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Effectiveness Of Incentive Spirometer Versus Lung Flute Machine Along with Chest Physiotherapy on Mucus Clearance and Fvc & Fev1 Among Subjects with Hospital Acquired Pneumonia - A Comparative

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ABSTRACT

Background: *Acute inflammation of the lung alveoli and surrounding airways is known as pneumonia. Pneumonia that develops 48 hours or longer following hospital admission and is not incubating at the time of admission is referred to as hospital-acquired pneumonia.*

Objectives: *The main goal of the study was to determine how well patients with hospital-acquired pneumonia responded to incentive spirometers, lung flute machines, and chest physical therapy in terms of mucus clearance, FEV, and FEV1.*

Subjects and Methods: *There was a pre-test and post-test relative study design. based on the selected criteria Thirty patients with hospital-acquired pneumonia received were selected. The lot technique was used to arbitrarily divide them into two groups. Group A consisted of fifteen patients who underwent both casket exertion and incitement spirometer treatment. Group B consisted of fifteen individuals who underwent both the casket exertion and lung flute machine treatment. For six weeks, each group received treatment. Digital spirometry was used to measure the pretest and post-test score values on mucus concurrence, FEV, and FEV1. To examine the efficacy of the treatment, paired and unpaired "t" tests were used.*

Result: *At the 0.05 level of significance, the group that received treatment with a lung flute machine and chest physiotherapy improved more in FVC and FEV1 than the other group that received treatment with an incentive spirometer and chest physiotherapy.*

Conclusion: *After applying a lung flute machine and receiving chest physical therapy for six weeks for individuals who have hospital-acquired pneumonia, there is a notable improvement in FVC.*

Clinical Implications: When used in conjunction with chest physical therapy, the lung flute machine has been shown to significantly enhance participants' FEV1 and FVC in cases of hospital-acquired pneumonia.

Keywords: *Hospital-acquired pneumonia, Incentive spirometer, Lung flute machine, Chest physiotherapy, Mucus clearance, Digital spirometry, FVC & FEV1.*

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1. Introduction

Pneumonia is an acute inflammatory condition affecting the lung alveoli and nearby airways. It results from an infection or other causes that trigger inflammation, causing blood vessels to dilate and leading to the accumulation of fluid in the alveoli. This condition is classified as a restrictive lung disease and can arise from infections with microorganisms, chemical exposure, gases, vapors, fatty or oily substances, or allergic reactions.[1]

Older adults and children are particularly at risk of severe pneumonia, with a significant number requiring hospitalization or intensive care. In 2016, pneumonia was responsible for approximately 16% of deaths among children under five worldwide, claiming around 900,000 lives, most of whom were under two years old. The mortality rate increases to 30% for patients admitted to intensive care with pneumonia. Elderly individuals, particularly those over 84, are especially vulnerable, accounting for more than half of pneumonia-related deaths. Pneumonia can be categorized into several types based on the causative pathogen, including bacterial, viral, fungal, aspiration, community-acquired, and hospital-acquired pneumonia.[2]

Hospital-acquired pneumonia (HAP) develops during a hospital stay and can be more severe than other lung infections due to the increased resistance of pathogens commonly found in hospital settings. This issue is especially relevant for patients receiving treatment in the hospital who may use respirators or breathing machines.[3] Early-onset HAP, which occurs within 4 days of admission, is typically caused by the same bacteria and viruses found in community settings. In contrast, late-onset HAP, which begins 5 days or more after admission, tends to have a worse prognosis and is usually caused by microorganisms acquired from the hospital environment.[4]

Infectious particles can spread through the cough of an infected person, from contaminated respiratory therapy equipment, from infections elsewhere in the body, or through the aspiration of bacteria from the mouth, throat, or stomach. For individuals with weakened immune systems, even microorganisms typically present in the oropharynx can lead to infections. When these microorganisms multiply, they release toxins that cause inflammation in the lung tissue, damaging the mucus and alveolar membranes. This results in edema and exudates filling the alveoli, which diminishes the surface area for carbon dioxide and oxygen exchange. Additionally, some bacteria can cause necrosis of lung tissue.[5,6]

