Effect of Lung Volume Recruitment Technique on Cough Efficacy in Post-Extubated Patients with Ineffective Cough

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ABSTRACT

Background: Controlled mechanical ventilation results in an ineffective cough that causes weaning and extubation failure and may be a threatening life cause. Also, the role of cough augmentation is unclear for critically ill patients requiring intubation and for post-extubation respiratory failure. **Purpose:** This study investigated the effect of the lung volume recruitment technique "LVR" in combination with traditional chest physiotherapy "TCP" on cough effectiveness assessed by measuring Cough peak flow "CPF" and Peak expiratory flow "PEF", Oxygen saturation, and the extubation success rate compared to TCP alone.

Subjects and methods: Fifty post-extubated patients, after mechanical ventilation for ≥ 48 hours, with suboptimal productive cough (CPF< 270L/min), ages 40 to 60 years old, were recruited and were randomly assigned into two groups. **Study Group (A):** Twenty-five patients who received TCP in addition to the LVR; and **Control Group (B):** Twenty-five patients who received the TCP only that involved percussion, vibration, and positioning methods. The treatment session for both groups was for 30 to 45 minutes, twice a day for four days or till the need for reintubation. Data obtained from both groups regarding CPF, PEF, and Oxygen saturation, were statistically analyzed and compared. **Results**: Group (A) showed significant improvements in CPF rate, PEF rate, and O2 saturation compared with baseline and group (B). Also, Group (A) showed a significant enhancement in extubation success rate compared to group (B). The improvement percentage of CPF rate, PEF rate, and O2 saturation was about 51.73%, 57.30%, and 4.11% respectively for group (A), and was about 14.74%, 15.74%, and 1.72% respectively for group (B) (with P value=0.0001; P<0.05). Also, the overall percentage of successful extubation was 92 % in group (A), and 72% in group (B). The net results gave the privilege of the intervention of the study group. **Conclusion:** It could be concluded that combining the LVR technique with TCP in post extubated patients with a suboptimal cough could be more beneficial for managing the cough ineffectiveness, by improving the CPF and PEF as measures of cough effectiveness, increasing the oxygen saturation, and for enhancing the success of extubation than TCP alone.

Keywords: Cough efficacy; Cough peak flow; Lung volume recruitment; Post extubated patients; Respiratory therapy.

INTRODUCTION

An effective cough is so vital in protecting against respiratory tract infections, so the importance of an intact cough mechanism is reflected in the occurrence of pulmonary problems, which are the most common cause of hospital admission in people with respiratory muscle weakness who are unable to cough effectively [1], [2]. Ineffective cough results in a tendency to retain bronchial secretions and an increased risk of pulmonary complications, such as frequent or recurrent pneumonia, atelectasis, and infectious respiratory problems [3]. Expiratory (cough) flow testing is useful as a monitoring or diagnostic tool in clinical practice and research [4]. Both peak expiratory flows (PEF) and cough peak flows (CPF) have been described as useful clinical measures of respiratory muscle function and cough effectiveness [5], [6]. Cough peak flow (CPF) gives an important measure of the cough strength which determines the effectiveness of the cough [7]. It is the maximum expiratory flow recorded immediately following the opening of the glottis during normal cough [8]–[10]. Cough effectiveness is suboptimal when cough peak flow (CPF) is less than 270 L/min [11], [12]. Controlled Mechanical Ventilation "CMV" has deleterious effects such as changes in mucociliary clearance and inhibition of coughing mechanism which, in turn, favor areas of hypoventilation and atelectasis, thus increasing the risk of ventilator-associated pneumonia and other respiratory infections[13], [14]. Respiratory compromise due to recurrent atelectasis, inability to clear secretions, and respiratory infections also increase morbidity and mortality [14]. Prolonged CMV results in respiratory muscle dysfunction shown in diaphragmatic atrophy and contractile dysfunction (i.e., Ventilator-induced diaphragmatic dysfunction "VIDD") affecting the ability of the person to cough effectively. Indeed, the onset of VIDD in both animals and humans is rapid as significant diaphragmatic atrophy and contractile dysfunction occur within the first 24 – 48 h of MV [15]. Although suctioning of secretions from the trachea to remove tracheobronchial and upper airway secretions is the standard of care, this method is ineffective for clearing peripheral airways and basal retained secretions [16], [17].

Cough augmentation techniques such as the lung volume recruitment technique have been supposed to be used for reinforcing cough effectiveness to prevent and manage respiratory complications associated with chronic conditions like secretion management, particularly for critically ill patients with controlled mechanical ventilation. The clinical practice guides referred to patients with respiratory muscle weakness after prolonged MV recommend the usage of cough augmentation in patients with Cough peak flow (CPF) ≤ 4.5 L/s (270 L/min) and using such techniques continuously in patients with CPF ≤ 2.7 L/s (160 L/min) [18]. But, it was found that the role of cough augmentation is unclear for critically ill patients with acute respiratory failure requiring intubation and for management of post-extubation respiratory failure, because what has been proven that secretion clearance was the most common indication for all techniques, whereas weaning from ventilation and preventing reintubation were infrequent indications [17]. So, they were rarely used to prevent intubation or re-intubation in critically ill patients, despite the well-known negative consequences of re-intubation and its association with impaired secretion clearance [19]. As a result, this study sheds light on promoting the use of those modalities in critically ill patients in enhancing the cough effectiveness and avoiding the deleterious complications and it adds to the existing pieces of literature with the respect to this topic.

