing staff, in terms of the V_T delivered, airway pressure, amount of positive end-expiratory pressure applied, flow rates, and F_{IO_2}, may be quite variable.[23,25,26,62,63]

Percussion and Vibrations: Although the effectiveness of percussion in enhancing sputum clearance has been extensively studied in stable, nonintubated patients with chronic pulmonary disease, no published data were found regarding its effectiveness for ICU patients. Percussion has been associated with detrimental effects, such as cardiac arrhythmias and a fall in pulmonary compliance in critically ill patients.[35,42]

The effectiveness of vibrations for ICU patients has been evaluated in two studies.[17,36] Eales et al,[36] investigating 37 patients receiving mechanical ventilation after cardiac surgery, found that ABG values and lung compliance did not significantly change during a treatment of MH and suction, with or without the addition of vibrations. Stiller et al[17] found that the addition of vibrations to a treatment of positioning, MH, and suction failed to significantly alter the rate of chest radiograph resolution of the atelectasis.

Suction: Although it is clear in the clinical setting that suction does achieve its aim of removing secretions from the central airways, to my knowledge, no studies have specifically investigated this. It has been shown that suction can be associated with many detrimental effects, such as hypoxemia and hemodynamic instability, as summarized by Paratz,[9] and tracheobronchial erosion and hemorrhage.[3] However, the use of sedation, reassurance, preoxygenation, and optimal technique minimizes the occurrence of these side effects.[9,64–66]

Continuous Rotational Therapy: In one of the largest studies to date investigating the use of continuous rotational therapy in the management of ICU patients, deBoisblanc et al[67] studied 120 critically ill patients (age and sex not noted) admitted to a medical ICU. From their clinical presentations, the majority of patients received a diagnosis of sepsis (61 patients) or obstructive airways disease (37 patients), and approximately 80% were receiving mechanical ventilation. Patients were randomly allocated to a group that was nursed on conventional beds and received standard 2-h turning by nursing staff or to a group that was nursed on oscillating beds that rotated through an arc of approximately 90° every 7 min. The treatment period lasted 5 days. Outcome measures included the incidence of pneumonia during the first 5 days of admission to the ICU, length of mechanical ventilation, length of ICU and hospital stay, and hospital mortality. Specific criteria were used to define pneumonia (a new chest radiograph infiltrate that persisted ≥ 3 days, temperature of > 38.3°C, purulent sputum, and the growth of one or more respiratory pathogens). Although it is noted that the chest radiographs were interpreted by a pulmonologist who was blinded to the treatment group, it is not stated whether the person making the overall diagnosis of pneumonia was also blinded to the patients' treatment groups, nor was examiner reliability assessed. The groups were comparable on admission into the study for perceived risk factors for the development of pneumonia. For example, there was no significant difference between groups in their mean APACHE II scores (mean, 16.8 control group; 18.5 oscillating bed group). Overall, a significantly lower incidence of pneumonia was seen in the group that was nursed on the oscillating beds (8.7%) compared with those patients nursed on conventional beds (21.6%). This effect was most noticeable for those patients with a diagnosis of sepsis (incidence of pneumonia, 23.1% control group; 2.9% oscillating bed group). However, no significant difference was found between groups in the duration of mechanical ventilation (mean, 9.9 days control group; 6.1 days oscillating bed group), length of ICU stay (mean, 10.8 days control group; 7.8 days oscillating bed group), length of hospital stay (mean, 18.5 days control group; 17.0 days oscillating bed group), or hospital mortality (27.5% control group; 39.1% oscillating bed group).