Pneumonia can be localized to a single lobe of the lung (lobar pneumonia) or dispersed throughout the lungs (bronchopneumonia). Bronchopneumonia is more commonly seen as a nosocomial (hospital-acquired) infection in hospitalized patients, infants, and the elderly, and can be quite severe.[7] The onset of symptoms can be abrupt (lobar pneumonia) or gradual (bronchopneumonia or lobular pneumonia). Symptoms typically include malaise, fever (often >40°C), chills, vomiting, confusion due to hypoxemia (especially in the elderly), and tachycardia. Additional symptoms may include cough, difficulty breathing, chest pain, wheezing, and increased vocal resonance.[8]

Diagnostic investigations typically involve chest X-rays, sputum and pleural fluid analysis, and blood cultures.[9,10]

A review of the literature identifies several treatment methods for managing hospital-acquired pneumonia (HAP), including manual hyperinflation, percussion, shaking, vibrations, and suctioning (when huffing or cough-inducing techniques are insufficient for sputum removal). Breathing exercises, autogenic drainage, and mobilization are also included.[11] Additionally, the incentive spirometer and lung flute machine have demonstrated improved effectiveness in clearing sputum.

An incentive spirometer is a medical device designed to facilitate Sustained Maximal Inspiration (SMI), featuring visual performance indicators. SMI involves a slow, deep inhalation from functional residual capacity to total lung capacity, followed by a breath hold of at least 5 seconds. As the patient inhales through the spirometer, a piston inside the device rises to measure the volume of inspired air, thereby helping to improve lung function. The Lung Flute is a handheld device used for positive expiratory pressure therapy, which employs sound waves to mobilize and clear mucus. It consists of a tube with a plastic mouthpiece and a Mylar reed that vibrates during use. The Mylar reed oscillates at a frequency that matches the resonance frequency of pulmonary mucus (16-25 Hz). This vibration reduces the viscosity of mucus through mechanical action from the sound waves, enhancing the function of the mucociliary escalator system and promoting the mobilization and thinning of mucus, thus supporting effective bronchial hygiene. Clinical trials have demonstrated that the Lung Flute is highly effective for bronchial hygiene. Chest Physiotherapy (CPT) is a technique that typically involves a caregiver performing manual chest percussion on a patient's chest wall. Chest percussion involves clapping on the chest wall to break up mucus and facilitate its movement. For this technique to be effective, the clapping must be done in a consistent and rhythmic pattern to generate vibrations that help move mucus from the lower airways to larger airways, where it can be more easily coughed out.[12]

Although numerous studies have explored the efficacy of various treatment methods, this study aims to evaluate the effectiveness of the incentive spirometer and lung flute machine, in combination with chest physiotherapy, on mucus clearance, forced vital capacity (FVC), and forced expiratory volume in one second (FEV1) in patients with hospital-acquired pneumonia.

2. Methodology

2.1` Study Design: A pre-test, post-test comparative study design was employed with two distinct intervention groups to evaluate the effectiveness of the incentive spirometer and lung flute machine, in conjunction with chest physiotherapy, for managing hospital-acquired pneumonia (HAP).

2.2 Subjects: The study population consisted of subjects with hospital-acquired pneumonia (HAP) from the Department of Cardiorespiratory Physiotherapy at Ashwin Multi-Specialty Hospital, Coimbatore. Thirty subjects were randomly assigned to two groups using the lottery method.

Inclusion criteria for the study were: 1. Both male and female patients; 2. Age between 50 and 65 years; 3. Presence of mucus secretion; 4. HAP as a postoperative pulmonary complication; 5. Forced vital capacity (FVC) ranging from 1.77 to 2.59 liters; 6. Forced expiratory volume in one second (FEV_1) ranging from 1.49 to 2.22 liters; 7. Rapid and shallow breathing.

2.3 Methods: After obtaining informed consent, subjects were randomly assigned to two groups using a simple randomization method prior to the implementation of the planned treatments. The demographic details of the subjects are presented in Table 1. Group A received treatment with the incentive spirometer and chest physiotherapy, while Group B was treated with the Lung Flute machine and chest physiotherapy. Both groups underwent their respective interventions for 30 minutes per session, twice daily, 5 days a week, over a period of 6 weeks. Pre- and post-intervention scores for mucus clearance, forced vital capacity (FVC), and forced expiratory volume in one second (FEV1) were assessed using digital spirometry, and the results were recorded.