MATERIALS AND METHODS:

Subjects: Fifty post-extubated adult patients of both sexes, after MV for ≥ 48 hours, with reduced productive cough effectiveness, were recruited in this study from Care Unites in departments at Kasr Al-Ainy Hospital, Cairo University. The participants' demographic data are shown in Table 1. All patients were carefully examined for inclusion and exclusion criteria and referred by the ICU resident and consultant for PT. Subjects were chosen based

on the identified inclusion criteria that 40 to 60 years old patients had undergone mechanical ventilation for ≥ 48 hours and less than 21 days in a controlled mode due to moderate or severe pneumonia and had been weaned after a successful spontaneous breathing trial with suboptimal CPF < 270 L/min, they were able to assume a sitting position and they were aware, cooperative, and able to understand and follow instructions during testing and treatment procedures and comply with treatment. Patients were excluded, based on the Canadian survey[17], if they had undergone tracheotomy before weaning[20] or had experienced less than 48 hours of MV, or who had significant or active hemoptysis, current undrained pleural effusion, recently untreated or previous pneumothorax or barotrauma, bullous emphysema, lung trauma, recent lobectomy, uncontrolled severe COPD or bronchospasm, and poorly controlled asthma [21], or if they had comorbidities interfering and compromising the success of either weaning or extubation, like unstable hemodynamics, cardiac instability, cardiac arrhythmia pericardial effusion, congestive heart failure, or acute coronary syndrome [20]. Patients who had originally inadequate respiratory muscle training performance such as those having NMD, i.e., myopathy or neuropathy. Patients with visual or auditory problems, impaired consciousness, or a neurological deficit resulted in bulbar affection. Patients who had indicated for MV but contraindicated for physical therapy like having a pulmonary embolism.

Design: This study which is a randomized controlled was conducted between December 2020 to October 2021. The study has been approved by the ethical committee of the faculty of physical therapy, Cairo University, Egypt (No. P.T.REC/012/003098), and also it was approved by ClinicalTrials.gov Registration (No. NCT05128552). After the study's purpose was stated and informed consent was given, the selected patients were randomly assigned into two equal groups based on the envelope method. After patients agreed to participate in the study, cards with either “group (A)” or “group (B)” recorded on them were closed in envelopes; then a blinded physical therapist was asked to select one envelope. According to the selected card, patients were assigned to their corresponding group. Recording data sheet: all data and information of each patient in this study including name, age, gender, date of ICU administration, MV connection, and weaning was recorded in a recording data sheet. The participants were informed to report any harmful effects throughout the treatment period. The study group (A) included 25 patients who were treated with traditional chest physiotherapy in addition to the LVR technique, while the control group (B) also included 25 patients who received the traditional chest physiotherapy only that involved percussion, vibration, and positioning methods.

Procedures of the study

- Before starting the study, the following tasks were performed before assessment, a brief medical history of each patient was taken to ensure that they were not having chronic respiratory problems, previous musculoskeletal disorders (such as kyphosis), neurological diseases that affect the respiratory muscles i.e., NMD, or significant or active hemoptysis that might restrict and influence the results of the study. Full physical and detailed clinical examination was done on all patients including assessment of the vital signs i.e.: Heart rate, respiratory rate, blood pressure, oxygen saturation, and temperature were examined before, though, and after each session to exclude any signs or symptoms that may interfere with the continuity of the study. Safety considerations through monitoring heart rate and blood pressure before and during applying the LVR to stop the procedure if (HR > 140 or < 60 b/m, or BP > 140/90 or < 90/60 mmHg), and also through assessment and reporting of adverse effects during the study. Patients should not eat a heavy meal for two hours before the session.

A. **The expiratory flows (CPF & PEF)** have been assessed for all patients of both groups before and after treatment by using the Mini-Wright Peak Flowmeter [22]. Each subject assumed a 45º body inclination or was in a sitting position, they were instructed to inhale as deeply as possible and then to perform a maximum expiratory flow with opened glottis through the oronasal mask that is connected to the Mini-Wright peak flowmeter. The mask was carefully secured onto the subject's face to minimize air leaks. They performed this maneuver (test) at least 3 times. The readings were noted with help of the displaced marker on the gradient peak flowmeter. Results were expressed in liters/minute and the maximum of the three PEF rate readings was recorded. Patients were given a rest period of ten minutes between the measurement of CPF and PEF rates[7]. From the same position, they were instructed to inhale as deeply as possible and then to perform a maximum coughing effort with closed glottis through the oronasal mask. They performed this maneuver (test) at least 3 times. Results were expressed in liters/minute and the maximum of the three CPF rate readings was recorded. This measuring procedure was done and reported initially at selecting our sample subjects for both study and group, then was done after each session and later on the 4th day.