Similar significant reductions in the incidence of lower respiratory tract infection, pneumonia, and atelectasis were found by Gentilello et al[68] (combined incidence of atelectasis and pneumonia, 65.8% control group; 33.3% kinetic therapy group) and Fink et al[69] (incidence of lower respiratory tract infection, 58.3% control group; 25.5% oscillating bed group; incidence of pneumonia, 39.6% control group; 13.7% oscillating bed group) for patients treated with continuous rotational therapy compared with conventional beds. Additionally, Fink et al[69] found, for survivors, a significantly lower duration of intubation (median, 7 days control group; 4 days oscillating bed group) and length of stay in hospital (median, 44.5 days control group; 20 days oscillating bed group) for patients nursed on the oscillating beds. In a crude cost-benefit analysis, Fink et al[69] noted that average costs per day of care in the ICU were not significantly different for patients treated with continuous rotational therapy compared with conventional beds. Significant improvements in ABG values and intrapulmonary shunt have also been noted during short periods on kinetic therapy beds for patients with mild to moderate acute lung injury.[70] It has been noted, however, that continuous rotational therapy may not be well tolerated by some patients, who may become agitated during treatment.[67,69]

Limb Exercises: To my knowledge, there are no published data regarding the ability of limb exercises to maintain joint range of motion and soft-tissue length, improve strength and function, or decrease circulatory risks for patients in the ICU. Limb movements, performed passively by a physiotherapist, have been shown to result in significant increases in metabolic and hemodynamic variables for critically ill patients, with, for example, approximately 15% increase in oxygen consumption demonstrated.[40,71] It has also been demonstrated that although passive and active limb movements through range do not significantly alter ICP or CPP,[29,72] exercises involving isometric contraction do have the potential to increase ICP and CPP significantly (mean increases of 4 mm Hg and 7 mm Hg, respectively, seen for patients with normal ICP).[72]

As well as performing passive limb exercises with ICU patients who are incapable of movement, some physiotherapists routinely provide resting splints, particularly for the hands and feet, with the aim of preventing contractures. There do not appear to be any published data regarding the effectiveness of splinting for this patient group.

Summary of Evidence

Table 1 summarizes the evidence concerning physiotherapy for intubated ICU patients receiving mechanical ventilation. There are data demonstrating that multimodality physiotherapy may result in short-term improvements in the pulmonary function of ICU patients. However, it has also been shown

Table 1—*Summary of Evidence and Evidence-Based Recommendations for Physiotherapy in the ICU*

Strong evidence that:	
	Physiotherapy is the treatment of choice for patients with acute lobar atelectasis
	Prone positioning improves oxygenation for some patients with severe acute respiratory failure or ARDS
	Positioning in side lying (affected lung uppermost) improves oxygenation for some patients with unilateral lung disease
	Hemodynamic status should be monitored during physiotherapy to detect any deleterious side effects of treatment
	Sedation before physiotherapy will decrease or prevent adverse hemodynamic or metabolic responses
	Preoxygenation, sedation, and reassurance are necessary before suction to avoid suction-induced hypoxemia
	Continuous rotational therapy decreases the incidence of pulmonary complications
Moderate evidence that:	
	Multimodality physiotherapy has a short-lived beneficial effect on respiratory function
	MH may have a short-lived beneficial effect on respiratory function, but hemodynamic status, airway pressure, or V_T should be monitored to detect any deleterious side effects of treatment
	ICP and CPP should be monitored on appropriate patients during physiotherapy to detect any deleterious side effects of treatment
Very limited or no evidence that:	
	Routine physiotherapy in addition to nursing care prevents pulmonary complications commonly found in ICU patients
	Physiotherapy is effective in the treatment of pulmonary conditions commonly found in ICU patients (with the exception of acute lobar atelectasis)
	Physiotherapy facilitates weaning, decreases length of stay in the ICU or hospital, and reduces mortality or morbidity
	Positioning (with the exception of examples cited above), percussion, vibrations, suction, or mobilization are effective components of physiotherapy for ICU patients
	Limb exercises prevent loss of joint range or soft-tissue length, or improve muscle strength and function, for ICU patients

that these techniques may have deleterious effects on hemodynamic and metabolic variables, particularly if used inappropriately. There is evidence from one study that twice-daily physiotherapy, in addition to routine nursing procedures, does not reduce the incidence of nosocomial pneumonia.[53] To my knowledge, no other studies have investigated the ability of physiotherapy to prevent pulmonary complications for intubated ICU patients receiving mechanical ventilation. Physiotherapy has been shown to be an effective treatment for acute lobar atelectasis, but, to my knowledge, no studies have attempted to establish whether physiotherapy results in a speedier resolution of other pulmonary diseases, overall reduction in length of stay, or improved outcomes for ICU patients. There is little research into the effectiveness of the individual components of physiotherapy, although positioning has been shown to improve pulmonary function in the presence of some disease processes, and vibrations have not been shown to be of additional benefit. Overall, it is clear that despite the widespread use of physiotherapy for intubated ICU patients receiving mechanical ventilation, there is perilously little research to support its role.

