Role of Physiotherapy in Weaning of Patients from Mechanical Ventilation in the Intensive Care Unit

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Abstract

Admission to an Intensive Care Unit (ICU) initiates an interprofessional and interdisciplinary approach to bring the patient back to health with normal or near normal function. Physiotherapists play a vital role in restoring function to the patient. The role of physiotherapy (PT) in the ICU has moved from primarily being one of only respiratory care to one that also encompasses early rehabilitation and exercise training. Early mobilization in the ICU has gained prominence in the recent years and is becoming standard practice across many centers. However, the impact on weaning with these interventions is not known. This review highlights the dysfunctions from an ICU admission and the rationale for instituting early PT in the ICU. In addition, evidence from systematic reviews and meta-analysis is reviewed to determine the impact of PT interventions on weaning. Evidence suggests the benefit of active mobilization and inspiratory muscle training in facilitating weaning. In addition, these interventions along with neuromuscular electrical stimulation further improve physical function and reduce the risk of critical illness polyneuromyopathy. Therefore, early PT does have significant functional benefits to ICU patients. However, more studies are required to determine how various interventions and intensities of exercise training improve weaning outcomes.

Keywords: Critical illness polyneuropathy, exercise, rehabilitation, targeted mobility, ventilator-induced diaphragmatic dysfunction

INTRODUCTION

Surviving a critical illness has now become the efforts of an interdisciplinary and interprofessional team approach. This team includes critical care physicians, nurses, dieticians, physiotherapists, respiratory therapists, and psychologists, to name a few. The growing emphasis on rehabilitation for patients in the Intensive Care Unit (ICU) has created a greater role of the physiotherapist from what was traditionally thought of, being restricted to only respiratory care.^[1] However, over the last decade, there has been an expansion in the role of the PT in the ICU toward rehabilitation and not only respiratory care.^[2] The reason for this major change has been the establishment of definitive musculoskeletal dysfunctions seen in the critically ill patient. With the definitions of critical illness polyneuromyopathy (CIPNM) and ventilator-induced diaphragmatic dysfunctions (VIDD) finding its way into part of the problems that ICU patients suffer from, there has been a great need to address these dysfunctions. Recent studies have demonstrated how CIPNM and VIDD affect outcomes with

respect to weaning, extubation, and length of stay (LOS).^[3-6] Therefore, targeting these dysfunctions to better improve outcomes has now become a priority for critically ill patients.

Admission to an ICU results in significant decrease in peripheral muscle strength and poor quality of life among ICU survivors.^[7,8] Within 7 days, a reduction in peripheral muscle strength by 11.3% has been observed with greater reductions in deltoid (13% reduction) and least reduction in ankle, plantar, and dorsiflexor muscle strength (10%).^[7] Considering the impact of ICU stay on the peripheral muscles, rehabilitation strategies have now focused greatly on early mobilization and exercises targeting peripheral muscles and respiratory muscles. Despite evidence showing benefits with rehabilitation and exercises, it continues to remain underutilized in the ICU, especially in India.^[9,10]

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This review will, therefore, focus on the various mechanisms resulting in various dysfunctions in ICU patients and will describe the various PT interventions used to promote weaning through a systematic review of systematic reviews.

PHYSIOLOGICAL DYSFUNCTIONS CONTRIBUTING TO WEANING DIFFICULTY IN THE INTENSIVE CARE UNIT PATIENT

Immobilization has severe deleterious effects on the human body.^[11] The changes that occur in the various organ systems are summarized in Table 1. Immobilization along with severe infection and a critical illness further compounds these physiological dysfunctions. Poor cardiovascular endurance seen in these patients greatly affects oxygen uptake of the exercising muscles and therefore results in early onset of fatigue.^[12] Similar changes also occur to the diaphragm which inevitably results in VIDD. Other postulated theories attributing the neuromuscular changes have been inflammatory axonal injury, muscle breakdown, reduced nerve excitability from sodium channelopathy, and bioenergetic failure.^[13] It is these factors that probably have the greatest impact by preventing extubation and prolonging the duration of ventilation and stay in ICU.^[14]