B. **Oxygen Saturation** also was measured for each subject from a sitting position using a pulse oximeter attached to a bedside monitor. It was done and reported at the initial assessment before the intervention, after each session, and finally on the 4th day.

C. **Extubation Success Rate,** the proportion of subjects who did not die and not be re-intubated 48 h after the scheduled extubation and starting the interventions was considered as the extubation success rate. Re-intubation within 48 hours of extubation is considered extubation failure.

Therapeutic procedures:

The average duration of the treatment session ranged from 30 to 45 minutes. For study group "A", each treatment with the LVR technique should be between two to four breaths. This was repeated 3 to 5 times, and a short rest of approximately half to one minute was allowed in between each treatment, to allow recovery. Adding to traditional chest physiotherapy, this was classed as one treatment session that was done twice a day for four days or till the need for reintubation for both groups according to the defined techniques for each group.

1) **The traditional chest physical therapy:** This approach was done with both the study group (A) and the controlled group (B) and was conducted as positioning for airway clearance and airway hygiene techniques "Percussion and Vibration" (30 minutes) in which patients were put in positions during the application of airway hygiene techniques to help in draining secretions from each lobe.

2) The lung volume recruitment technique: This approach was done only with the study group (A) which included 25 patients who received both the traditional chest physiotherapy and the LVR technique twice a day for four days from the extubation. This phase of treatment is classified into various phases:

A- Preparatory phase:

− **Preparation of the device:** With collaboration with the infection control team, the LVR bag, and the one-way valve "pocket" mask continuously was sterilized every session with alcohol and warm water for the same patient, but a different LVR bag with the one-way valve mask was used for each patient. The mask was carefully secured onto the subject's face to minimize air leaks. Bacterial filter to minimize cross-infection. The Ambu bag was checked routinely before each session for any problem either the pressure valve or other components.

− **Preparation of the patient:** The patient was set in a comfortable position and put the nose clip on the patient's nose if needed and prepared tissues beside him and the last meal had been eaten at least 2 hours ago before the session.

Preparation of the environment: The mechanical ventilation was switched on and adjusted on standby, there was a source of oxygen and oxygen mask, inhalers like

bronchodilators, and the inhalator device was prepared too. Also, there was a team responsible to deal with urgent events such as sudden arrests with all the facilities available in the crash card in the ICU.

- **B- Application phase:**

The lung volume recruitment technique was delivered to each subject by following the next steps:

1. The necessary equipment was assembled and checked that it was not damaged and was correctly configured and calibrated for use. 2. It was best performed with the patient positioned at 45º body inclination or in a sitting position. 3. The patient and carers were provided with information on the treatment and the procedure and their understanding of the technique was checked. 4. A signal was established with the patients that they used to indicate when maximum insufflation capacity has been reached like hand waving. 5. The patient was asked to take a deep breath and then hold it if they were able to do this. If the patient did not have respiratory strength, the practitioner started the first squeeze of the bag, coordinating this with inspiration from the patient. 6. The nose and mouth were covered tightly with the oronasal mask and the therapist gently squeezed the bag coordinating with the patient's inspiration. 7. The bag was squeezed 2 to 4 times consecutively at a low inspiratory flow, with an inspiratory pause achieving maximal lung insufflation capacity, and then it was released quickly to provide a high expiratory flow. If the patient was able to do this, he was asked to hold the maximum insufflation for 3–5 seconds. 8. Once the patient's lungs were full or the patient gave the signal that maximum insufflation capacity had been reached or when he felt a stretch in the chest or slight discomfort, the interface was removed, then he was asked to cough forcefully. 9. After a short rest of approximately half to one minute in between each treatment, the whole process (steps 5–8) was repeated three to five times. The blood pressure and heart rate might fluctuate during treatment. The patient might need longer rests as cycles were repeated or if there were fluctuations. 10. The outcomes of treatment were recorded in records by reassessing the CPF&PEF.

Statistical analysis:

- Data were screened, for normality assumption test and homogeneity of variance. Normality test of data using Shapiro-Wilk test was used, that reflect the data was normally distributed ($P>0.05$) after removal outliers that detected by box and whiskers plots. Additionally, Levene's test for testing the homogeneity of variance revealed that there was no significant difference ($P>0.05$). So, the data were normally distributed and parametric analysis was done. The statistical analysis was conducted by using the statistical SPSS Package program version 25 for Windows (SPSS, Inc., Chicago, IL). Quantitative data included the mean and standard deviation for age, period of intubation, CPF, PEF, Oxygen saturation, and rate of successful extubation variables. While qualitative data included the number and percentage of gender variable. To compare between both groups by independent t-test for age variable and chi-square test for gender and extubation's success variables. Multivariate analysis of variance (MANOVA) was used to compare the tested major variables of interest in different tested groups and measuring periods. A mixed design 2 x 2 MANOVA-test was used, the first independent variable (between subject factors) was the tested group with 2 levels (group (A) vs. group (B)). The second independent variable (within-subject factor) was measuring periods with 2 levels (before and after treatment). Three dependent variables were the CPF, PEF, and oxygen saturation. Bonferroni correction test was used to compare between pairwise within and between groups of the tested variables which F was significant from the MANOVA test. All statistical analyses were significant at the level of probability ($P <0.05$).