Recommendations for Evidence-Based Practice

Based on the research available, what recommendations can be made regarding evidence-based practice for physiotherapy in the ICU (Table 1)?

Prevention of Pulmonary Complications

Is there sufficient evidence to dictate whether physiotherapists should routinely use respiratory techniques with all intubated patients receiving mechanical ventilation with the intention of preventing complications? An intubated patient in the ICU has many factors that may adversely affect airway clearance, including the presence of an artificial airway, inadequate humidification, medications, underlying pulmonary disease, and mucosal damage as a result of suction.[3,73] Thus, there are theoretical reasons why physiotherapy may be routinely required. However, the expectation that physiotherapy provided a few times a day (in addition to routine nursing care) will decrease the incidence of pulmonary complications may be unrealistic, given that many of the major causative factors responsible for the high incidence of complications are not addressed (*eg*, prolonged immobility, microaspiration, reduced host defenses, poor nutritional status, colonization of ventilator circuits, and antibiotic treatment leading to lower-airway colonization and superinfection).[74–79]

Given the overall limited evidence regarding the effectiveness of physiotherapy in the ICU, and the results of one study in which twice-daily physiotherapy did not reduce the incidence of nosocomial pneumonia,[53] it could be argued that the routine use of respiratory physiotherapy for all patients is not evidence-based and is therefore unsupportable.

Most authors who have discussed the role of physiotherapy in the ICU propose that it should be a therapy that is given for specific indications rather than routinely.[2,3,5] For example, Ciesla[5(p609)] described the aim of physiotherapy as being to ". . . minimize pulmonary secretion retention, to maximize oxygenation, and to reexpand atelectatic lung segments." Judson and Sahn[3(p222)] concluded that "Chest physiotherapy is clearly effective in intubated patients with acute lobar collapse; however, the routine use of chest physiotherapy in intubated patients has not been shown to be of value and cannot be recommended." Although it is easy to sympathize with these comments, it must be acknowledged that the current lack of evidence does not allow a firm directive to be made regarding the benefits, risks, and costs associated with the provision of routine multimodality respiratory physiotherapy to all intubated ICU patients receiving mechanical ventilation. Thus, the decision as to whether respiratory physiotherapy should be provided routinely or selectively in addition to routine nursing care can, at this time, only be made by consultation between physiotherapists and other ICU staff in individual units.

Treatment of Pulmonary Conditions and Complications

There is comparatively strong evidence to indicate that physiotherapy is the treatment of choice, at least initially, for patients with acute lobar atelectasis, without the need for additional fiberoptic bronchoscopy.

As there is no evidence concerning the ability of physiotherapy to improve the clinical course of other pulmonary conditions commonly found in ICU patients, no other recommendations can be made. It may be unrealistic to expect that physiotherapy will speed the overall recovery of patients with the pulmonary conditions common to the ICU as, in most instances, the physical techniques that constitute physiotherapy would not seem likely to reverse the underlying pathophysiologic conditions. However, clearly some pulmonary conditions, such as acute lobar atelectasis, do respond favorably to physiotherapy.