Inactivity and bed rest are the most common things that are seen in patients which can promote weakness besides the primary disease process. Muscles are less frequently activated and for shorter periods as compared to normal living, leading to increased muscle catabolism and depressed contractile function termed as mechanical unloading.^[15] Other contributing factors, apart from the systemic illness, to muscle weakness include nutritional status and myotoxic and neurotoxic side effects of pharmacological agents.^[16]

RATIONALE FOR PHYSIOTHERAPY IN THE INTENSIVE CARE UNIT

Exercise training, through either aerobic or resistance training, has been shown to have great physiological impact on the various systems of the body. The effects of both acute and chronic responses to exercise have been used as the foundation for prescription of exercise in the prevention and control of various noncommunicable diseases.^[17] Details of the effects of exercise on the various systems of the body are beyond the scope of this paper. Briefly, acute and chronic exposure to exercise stimulus results in various adaptations in the various physiological systems that, in turn, result in protective effects with respect to cardiovascular, pulmonary, and musculoskeletal health [Table 2].^[17] In addition, effects on the various inflammatory pathways and endothelial function cannot be disregarded.^[18-20] With these wide ranges of benefits with exercise training, the role of exercise training in the ICU cannot be undermined.

Earlier, rehabilitation (described as the third phase of medicine) was earlier implemented after a period of critical illness where strategies were deferred until the patient was medically and

Table 1: Adverse effects of immobilization

Organ system	Effect
Musculoskeletal	
Muscles	Reduced strength, endurance, flexibility, and bulk
Joints	Reduced flexibility, joint contractures
Bone	Osteopenia and osteoporosis
Cardiovascular	Reduced stroke volume, cardiac output, and exercise capacity Reduced orthostatic tolerance and venous return Deep vein thrombosis
Respiratory	Atelectasis Pneumonia
Integumentary	Pressure ulcers
Psychological	Reduced self-image and stress tolerance Anxiety Depression

Table 2: Physiological effects of mobilization

Organ system	Effects
Pulmonary system	Improves ventilation-perfusion Improves rate and depth of respiration Facilitates mucociliary clearance Improves strength and quality of cough
Cardiovascular system	Improves stroke volume and venous return, myocardial contractility, coronary perfusion, and heart rate Reduces peripheral vascular resistance and improves peripheral blood flow
Muscular system	Improves blood flow to exercising muscle Facilitates better oxygen extraction
Neurological system	Improves alertness and arousal Increases cerebral electrical activity
Hematological system	Reduces circulatory stasis
Lymphatic system	Improves pulmonary lymphatic flow and drainage
Endocrine system	Increase release, distribution, and degradation of catecholamines
Renal system	Improves glomerular filtration and urine output
Gastrointestinal system	Improves gut mobility
Integumentary system	Improves cutaneous circulation

surgically stable. Studies done with early rehabilitation starting at a point where the patient is physiologically stable and continuing through the critical care stay had a positive impact in improved physical functioning and thereby contributed to early discharge from critical care. Considering the various physiological dysfunctions in the ICU and the way they have potential to respond to exercises, it is no surprise that there is a strong rationale for early mobilization and exercise training for critically ill patients. Early initiation of rehabilitation has been found to reduce health-care costs by reducing dependence, nursing care, LOS, and preventing disability.^[21] Therefore, interventions should be initiated as soon as possible after the critically ill patient is admitted in the ICU; the interventions should include exercises to maintain the range of motion and muscle strength, proper positioning to prevent pressure ulcers,

compression neuropathies, and pulmonary care.^[22] A simple yet effective algorithm put forward a few years ago by Hanekom *et al.*^[23] provided a clear overview of how to sequentially assess, plan, and progress mobilization in the ICU patient.