Results;

Subject characteristics: In the current study, a total of 50 patients participated and they were randomly distributed into 2 groups (25patients/group). No significant differences existed in the demographic data for age (P=0.375; P>0.05), gender (P=1.000; P>0.05) and period of intubation (P=0.910; P>0.05) between group (A) and group (B) (Table 1). The statistical analysis using 2x2 mixed design MANOVA (Table 2) indicated that there were significant differences (F-value=35.715; P=0.0001; P<0.05) of the tested groups (the first independent variable) on all tested dependent variables which including CPF, PEF, and oxygen saturation. Also, there were significant differences (F-value=152.239; P=0.0001; P<0.05) in the measuring periods (the second independent variable) on the tested dependent variables. Moreover, the interaction between the two independent variables (groups x time) was significant (F-value=34.465; P=0.0001; P<0.05), which indicated that the effect of the tested group (first independent variable) on the dependent variables was influenced by the measuring periods (second independent variable).

Table 1: Comparison of age, gender and period of intubation between both groups

Items	Groups		*P*-value
	Group (A) (n=25)	Group (B) (n=25)	
Age (year)	54.88 ±4.72	53.64 ±5.05	0.375
Gender (males: females)	15 (60%) : 10 (40%)	15 (60%) : 10 (40%)	1.000
Period of intubation (Days)	7.20 ±1.22	7.24 ±1.26	0.910

Quantitative data (age & period of intubation) are expressed as mean ±standard deviation and compared by independent t-test. Qualitative data (gender) are expressed as numbers (percentage) and compared by the chi-square test. P-value: probability value

Table 2: Main effects of independent variables by 2 x 2 MANOVA test for dependent measuring variables.

Source of variation	Wilk's Lambada value	F-value	P-value
Groups effect	0.467	35.715	0.0001*
Time effect	0.171	152.239	0.0001*
Groups x time interaction effect	0.476	34.465	0.0001*

Pairwise comparison tests (Post hoc test) for CPF, PEF, and oxygen saturation within each group (Table 3) showed that there was a significantly increased in CPF (P=0.0001; P<0.05), PEF (P=0.0001; P<0.05), and oxygen saturation (P=0.0001; P<0.05) after-treatment compared to before-treatment within group A and group B. Group (A) improved CPF, PEF, and oxygen saturation by 51.73, 57.30, and 4.11%, respectively) than group (B) (14.74, 15.74, and 1.72%, respectively). Moreover, pairwise comparison tests (Post hoc test) for CPF, PEF, and oxygen saturation between both groups (Table 3) indicated no significant differences (P>0.05) before treatment of CPF, PEF, and oxygen saturation. While, after-treatment, there were significant differences in CPF (MD=

69.80; P=0.0001; P<0.05), PEF (MD=72.60; P=0.0001; P<0.05), and oxygen saturation (MD= 2.08; P=0.0001; P<0.05) between group (A) and group (B). Also, there was a significant difference in extubation success (P=0.046; P<0.05) between group (A) and group (B). The overall percentage of extubation was 92 % in group (A), whereas 72% in control one. While the overall failed percentage of extubation was 8% in group (A), whereas 28% in group (B) (Table 4).

Table 3: Mixed MANOVA within and between group comparison for outcomes variables

Outcomes variables	Items	Groups (Mean ±SD)		Mean difference	*P*-value
		Study group (n=25)	Control group (n=25)		
CPF	Before-treatment	179.40 ±17.03	176.40 ±15.78	3.00	0.572
	After-treatment	272.20 ±24.92	202.40 ±15.35	69.80	0.0001*
	Mean difference	92.80	26.00		
	Improvement %	51.73%	14.74%		
	95% CI	82.31 – 103.28	15.51 – 36.48		
	P-value	0.0001*	0.0001*		
PEF	Before-treatment	160.20 ±20.23	155.00 ±13.46	5.20	0.354
	After-treatment	252.00 ±27.68	179.40 ±14.23	72.60	0.0001*
	Mean difference	91.80	24.40		
	Improvement %	57.30%	15.74%		
	95% CI	80.71 – 102.88	13.31 – 35.48		
	P-value	0.0001*	0.0001*		
Oxygen saturation	Before-treatment	95.28 ±0.61	95.48 ±0.82	0.20	0.329
	After-treatment	99.20 ±0.76	97.12 ±0.66	2.08	0.0001*
	Mean difference	3.92	1.64		
	Improvement %	4.11%	1.72%		
	95% CI	3.51 – 4.32	1.23 – 2.04		
	P-value	0.0001*	0.0001*		

Data are expressed as mean ± standard deviation (SD) CI: confidence interval P-value: probability value * Significant (P<0.05)

Table 4: Comparison of extubation's success distribution between both groups

Items	**Groups**		***P*-value**
	Study group (n=25)	**Control group (n=25)**	
Extubation (successful: failed)	23 (92%) : 2 (8%)	18 (72%) : 7 (28%)	0.046*

Data are expressed as number (percentage), P-value: probability value * Significant (P<0.05)

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The distribution number (percentage) of patients who experienced temporary hemodynamic compromise in group (A) was 2 (8 %), while no one experienced any adverse effects in group (B). The statistical analysis by chi-square test revealed that there was a significant difference in the number of patients who had complications (P=0.046; P<0.05) between group (A) and group (B). The overall percentage of patients who experienced adverse effects was 8 % in the group (A). There was no mortality percentage as for the two groups within the time frame of the study.