The study measured mucus clearance, forced vital capacity (FVC), and forced expiratory volume in one second (FEV1) to evaluate the effectiveness of the treatments. The efficacy of reducing mucus secretion and improving FVC and FEV1 in patients with hospital-acquired pneumonia was assessed using digital spirometry. Scores for mucus clearance, FVC, and FEV1 were recorded before and after each treatment session for both groups. After the 6-week treatment period, all measurements were repeated on the final day to obtain post-treatment scores.

3. Description of Interventions

3.1 Incentive spirometer along with chest physiotherapy

Group A received treatment involving the incentive spirometer combined with chest physiotherapy. Patients were instructed to perform the exercises 10 times (2 sets) per session. The treatment lasted 30 minutes per session, twice daily, 5 days a week, for a total of 6 weeks.

3.2 Incentive spirometer

Patient position: Semi-fowler position;

Therapist position: Standing near the patient

Procedure: The patient was instructed to form a tight seal around the mouthpiece and take a deep, slow inhalation. They were advised to observe the visual feedback on the spirometer and, if possible, hold their breath at the end of the inhalation for 4-5 seconds. Afterward, the patient should relax the seal around the mouthpiece, exhale, and return to normal breathing with a relaxed shoulder girdle.

Repetitions – 10 times (2 sets); Hold period – 4 to 5 seconds; Rest period – 5 seconds between each breath.

3.3 Chest physiotherapy

Patient position: Supine lying; Therapist position: Walk Stand near the patient

Procedure: While the patient is lying in the supine position, the therapist performs percussion, followed by shaking and vibration techniques. The percussion is administered at a rate of 100 to 150 percussions per minute. Each session lasts 10 to 15 minutes and is conducted alongside the use of the incentive spirometer, twice daily, 5 days a week, for a duration of 6 weeks.

3.4 Lung flute machine along with chest physiotherapy

3.4.1 Lung flute machine

Group B received treatment involving the Lung Flute machine combined with chest physiotherapy. Patients were instructed to perform the activity 10 times (2 sets) per session. Each treatment session lasted 30 minutes and was conducted twice daily, 5 days a week, over a period of 6 weeks. Patient position: Semi-fowler position / High sitting position; Therapist position: Standing near the patient;

Procedure: The patients were instructed to take a deep inhalation and then place their lips around the mouthpiece of the Lung Flute, exhaling forcefully through it. They were also advised to remove the mouthpiece and swallow before repeating the process. This was done in 10 repetitions of 2 sets each, with a 5-second rest between breaths. Approximately 5 minutes after the session, mucus may accumulate at the back of the throat, potentially leading to vigorous coughing.

3.5 Statistical Analysis: Data were analyzed using SPSS (Statistical Package for the Social Sciences) for Windows, version 20.0. A paired t-test was used to compare the pre- and post-test scores within each group. An unpaired t-test was employed to compare the pretest and post-test scores between the two groups. A p-value of less than 0.05 was considered statistically significant.

4. Results

The demographic characteristics of the subjects are detailed in Table 1. Group A comprised 8 males and 7 females, while Group B included 9 males and 6 females. The average age for males in Group A was 53%, and for females, it was 47%. In Group B, the average age for males was 60%, and for females, it was 40%.

Table 1: Demographic characteristics of the subjects

Demographic profile	**Experimental group -I**	**Experimental group-II**
	Mean	**Mean**
Age	59.5	57.2
Gender (male : female ratio)	9:6	10:5
No. of patients	15	15

The pre-treatment scores for the two outcome measures were analyzed using an unpaired t-test, and the obtained value was lower than the critical t-table value at the 0.05 significance level [Table 2]. This indicates that the mean scores for all dependent variables, including FVC and FEV1, were similar at the pre-intervention stage before any therapeutic interventions were applied.

Table 2: Comparison of FVC & FEV1 of subjects with HAP, in both experimental group I and experimental group II during the preintervention stage.

Outcome parameters	Groups	Mean	SD	T – value
FVC	Experimental group – I	2.14	0.1	0.191
	Experimental group -II	2.16	0.2	
FEV_1	Experimental group – I	2.16	0.1	0.188
	Experimental group -II	2.13	0.2	

Non- significant at 0.05 levels ($p>0.05$)

Further analysis was conducted to determine if there was a significant difference in the dependent variables between the pre-treatment phase and the end of the 6-week intervention period in both experimental groups. The results revealed that both groups demonstrated a significant difference in FVC and FEV1 between the pre-intervention phase and the end of the 6-week intervention, with a significance level of 0.05, as detailed in Table 3.