ROLE OF VARIOUS PHYSIOTHERAPY INTERVENTIONS TO FACILITATE WEANING

Having various options to facilitate early mobilization and exercise requires an evidence-based approach to choosing appropriate interventions. Till date, most of the studies on critical care rehabilitation have been from high-income countries and have made use of various exercises and technologies to promote early mobilization and exercise training.^[24] To better understand what interventions will provide better results with respect to weaning and its related outcomes, we performed a systematic search of various reviews in PubMed. All human trials studying the effects of various physiotherapy interventions in adult ICU patients and reporting outcomes on weaning and related measures (i.e., duration on mechanical ventilation, LOS in ICU, cost, mortality, incidence of ventilator-associated pneumonia, and success of extubation) where provided were extracted from the reviews. For interventions not covered in the systematic or narrative reviews, results from well-controlled randomized controlled trials have been reported. All articles were screened independently for inclusion by two authors (AB, LTV), and any conflict was arbitrated by the third author (ASB) using the web application Rayyan.^[25] The search in PubMed retrieved 63 articles, of which 15 were screened for inclusion with full texts. From these 15, only eight were systematic reviews while all the rest were narrative reviews. The narrative reviews have also been summarized in Table 3.

Inspiratory muscle training

Inspiratory muscle training (IMT) makes the use of devices for improving the strength of the diaphragm and other respiratory muscles. Devices make the use of varying narrow apertures, through which the patient has to inspire, thereby increasing the demand on the respiratory muscles. Threshold devices are the most commonly used in IMT, and varying levels of maximal inspiratory pressure (P_{imax}) targets can be set with this device. IMT has been used successfully in various cardiopulmonary conditions such as chronic obstructive pulmonary disease and in heart failure.^[34,35] In the ICU setting, for patients on mechanical ventilation, an alternate option is by altering the pressure trigger sensitivity by 20% of the first P_{imax}.^[36,37] The data were conflicting from both these studies with the study by Elbouhy *et al.* demonstrating a significant improvement in weaning success with IMT using the ventilator.^[37] The findings were similar to anecdotal observations where the use of the ventilator to train difficult to wean patients has facilitated weaning and extubation from the author's institute (Babu, Unnikrishnan, Shanbagh; Manipal, India; 2014). Altering sensitivity of the trigger to achieve at least 70% of the spontaneous tidal volume 5 times per session, 4 times a day,

had been used to improve endurance and strength of the inspiratory muscles in difficult to wean individuals resulting in favorable outcomes. Progression of training was by increasing the number of repetitions per session and later even reducing the pressure support. When using other methods of IMT, such as threshold devices, studies have shown favorable benefits. A previous systematic review by Moodie *et al.* did not find any change in weaning outcomes and LOS in the ICU.^[27] However, a more recent review by Elkins and Dentice found that the results are in favor of IMT when it comes to improving rapid shallow breathing index, P_{imax}, and weaning success.^[30] An updated review on IMT using threshold devices by Volpe *et al.* in 2016 found that they were better at facilitating weaning by improving inspiratory muscle strength.^[33] Thus, there appears to be a greater thrust toward the benefits of IMT to facilitate liberation from mechanical ventilation.

Active mobilization

Active mobilization is a general term used in rehabilitation and PT. However, with respect to critical care rehabilitation, along with active mobilization, early initiation of this program is vital. A previous study has defined early mobilization as “the intensification and early application (within the first 2–5 days of critical illness) of the physical therapy that is administered to critically ill patients.”^[38] The evidence reviewed describes the early initiation of various physiotherapy interventions such as active exercises and mobilization out of bed. The evidence from systematic reviews and meta-analysis suggests that active mobilization improves the weaning rate (relative risk [RR] 3.56 [0.44–28.61] *P* = 0.230) and reduces the duration of mechanical ventilation (RR is –6.0 [–7.1–5.0]). In addition, the review also found improvements in physical function with early initiation of physiotherapy. Thus, the physiotherapist plays a vital role in the ICU team to help improve the function of critically ill patients. This has been observed in a study by Garzan-Serrano in 2011, where it was seen that physiotherapists were able to mobilize patients to higher levels when compared to nurses. Furthermore, routine involvement of physiotherapists would help patients achieve better levels of mobility.^[39] Although there is evidence to prove that active mobilization is helpful in patients in ICU. The point prevalence of mobilized patients, according to a study conducted in Germany, among people on mechanical ventilation and those with an endotracheal tube was 24% and 8%, respectively.^[40] Therefore, even though the utilization of active mobilization is common, its application and the reduced prevalence of patients being mobilized suggest that there is a greater need to promote the use of early mobilization in the ICU.