DISCUSSION

This study was conducted prospectively to assess the effect of the lung volume recruitment technique in combination with traditional chest physiotherapy on cough effectiveness assessed by measuring CPF and PEF rates, O2 saturation, and the extubation success rate in post-extubated patients with ineffective cough compared to traditional chest physiotherapy alone. According to these results, it could be concluded that there was a significant difference in the mean, ±SD values of CPF, PEF, and Sat. O2 at post-treatment between both groups. So, this significant increase in CPF, PEF, and Sat. O2 at post-treatment, and also the significant difference in the rate of successful extubation favor group (A) over group (B). The role of cough augmentation is unclear for critically ill patients with acute respiratory failure requiring intubation and for management of post-extubation respiratory failure, so it is rarely used to prevent intubation or re-intubation in critically ill patients, despite the well-known negative consequences of re-intubation and its association with impaired secretion clearance [19]. **Rose et al., (2016)** conducted a cross-sectional survey to identify the rate of usage of cough augmentation techniques including the LVR technique, and their indications and contraindications, outcomes, and complications with patients requiring prolonged mechanical ventilation and had shown that secretion clearance was the most common indication for all techniques, whereas weaning from invasive and noninvasive ventilation were infrequent indications. As a result, this study focused on highlighting and promoting the use of these modalities with critical care patients. Effect of the Lung Volume Recruitment technique on postextubaed patients with weak and productive cough (CPF < 270L/min) was examined in this study by assessing the Cough Peak Flow Rate, Peak Expiratory Flow Rate, and Oxygen Saturation. Those variables were measured initially before starting the treatment (Pre) and at the end of executing the treatment (Post) and then realizing the number of patients successfully extubated in each group.

As for the first and second variables (CPF&PEF), there was a significant increase in cough peak flow rate with an improvement percentage of about 51.73% and 14.74% for group (A) and group (B) respectively compared to the baseline (P value=0.0001; P<0.05) (Table 3). Also, a significant peak expiratory flow rate increase existed with percentages of about 57.30% and 15.74% for group (A) and group (B) respectively compared to the baseline (P value=0.0001; P<0.05) (Table 3). This significant increase in both CPF and PEF post-treatment was in favor of the study group (A).

This significant improvement with using the LVR technique might be revealed that the mechanical properties of lung tissues and the chest wall are altered by LVR. Inflations that result in significant improvements in lung capacity may act as a range-of-motion exercise for the articulations of the chest wall, improving laxity [23]. Expiratory flow and cough strength improved immediately as a consequence of LVR's manual application of positive airway pressures and increased inspiratory lung volumes during the cough's early inspiratory phase, resulting in higher forced vital capacity. This simply stores elastic energy in the lungs and chest wall (at a volume greater than intrinsic muscle capacity), enhancing elastic recoil and putting even weaker expiratory muscles in a better length-tension relationship. As a result, there is an improvement in expiratory flows during the expulsive phase, as well as a large increase in CPFs, facilitating sputum expectoration [24]. Following the use of the procedure, the immediate improvements may last for roughly 30 minutes [25]. Acute changes in lung compliance may be achieved through redistribution of alveolar surface forces without increasing static lung volumes, as in deep breathing. Repeated inflations over voluntary VC, however, may produce a similar reaction. The mechanism of improvement in the long-term elevation of CPF is most likely related to improvements in lung and chest wall compliance since LVR

is a passive intervention that does not include muscular training. Supra-maximal lung inflation increases pulmonary compliance, perhaps through alleviating atelectasis (partially collapsed lung tissue due to reduced airflow). Stacking breaths has been shown to help with atelectasis, increasing inspiratory volume, rib cage movement, and voice loudness [23], [24]. As a result, patients with weak inspiratory muscles or low vital capacity may benefit from hyperinflation procedures [26].

Antonio Sarmento, de Andrade, et al., (2017) investigated the immediate effects of LVR on cough peak flow and operational volume fluctuations in twenty healthy patients of both sexes in cross-sectional research. Immediately after AS, they discovered statistically significant increases in cough peak flow and inspiratory capacity.

An and Shin, (2018) performed a randomized controlled experiment with 24 Cervical SCI patients who were randomly assigned to either the LVR or the incentive spirometry training (IST) groups. After training, both groups' FVC, FEV1, MEP, MIP, and CPF values improved significantly. In the post-test, the FVC in the LVR group was considerably greater than in the IST group, as was the mean change in CPF, FEV1, and MIP. They found that LVR improved pulmonary function, respiratory strength, and CPF in CSCI patients. To increase coughing ability, pulmonary function, and respiratory muscle strength, LVR should be used in respiratory rehabilitation programs.