Table 3: Comparison of FVC & FEV1of subjects with HAP among two experimental groups between the pre-intervention and post-intervention phase.

Dependent variable	Groups	Pre-intervention stage		Post-intervention stage (at the end of 6 weeks)		T – value
		Mean	SD	Mean	SD	

FVC	Experimental group – I	2.14	0.1	3.86	0.2	19.088
	Experimental group –II	2.16	0.2	4.34	0.14	22.081
FEV_1	Experimental group – I	2.16	0.2	3.32	0.26	9.25
	Experimental group - II	2.14	0.1	4.01	0.1	22.16

Significant at 0.05 levels ($p<0.05$)

Additionally, a significant difference was found between the two experimental groups when evaluating the impact of the 6 weeks of therapeutic intervention on the dependent variables FVC and FEV1. Furthermore, the mean scores for both outcome variables were higher in experimental group II compared to experimental group I, as shown in Table 4.

Table 4**:** Comparison of FVC & FEV1 of subjects with HAP at the end of post-intervention stage

Outcome parameters	Groups	Mean	SD	T – value
FVC	Experimental group – I	3.86	0.2	4.204
	Experimental group –II	4.34	0.1	
FEV1	Experimental group – I	3.32	0.26	5.378
	Experimental group – II	4.01	4.01	

Significant at 0.05 levels ($p<0.05$)

From table 4, it is inferred that the experimental group II which was exposed to the treatment combinations of lung flute machine along with chest physiotherapy showed better improvement in FVC and than the experimental group –I that was exposed to the treatment combinations of incentive spirometer along with chest physiotherapy at 0.05 levels of significance.

Discussion

Pneumonia is an acute inflammatory condition affecting the lung alveoli and surrounding airways. Hospital-acquired pneumonia (HAP) is defined as pneumonia that develops 48 hours or more after hospital admission and was not present at the time of admission. Early-onset HAP, occurring within 4 days of admission, is typically caused by the same bacteria and viruses found in the community. In contrast, late-onset HAP, which begins 5 days or more after admission, generally has a worse prognosis and is often caused by microorganisms acquired from the hospital environment.

This present study has demonstrated the effectiveness of incitement spirometer and Lung flute machine along casket activity among subjects with Hospital acquired Pneumonia. An incitement Spirometer is a medical device that facilitates SMI (Sustained Minimal Alleviation) with incorporated visual pointers of performance. An SMI is a slow, deep alleviation from the functional residual capacity up to the total lung capacity, followed by ≥ 5 seconds breath hold. It's designed to mimic natural sighing or yawning by encouraging the case to take long, slow, deep breaths. This decreases pleural pressure, promoting increased lung expansion and better gas exchange. It works in order to prop the therapist in guiding the case to optimal performance and likewise case's uses this visual feedback to cover their own sweats. The device gives the individual visual feedback regarding inflow and volume and help and reverse atelectasis when used meetly and regularly. The visual dimension of the remedy serves as a provocation or thing for the case to try to meet by repeating the minimal trouble frequently[13].There are generally two types of incitement spirometer, videlicet Flow- acquainted and Volume- acquainted incitement spirometer. The volume- acquainted type has a one- way stopcock with capacity up to 4000 ml. Current substantiation tells us that using this type of spirometer requires lower breathing work and improves diaphragmatic function[14].

The Lung Flute is a handheld positive expiratory pressure (PEP) device that uses sound waves to mobilize and clear secretions in the lungs. It is tubular with a plastic mouthpiece at one end, attached to a Mylar reed that flutters during use. The Mylar reed is fixed on the other end to increase air pressure within the device, providing auditory impedance. When in use, the Mylar reed oscillates at a frequency matching the resonance frequency of pulmonary secretions (16-25

Hz). This mechanical vibration reduces the density of these secretions, facilitating their removal by the mucociliary escalator system, which moves the loosened mucus out of the airways for easier expectoration.