Neuromuscular electrical stimulation

Neuromuscular electrical stimulation (NMES) makes the use of low-intensity electrical currents which stimulate a contraction in the skeletal muscles. This involves placing electrodes over the belly of the muscle and adjusting the intensity to obtain a visible contraction of the muscle. This prevents unwanted loss of muscle strength and bulk. The recent evidence from Wageck *et al.* shows that there were

Table 3: Summary of articles assessing the effects of physiotherapy interventions on weaning and related outcomes

Author (year)	Sample description	Sample size/ methodology rating	Intervention	Description	Results
Meta-analysis					
Delaney <i>et al.</i> (2006) ^[26]	Patients requiring mechanical ventilation in ICU	15 studies/1169 participants/ low-quality evidence	Kinetic therapy	Kinetic treatment bed; 51°-144°; 2-30/h for 10-24 h/day	Incidence of nosocomial pneumonia decreased (OR 0.38, 95% CI 0.28-0.53, $P<0.001$) Duration of MV - no difference (MD - 0.14 days 95% CI - 0.29-0.02, $P=0.08$) LOS ICU - no difference (MD 0.064 days, 95%CI - 0.21-0.086, $P=0.40$) LOS hospital - no difference (MD 0.05 days, 95% CI - 0.18-0.27, $P=0.69$)
Moodie <i>et al.</i> (2011) ^[27]	Intubated or tracheostomized patients receiving MV	3 studies/150 participants/2 high-quality studies, 1 low-quality study	IMT	Threshold IMT in 2 studies and ventilator trigger settings in 1 study; 20% of MIP to maximum pressure tolerated; 5-30 min; 5-7 days/week	Weaning success (RR = 1.20, 95% CI 0.76-1.91), weaning duration (MD=21 h, 95% CI - 10-53), and survival (RR=1.22, 95% CI 0.54-2.77); NS but favored IMT Reintubation (RR=0.60, 95% CI 0.17-2.12); and need for tracheostomy NS (RR=1.41, 95% CI 0.27-7.38) MIP improved in IMT by MD of 8 cmH ₂ O; ($P<0.001$)
Hermans <i>et al.</i> (2014) ^[28]	Cochrane review	5 RCTs/ Moderate to high quality	Early PT and NMES	Physiotherapy, electrical muscle stimulation, and rehabilitation programs along with various other interventions including nutrition, supplemental therapy, antioxidant therapy	Early PT versus control: Duration of MV: Early PT significant reduction in duration of MV (median [IQR] 3.4 days [2.3-7.3] vs. 6.1 days [4.0 to 9.6]) (1 study) duration of ICU stay: No effect on duration of ICU stay (intervention median 5.9 days [IQR 4.5-13.2] control median 7.9 days [IQR 6.1-12.9 days] $P=0.08$). (1 study) serious adverse events: 1 participant - desaturation <80% occurred, no serious adverse events observed Electrical muscle stimulation versus control: No change in duration of MV; no effect on LOS in ICU or mortality
Wageck <i>et al.</i> (2014) ^[29]	Critical patients in ICU (medical, surgical, neurological, and trauma)	8 studies/Low to moderate quality	NMES	Quadriceps, hamstrings, biceps brachii; 30-60 min/day; 1-2 sessions/day; 1-4 weeks or until extubation	Better weaning period (1 vs. 3 days) and shorter ICU stay (4 vs. 6 days) Improved muscle strength and function, reduced risk of CIPNM (OR: 0.22, 95% CI=0.05-0.92; $P=0.04$) Higher venous flow rate
Elkins and Dentice (2015) ^[30]	Critical patients in ICU (medical, surgical, neurological, and trauma)	6 studies/ Moderate to high quality	IMT using ventilator or threshold training device	5-30 min or 3-6 sets of 6-10 breaths; 2 sessions/day 3-7 days/week	Significantly better RSBI, 15 breaths/min/L (95% CI 8-23); MIP 7 cmH ₂ O (95% CI 5-9); weaning success (RR 1.34 [95% CI 1.02-1.76])
Burke <i>et al.</i> (2016) ^[31]	Patients admitted in critical care and explained by ICF model	11 RCTs/ moderate quality and 1 case control study/ good quality	NMES	Initiated 3-30 days of acute episode with a focus on quadriceps, peroneus, vastus glutei, tibialis anterior, and triceps surae. Biceps brachii (only in one study) Biphasic symmetrical or asymmetrical waveforms at 35-100 Hz, with pulse widths between 200 μ s and 400 μ s. Intensities between 15 and 150 mA or until visible contraction or maximum tolerated level for 30 min to 55-60 of continuous administration or two 30 min sessions daily for 7-30 days or till extubated or discharged or till muscle power is 4/5	Conflicting results on mortality, 1 study ($n=80$) 10% mortality in intervention versus 15% (control). Another study ($n=142$) 40% (intervention) versus 31% (control). Beneficial effects on MV in COPD patients (1 study). Another study of mixed pathology - shorter weaning period of 1 day (intervention) versus 3 days (control). Better ROM with improved angle of dorsiflexion in the ankle joint with NMES. Muscle strength improved by a mean difference of 0.93 (95% CI 0.51-1.35); $P<0.0001$