Reyes, et al., (2020) examined the effects of air stacking (AS) and an expiratory muscle training (EMT) program on voluntary and reflex cough peak flow (CPF) in 33 Parkinson's disease patients who were divided into three groups: control, EMT, and EMT+AS. They discovered that EMT combined with AS improved reflex and voluntary CPF more than EMT alone. For reflex CPF, the EMT with AS had a stronger impact than for voluntary CPF.

As for the third variable in the study, Oxygen saturation, it was measured to assess whether the LVR technique affected the oxygenation function or not. It was found that there was a significant oxygen saturation improvement with percentages of about 4.11% and 1.72% for group (A) and group (B) respectively compared to the baseline (with P value=0.0001; $P<0.05$) (Table 3). This significant increase in oxygen saturation post-treatment was in favor of the study group (A).

Those changes through the group using the LVR technique might be revealed that LVR resulted in an expansion of the respiratory system (i.e., chest wall) over total lung capacity (TLC) levels, as well as an alveolar gas compression amount estimated by 2.1 % of lung volume at TLC. Because lung volume affects gas compression, it's plausible to suppose that applying positive pressure above the higher inflection point of the pressure-volume curve via LVR causes alveolar overdistension, which improves gas exchange and consequently oxygen saturation [30].

Cha et al., 2016 measured pulmonary function parameters, cough peak flow (CPF), oxygen saturation, and the 6-minute walk test for 27 elder subjects to examine the effect of air stacking exercise on lung capacity, and activities of daily living, and walking ability in elderly adults. They found significant intergroup differences for CPF, oxygen saturation, forced expiratory volume in one second (FEV1), and forced vital capacity (FVC) results after the intervention.

The fourth variable in the study was extubation success and it’s defined as if the patient doesn’t need to be re-intubated or died within the first 48 hours after extubation. the overall percentage of successful extubation was 92.00% in group (A), whereas 72% in group (B). While, the overall percentage of failed extubation was 8 % in group (A), whereas 28% in group (B) (Table 4). This significantly greater percentage of the extubation success rate and the significantly lower percentage of extubation failure rate post-treatment were in favor of group A.

Rose et al., (2017) conducted the first systematic review to determine extubation success using cough augmentation

techniques compared to no cough augmentation for critically-ill adults and children with acute respiratory failure admitted to a high-intensity care setting capable of managing mechanically-ventilated people and to determine the effect of cough augmentation techniques on reintubation, weaning success, mechanical ventilation, and weaning duration, adverse effects, length of stay and mortality. only one eligible randomized controlled trial **(Crowe, et al., 2006)** [32], and one non-randomized cohort study **(Niranjan, et al., 1998)** [33], were identified that used the lung volume recruitment with critically ill patients after mechanical ventilation (breath stacking) using a resuscitation bag equipped with a one-way valve to manually inflate to maximal insufflation capacity. The control groups of included studies comprised usual care, including standard respiratory physiotherapy. The non-randomized study (Niranjan 1998) reported that all the six intubated children meeting the inclusion criteria were successfully extubated. However, all children in the control group received a tracheostomy, as this was the standard care procedure at that time, making the comparison problematic. While this study stated that the overall successful percentage of extubation was 92.00% in the study group (A), whereas 72% in the control group (B) (Table 4), so there was a significant difference in extubation success between group (A) and group (B) favoring the LVR. No study of them reported reintubation rates other than those used to define extubation success. While in this study the patients who had a failed extubation had been all re-intubated and did not die, so the rate of extubation failure can be considered as a rate of reintubation where the overall failed percentage of extubation was 8.00% in group (A), whereas 28% in group (B), and this also favoring the LVR (Table 4). Niranjan 1998 reported mortality in the follow-up period after hospital discharge but only for those receiving the intervention, making comparison problematic. In this study, no participant in either group died within the time frame. Crowe 2006 reported on adverse events that one participant in the breath stacking protocol experienced an episode of coughing during suctioning, with the participant's blood pressure remaining elevated to a maximum of 190 mmHg for more than 30 minutes. No participant in either study group experienced new-onset arrhythmias, more than a 25% increase in heart rate, or developed a pneumothorax. Niranjan 1998 did not report adverse events associated with the study intervention. This study reported about two patients receiving the LVR experienced hemodynamic compromise, defined as systolic blood pressure lower than 90 mmHg for 20-30 minutes. Seven (28%) of group (B) compared to two (8%) participants receiving the LVR protocol experienced secretion encumbrance associated with severe hypoxemia, warranting reintubation.

The limitations of the study were mostly represented by the inability to have a larger sample size due to many causes, firstly the rate of successful Spontaneous breathing trials and achieving the weaning criteria is variable and is not enough. Secondly, tracheostomized patients and patients with bulbar affection were excluded to make the sample adhere to the relatively stringent inclusion criteria to eliminate any concerns regarding the technique's effectiveness. Adding to that, all selected subjects were ventilated due to moderate and severe pneumonia only, so the results of this study cannot be applied to other pathological conditions that required mechanical ventilation, causing a small sample size and affecting the generalization of results. Also, it was limited by Hemodynamic instability or any vital abnormality like temporary hypotension that might stop the session as happened with two patients in the group (A). At the beginning of treatment, some patients had respiratory distress (high RR) or patient-maneuver desynchrony. The fatigue or exhaustion felt by patients and their variable maximum inspiratory capacity or threshold might affect the procedure and the results. Finally, discharging or transferring patients to another place or hospital and the duration of the intervention was short made the

follow-up for the patients variable or difficult.