Short-term Benefits of Physiotherapy

As the available evidence shows that respiratory physiotherapy has, at best, a short-lived beneficial effect on pulmonary function, this should be considered when identifying patients who require respiratory physiotherapy and making decisions about treatment frequency. If a patient has a pulmonary condition that is likely to resolve quickly, a single session of physiotherapy or a number of treatments over a few hours may be an effective means of management. Alternatively, respiratory physiotherapy may be indicated when short-term improvements in pulmonary function are desired, while waiting for other treatments to take effect or spontaneous recovery to occur. However, if the underlying condition that is adversely affecting pulmonary function is unlikely to resolve quickly, as is the case for many intubated ICU patients receiving mechanical ventilation, any beneficial effect from physiotherapy is likely to wear off within a short time of treatment cessation. To compensate for this, physiotherapy techniques could be applied at more frequent intervals. Alternatively, rather than relying on possible short-term beneficial effects from physiotherapy intervention, it may be more effective to alter background ventilatory variables (*eg*, by increasing the V_T, level of pressure support, or amount of positive end-expiratory pressure) to achieve beneficial effects that are likely to be of longer duration.

Selection of Treatment Techniques

Limited recommendations for evidence-based practice can be made about which treatment techniques physiotherapists should use.

When considering the management of intubated patients receiving mechanical ventilation with specific pulmonary conditions and complications, positioning to improve oxygenation has been shown to be of short-term value for some patients with conditions such as ARDS and unilateral lung disease. There is also limited evidence available to assist therapists in the selection of the most effective techniques to use in the treatment of acute lobar atelectasis. Apart from these specific examples, there are insufficient data to enable physiotherapists to select treatment techniques using evidence-based practice for patients with specific pulmonary conditions.

As far as the routine management of intubated ICU patients receiving mechanical ventilation is concerned, it is likely, despite the lack of evidence concerning suction, that the majority of intubated patients will require regular suction to maintain a patent endotracheal or tracheostomy tube, and to clear the central airways of secretions, regardless of the patient's underlying disease. There is evidence to show that preoxygenation, sedation, good technique, and reassurance are mandatory to avoid suction-induced hypoxemia. However, the necessity for any other routine treatment beyond this (*eg*, positioning, MH, vibrations, percussion) cannot currently be supported or refuted on the basis of the available evidence. The effect of mobilization on pulmonary function, weaning from mechanical ventilation, improving muscle strength and function, and preventing contractures has not been investigated (to my knowledge), so it is not certain whether mobilization should be seen as a respiratory physiotherapy technique or as the start of the rehabilitation process for ICU patients.

There is research showing that the use of continuous rotational therapy decreases the incidence of pulmonary complications (such as nosocomial pneumonia) for critically ill patients. However, given the considerable expense of purchasing or renting these beds and the lack of definitive cost-benefit analyses, further studies are needed before a firm recommendation regarding their widespread use can be made.

Monitoring During Physiotherapy

A clear recommendation for evidence-based practice that can be made from a review of the literature is that hemodynamic status should always be carefully monitored to ensure there are no detrimental effects as a result of any physiotherapy intervention. Similarly, when appropriate, ICP and CPP should be monitored during physiotherapy intervention. To err on the side of caution, it is recommended that during MH, airway pressure and/or VT be monitored in addition to hemodynamic status to minimize the risk of hemodynamic instability, volutrauma, and barotrauma. Although monitoring of metabolic status is not routinely used for ICU patients, physiotherapists should carefully consider each patient's reserve before any intervention in view of the evidence that physiotherapy may increase metabolic demand significantly.

Professional Roles

An area of considerable controversy that, at times, engenders professional jealousy concerns the delineation of the various roles of ICU staff, in particular between physiotherapists and nursing staff. Although there are comparatively clear delineations for some tasks (*eg*, delivery of medications and general patient care are usually seen as the sole responsibility of nursing staff, and physiotherapists are usually responsible for providing patients with rehabilitation regimens), many tasks do not fall solely into the lap of either profession. In particular, respiratory techniques may be performed only by physiotherapists, only by nursing staff, or by a combination of physiotherapists and nursing staff, depending on factors such as the time of day, the patient's condition, and staffing levels and expertise. Similar conflicts may arise in ICUs in which both physiotherapists and respiratory therapists work. As no research has been done (to my knowledge) comparing the ability of various professional groups to perform selected tasks, it is not possible to use evidence-based practice to decide which professional group should perform which task. Given this lack of evidence, a balanced, unemotional decision based on factors specific to each individual ICU and including a consideration of economic implications is all that can be recommended at this time.