Contd...

Table 3: Contd...

Author (year)	Sample description	Sample size/ methodology rating	Intervention	Description	Results
Systematic reviews					
Li (2013) ^[32]	Patients on MV >24 h Medical and surgical ICU and HDU	17 studies sample size ranged from 17 to 510 Moderate quality Case series - low	Early mobilization ranging from passive movements to ambulation and cycle ergometer	Passive movements, bed mobility exercise, chair sitting, standing, walking, strengthening 20-120 min 3-6 sessions/weeks	6MWD improved, FIM scores improved, conflicting evidence about MIP, weaning rate, duration of mechanical ventilation, LOS ICU and LOS hospital. Safety: No study reported requirement of lifesaving measures or modification in patient's medical care
Volpe <i>et al.</i> (2016) ^[33]	Respiratory failure	5 studies (n=267)/high quality	IMT using ventilator or threshold training device	Similar findings as Elkins <i>et al.</i> ^[30]	Similar findings as Elkins <i>et al.</i> ^[30]

6MWD: 6 min walk distance, CI: Confidence interval, CIPNM: Critical illness polyneuropathy, FIM: Functional independence measure, IMT: Inspiratory muscle training, LOS: Length of stay, MD: Mean difference, MIP: Maximal inspiratory pressure, MV: Mechanical ventilation, NMES: Neuromuscular electrical stimulation, NS: Not significant, OR: Odds ratio, PT: Physiotherapy, RCTs: Randomized controlled trials, ROM: Range of motion, RR: Relative risk, RSBI: Rapid shallow breathing index, ICU: Intensive Care Unit, ICF: International Classification of Functioning, COPD: Chronic obstructive pulmonary disease, IQR: Interquartile range, HDU: High dependency unit

differences in outcomes between groups receiving NMES and those not receiving it [Table 3].^[29] However, even though the outcomes on weaning were not statistically significant, they did observe significant risk reductions in the development of critical illness polyneuropathy (odds ratio [OR]: 0.22, 95% confidence interval [CI] = 0.05–0.92; $P = 0.04$). A Cochrane review further supported these findings in that there were no significant changes to weaning and its related outcomes.^[28] However, Burke *et al.* found that NMES did have an impact on physical function, which still suggests potential for NMES to have a functional impact.^[31] This area of study, however, lacks good quality evidence and requires more intensive research to explore how the use of NMES will facilitate early mobilization and also weaning.