CONCLUSION

It could be concluded that combining the lung volume recruitment technique with traditional chest physiotherapy in post extubated patients with a suboptimal cough could be more beneficial for managing the cough ineffectiveness, by improving the CPF and PEF as measures of cough effectiveness, increasing the oxygen saturation, and for enhancing the success of extubation and reducing the rate of re-intubation than traditional chest physiotherapy alone.

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ABBREVIATIONS

AS (Air stacking)
COPD (Chronic obstructive pulmonary disease)
CMV (Continuous Mandatory Ventilation)
CPF (Cough peak flow)
FEV1 (Forced expiratory volume at the 1st second)
FVC (Forced vital capacity)
ICU (Intensive Care Units)
LVR (Lung Volume Recruitment)
MEP (Mean expiratory pressure)
MIP (Mean Inspiratory Pressure)
MV (Mechanical Ventilation)
NMD (neuromuscular disease)
PEF (Peak expiratory flow)
SCI (Spinal cord injury)
SPSS (The statistical package for social studies)
TCP (Traditional Chest physiotherapy)
VC (Vital capacity)
VIDD (Ventilator Induced Diaphragmatic Dysfunction)

REFERENCES

1- Rafiq MK, Bradburn M, Mustfa N, Mcdermott CJ, Annane D. Mechanical cough augmentation techniques in amyotrophic lateral sclerosis/motor neuron disease. Cochrane Database of Systematic Reviews. 2016;2016(12). doi:10.1002/14651858.CD012482
2- Mutolo D, Iovino L, Cinelli E, Bongianni F, Pantaleo T. Physiology of the Cough Reflex: Sensory and Mechanical Features. In: Cough: Pathophysiology, Diagnosis and Treatment. Springer International Publishing; 2020:3-21. doi:10.1007/978-3-030-48571-9_1
3- Fernández-Carmona A, Olivencia-Peña L, Yuste-Ossorio ME, Peñas-Maldonado L. Ineffective cough and mechanical mucociliary clearance techniques. Medicina Intensiva (English Edition). 2018;42(1):50-59. doi:10.1016/j.medine.2017.12.005
4- Kulnik ST, MacBean V, Birring SS, Moxham J, Rafferty GF, Kalra L. Accuracy of portable devices in measuring peak cough flow. Physiological Measurement. 2015;36(2):243-257. doi:10.1088/0967-3334/36/2/243
5- Matsuda C, Shimizu T, Nakayama Y, Haraguchi M. Cough peak flow decline rate predicts survival in patients with amyotrophic lateral sclerosis. Muscle & Nerve. 2019;59(2):168-173. doi:10.1002/MUS.26320
6- Lechtzin N, Cudkowicz ME, De Carvalho M, et al. Amyotrophic Lateral Sclerosis and Frontotemporal Degeneration Respiratory measures in amyotrophic lateral sclerosis. Published online 2018. doi:10.1080/21678421.2018.1452945

7- Shahane N, Jiandani MP. Correlation of Peak Cough Flow Rate with Peak Expiratory Flow Rate In Patients With Chronic Respiratory Diseases. National Journal of Integrated Research in Medicine (NJIRM). 2018;9(3):21-25.
8- Morrow BM, Angelil L, Forsyth J, Huisamen A, Juries E, Corten L. The utility of using peak expiratory flow and forced vital capacity to predict poor expiratory cough flow in children with neuromuscular disorders. South African Journal of Physiotherapy. 2019;75(1).
9- Chatwin M, Toussaint M, Gonçalves MR, et al. Airway clearance techniques in neuromuscular disorders: A state of the art review. Respiratory Medicine. 2018;136:98-110. doi:10.1016/j.rmed.2018.01.012
10- Oliveira M, Gomes R. Airway Clearance Techniques in Neuromuscular Disorders. Noninvasive Ventilation in Sleep Medicine and Pulmonary Critical Care. Published online 2020:75-82. doi:10.1007/978-3-030-42998-0_9
11- Yamashina Y, Tabira K, Aoyama H, et al. Cough Peak Flow of Independent Elderly People. Advances in Physical Education. 2020;10(04):347-353. doi:10.4236/APE.2020.104028
12- Laveneziana P, Albuquerque A, Aliverti A, et al. ERS Statement on Respiratory Muscle Testing at Rest and during Exercise. Vol 53. European Respiratory Society; 2019. doi:10.1183/13993003.01214-2018
13- Borges LF, Saraiva MS, Saraiva MAS, Macagnan FE, Kessler A. Expiratory rib cage compression in mechanically ventilated adults: systematic review with meta-analysis (Manobra de compressão torácica expiratória em adultos ventilados mecanicamente: Revisão sistemática com metanálise). Revista Brasileira de Terapia Intensiva. 2017;29(1):96-104. doi:10.5935/0103-507X.20170014
14- Toussaint M, Pernet K, Steens M, Haan J, Sheers N. Cough augmentation in subjects with duchenne muscular dystrophy: Comparison of air stacking via a resuscitator bag versus mechanical ventilation. Respiratory Care. 2016;61(1):61-67. doi:10.4187/respcare.04033
15- Powers SK, Wiggs MP, Sollanek KJ, Smuder AJ. Ventilator-induced diaphragm dysfunction: Cause and effect. American Journal of Physiology - Regulatory Integrative and Comparative Physiology. 2013;305(5):464-477. doi:10.1152/ajpregu.00231.2013
16- Mantellini E, Perrero L, Provenzano G, Petrozzino S. Secretion management in the mechanically ventilated patient. Working Paper of Public Health. 2012;1(1):1328-1342. doi:10.4081/wpph.2012.6783
17- Rose L, Adhikari NK, Poon J, Leasa D, McKim DA. Cough augmentation techniques in the critically ill: A canadian national survey. Respiratory Care. 2016;61(10):1360-1368. doi:10.4187/respcare.04775
18- Strickland SL, Rubin BK, Drescher GS, et al. AARC clinical practice guideline: Effectiveness of nonpharmacologic airway clearance therapies in hospitalized patients. Respiratory Care. 2013;58(12):2187-2193. doi:10.4187/respcare.02925
19- Rose L, Adhikari NKJ, Leasa D, Fergusson DA, Mckim D. Cough augmentation techniques for extubation or weaning critically ill patients from mechanical ventilation. Cochrane Database of Systematic Reviews. 2017;2017(1). doi:10.1002/14651858.CD011833.pub2
20- Trebbia G, Lacombe M, Fermanian C, et al. Cough determinants in patients with neuromuscular disease. Respiratory Physiology and