The Lung Flute, a small, self-powered audio device, has been classified by the FDA as part of the Oscillatory Positive Expiratory Pressure (OPEP) family, which includes devices like the Flutter® and the Acapella. Unlike traditional OPEP devices that use oscillatory back pressure, the Lung Flute operates based on auditory energy. When exhaled into with sufficient force to make the reed oscillate, the Lung Flute generates a sound wave of 16 to 22 Hz with an output of 110 to 115 dB, using 2.5 cm H2O of pressure. This sound wave travels down the tracheobronchial tree, loosening secretions through vibration and enhancing mucociliary clearance in the lower respiratory tract, which results in the induction of cough. This functionality of the Lung Flute is utilized for both diagnostic testing and the improvement of mucus clearance from the lower airways. Clinical trials have demonstrated the Lung Flute to be a highly effective tool for bronchial hygiene.

Chest Physiotherapy (CPT) is an airway clearance technique that typically involves another individual manually performing chest percussion on a patient's chest wall to help mobilize secretions.

Chest percussion is defined as manually clapping on a person's chest wall to break up mucus and prevent buildup. For this technique to be effective, clapping must be performed in a repeated and rhythmic beat sequence to create vibrations that help move mucus from the smaller airways to larger ones, where it is more easily coughed out[18]. It encompasses a group of treatments designed to help patients improve respiratory function and prevent airway obstruction. For instance, chest physical therapy often includes vibrations (also used to help dislodge mucus) and postural drainage. Postural drainage relies on gravity to help patients drain mucus from different areas of the lungs into the mouth. By combining chest percussion with vibrations and postural drainage, these techniques work together to break up and move mucus upward, where it's easier to expel from airways[19].

In 2021, Toor H and Kashyap S conducted a study in physical medicine and rehabilitation involving 48 patients, aged 58 years on average, including 21 females and 27 males. The patients were instructed to lie down and inhale and exhale through a tube 10 times, recording the highest volume achieved during these breaths. The baseline maximal inspiration for the participants was 1885.4 ml prior to the exercise. An increase in lung capacity was observed for all participants over the study period. By the end of the four-week study, the average maximum inspiratory volume had risen to 2235.4 ml. A paired t-test demonstrated a significant difference between the baseline volume (1885.4 ml) and the maximum volume (2235.4 ml). The study concluded that

the use of an incentive spirometer increased lung volume by 16% over 30 days. [20]

In 2022, Prateek Upadhyay and Prashant Ahlawat conducted a study on the improvement in the quality of life for pulmonary disease survivors with minimal interventions. They highlighted that the Lung Flute, a handheld device approved by the FDA, helps enhance patients' mucus-clearing ability. A study by Senthi et al., which involved 69 patients, observed a decrease in the incidence of acute exacerbations and an increase in patient satisfaction. Additionally, research by Elhawary A et al. showed that sputum samples taken after using the Lung Flute contained a higher number of cellular components, increased levels of fibrinogen and elastase, and a higher purulent score, thus confirming its efficacy.

In this study, 30 subjects were selected based on specific criteria and divided into two groups using a randomized trial by lot method. GROUP A consisted of 15 subjects who received treatment with an incentive spirometer along with chest physiotherapy. GROUP B also had 15 subjects and received treatment with a Lung Flute machine in addition to chest physiotherapy. The study was conducted over a period of 12 weeks. Pre-test and post-test scores for FVC (Forced Vital Capacity) and FEV_1 (Forced Expiratory Volume in one second) were measured using digital spirometry and recorded before and after 6 weeks of treatment.

Statistical analysis using paired and unpaired 't' tests demonstrated significant improvements in FVC and FEV_1 following interventions in both groups. However, Group B (Lung Flute machine along with chest physiotherapy) showed significantly greater improvement in mucus clearance and FVC & FEV_1 compared to Group A (Incentive spirometer along with chest physiotherapy) among subjects with Hospital Acquired Pneumonia. [21]

5. Limitations:

- This study was limited to a particular age group.
- This study was conducted for a short duration.
- This study did not include a control group.
- This study has included only one outcome measure.
- There was no follow up.

6. Conclusion

The study concluded that both groups showed a statistically significant difference in Forced Vital Capacity (FVC) and Forced Expiratory Volume per second (FEV_1) among subjects with Hospital

Acquired Pneumonia after 6 weeks of treatment. Group A received an Incentive spirometer along with chest physiotherapy, while Group B used a Lung Flute machine along with chest physiotherapy. However, Group B exhibited significantly greater improvement compared to Group A.

7. Conflict of interest

No potential conflict of interest was reported by the authors.

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