Respiratory care

Traditionally, physiotherapists have been involved in the respiratory care of patients on mechanical ventilation in ICU. The respiratory care involves optimization of ventilation, airway clearance, prevention of pulmonary complications, and hastening weaning from mechanical ventilation.^[41] Although respiratory care is empirically provided to all the patients on mechanical ventilation, there is limited evidence to support this. Since no systematic reviews on respiratory care and weaning were retrieved, a scoping search of randomized controlled trials was performed. This yielded five randomized controlled trials,^[42–46] of which four studies showed that respiratory care by physiotherapists has beneficial effects on weaning outcomes, length of ICU, and hospital stay. However, the findings from the study conducted by Templeton and Palazzo do not support these, thus highlighting a continuing conundrum.^[46] Well-designed prospective randomized controlled trials in the area are warranted at this moment.

Positioning and kinetic therapy

Positioning is an important part of physiotherapy interventions and is been widely used in the ICU. Lateral positioning has been used as a method to overcome the adverse effects of immobilization.^[47] One review did identify improvements in pulmonary function with no impact on weaning reported. Another form of positioning has been the use of continuous rotating frames or kinetic therapy. Kinetic therapy utilizes continuous rotation with a specific rotational bed to help reduce the pulmonary complications and other complications of immobilization. The review on this did not show a demonstrable impact on weaning though it did show an improvement in reduction in pneumonia (OR 0.38, 95% CI 0.28–0.53, $P < 0.001$).^[26] However, there was no effect on LOS in the ICU or in hospital.

CLINICAL IMPLICATIONS

The findings from the review of reviews suggest that early physiotherapy (active mobilization, IMT, and NMES) in the ICU has numerous benefits. Although positioning is used routinely and has its effects on pulmonary system, there is no evidence of its beneficial effect on weaning. With respect to facilitating weaning, active and early mobilization and IMT need to be instituted early in the ICU. Institution of these techniques will facilitate weaning from mechanical ventilation. However, the success of these interventions will also depend on the underlying condition and the prognosis of the patient. Therefore, the authors believe that a concept of “Targeted mobility therapy” or TMT would be a novel idea to adopt [Figure 1]. This concept will provide holistic care and will be a part of all ICU therapies and management strategies for critically ill patients. This concept will work as a scientifically

Figure 1: Targeted mobility therapy

driven, dynamic bundle of rehabilitation interventions and will include providing respiratory care and hygiene as required along with various evidence-based interventions (namely, active mobilization and strengthening including IMT) to ensure best outcomes for critically ill individuals admitted to the ICU. This concept, however, is purely speculative at this juncture and will need to be tested prospectively in the future.

FUTURE SCOPE

This review has highlighted the various gaps in critical care research with respect to how various physiotherapy interventions have an impact on weaning outcomes. Although it is now becoming standard practice to initiate early physiotherapy in the ICU, there is still a need for more rigorous studies on the effects of these interventions on weaning and its related outcomes. The use of ventilator-targeted IMT, though ineffective in the individual studies, does demonstrate to be a feasible method of training. More rigorous trials in this area hold potential to initiate IMT in ventilated patients who are conscious and able to respond to commands.

CONCLUSIONS

Early initiation of physiotherapy through early mobilization and IMT facilitates faster weaning of patients from ventilator. However, more high-quality evidence is required to be able to provide strong clinical recommendations for the use of these interventions as a guideline-based recommendation. Nevertheless, the clinical benefits observed from various studies with early physiotherapy suggest the need to implement early physiotherapy to all critically ill patients admitted to the ICU.

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