Neurobiology. 2005;146(2-3):291-300. doi:10.1016/j.resp.2005.01.001

22- Kaminska M, Browman F, Trojan DA, Genge A, Benedetti A, Petrof BJ. Feasibility of lung volume recruitment in early neuromuscular weakness: A comparison between amyotrophic lateral sclerosis, myotonic dystrophy, and postpolio syndrome. PM and R. 2015;7(7):677-684. doi:10.1016/j.pmrj.2015.04.001

23- Garnis N, Yulianto E, Hamzah T. Peak Flow Meter Equipped with Inspection Results Indicator. JEEMI. 2019;1(1). doi:10.1234/jeeemi.v1i1.9xx

24- Molgat-Seon Y, Hannan LM, Dominelli PB, et al. Lung volume recruitment acutely increases respiratory system compliance in individuals with severe respiratory muscle weakness. ERJ Open Research. 2017;3(1). doi:10.1183/23120541.00135-2016

25- McKim DA, Katz SL, Barrowman N, Ni A, Leblanc C. Lung volume recruitment slows pulmonary function decline in duchenne muscular dystrophy. Archives of Physical Medicine and Rehabilitation. 2012;93(7):1117-1122. doi:10.1016/j.apmr.2012.02.024

26- Armstrong A. Developing a breath-stacking system to achieve lung volume recruitment. Br J Nurs. 2009;18(19):1166-1169. doi:10.12968/bjon.2009.18.19.44820

27- Spinou A. Non-pharmacological techniques for the extremes of the cough spectrum. Respiratory Physiology and Neurobiology. 2018;257:5-11. doi:10.1016/j.resp.2018.03.006

28- Sarmento A, de Andrade AFD, Lima ÍNDF, Aliverti A, de Freitas Fregonezi GA, Resqueti VR. Air stacking: A detailed look into physiological acute effects on cough peak flow and chest wall volumes of healthy subjects. Respiratory Care. 2017;62(4):432-443. doi:10.4187/respcare.05189

29- An SK, Shin WS. Effect of air stacking training on pulmonary function, respiratory strength and peak cough flow in persons with cervical spinal cord injury. Physical Therapy Rehabilitation Science. 2018;7(4):147-153. doi:10.14474/PTRS.2018.7.4.147

30- Reyes A, Castillo A, Castillo J. Effects of Expiratory Muscle Training and Air Stacking on Peak Cough Flow in Individuals with Parkinson's Disease. Lung. 2020;198(1):207-211. doi:10.1007/s00408-019-00291-8

31- Sarmento A, Resqueti · V R, Fregonezi GAF, Aliverti · A, Hopkins S, Aliverti A. Assessment of gas compression and lung volume during air stacking maneuver. European Journal of Applied Physiology. 2017;117:189-199. doi:10.1007/s00421-016-3511-y

32- Cha HG, Choe YW, Kim MK. The Effects of Air Stacking Exercise on Pulmonary Function in Elderly Adults. Journal of the Korean Society of Physical Medicine. 2016;11(4):55-64. doi:10.13066/KSPM.2016.11.4.55

33- Crowe J, Rajczak J, Elms B. Safety and Effectiveness of Breath Stacking in Management of Persons with Acute Atelectasis. Physiotherapy Canada. 2006;58(4):306-314. doi:10.3138/PTC.58.4.306

34- Niranjan V, Bach JR. Noninvasive management of pediatric neuromuscular ventilatory failure. Crit Care Med. 1998;26(12):2061-2065. doi:10.1097/00003246-199812000-00042