Additional Role of Physiotherapists in the ICU

It has been my observation that in many ICUs, physiotherapists tend to restrict their role to one predominantly involving respiratory assessment and treatment. An additional role that physiotherapists may have in the ICU is the assessment and management of neurologic and musculoskeletal complications. Although this additional role has been previously acknowledged,[2,80] to my knowledge, there are no published data to support it. Nevertheless, regular neurologic assessment enables the early detection of neurologic deficits, particularly the neuromyopathies often found in critically ill patients,[81,82] and, less frequently, other lesions involving the peripheral and central nervous systems, all of which may significantly affect the management and outcome of patients. Thorough musculoskeletal assessment ensures that fractures or soft-tissue injuries have not been overlooked (particularly relevant for trauma patients) and enables early detection of the onset of joint stiffness or soft-tissue tightness. Physiotherapists, with their broad knowledge of neurologic and musculoskeletal conditions, would seem particularly well placed to provide such holistic assessment and the appropriate treatment required.

Areas for Future Research

It is clear that virtually every aspect of the physiotherapy management of intubated ICU patients receiving mechanical ventilation requires validation. Further study to investigate the short-term effect of physiotherapy treatments on pulmonary and hemodynamic variables, preferably with the inclusion of control groups, will be of value. However, the role of physiotherapy in the ICU will continue to be questioned until it has been shown to have a favorable impact on broader outcomes of ICU patients. Therefore, randomized, controlled trials evaluating the effect of multimodality physiotherapy on the incidence of nosocomial pneumonia, bronchopulmonary infection, and atelectasis, similar to that performed by Ntoumenopoulos et al,[53] will be particularly useful as they would help establish the necessity for routine physiotherapy beyond regular position change, preoxygenation, and suction. Similarly, the effect of physiotherapy on the rate of recovery (*eg*, rate of resolution of abnormalities seen on chest radiograph, duration of mechanical ventilation, duration of antibiotic medication, length of ICU and hospital stay) for patients with pulmonary conditions commonly found in ICU (*eg*, pneumonia, exacerbation of chronic airflow limitation, ARDS) could be investigated in randomized, controlled studies. The effect that aggressive mobilization has on pulmonary and hemodynamic variables and broader outcomes, such as those previously mentioned, may help establish whether these techniques are therapeutic to the patient's underlying respiratory dysfunction or should be seen as the initial phase of rehabilitation. Research could also be undertaken to evaluate the necessity for performing limb movements or splinting to prevent loss of joint range and soft-tissue length for unconscious ICU patients. Similarly, the ability of exercise programs to achieve a sufficient training intensity to maintain or increase strength and endurance, improve function, and facilitate recovery could be evaluated on a sample of conscious ICU patients. Further study is also required on the ability of continuous rotational therapy to prevent pulmonary complications, reduce the duration of mechanical ventilation and intubation, and decrease the length and costs of ICU and hospital stay.

Conclusion

Although physiotherapy is seen as an integral part of the multidisciplinary team in most ICUs, there is only limited evidence concerning the effectiveness of physiotherapy in this setting. Physiotherapy may have short-term beneficial effects on pulmonary function, but it may also adversely affect the hemodynamic and metabolic status of intubated patients receiving mechanical ventilation. Physiotherapy has been shown to be effective in the treatment of acute lobar atelectasis but, in one study, did not decrease the incidence of nosocomial pneumonia. To my knowledge, there are no data concerning its effectiveness in preventing or treating other pulmonary conditions common to ICU patients, and there is only limited evidence concerning which individual physiotherapy techniques are effective. The ability of physiotherapy to facilitate weaning and to improve function and outcomes of intubated ICU patients receiving mechanical ventilation is unknown. Although recommendations can be made concerning evidence-based practice for physiotherapy in the ICU, these are limited because of the lack of data evaluating the effectiveness of physiotherapy in this setting. There is an urgent need for further research to be conducted to justify the role of physiotherapy in the ICU.

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