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Effect of high-frequency chest wall oscillation versus chest physiotherapy on lung function after lung transplant

Angeli Esguerra-Gonzales, RN [a], Monina Ilagan-Honorio, RN [a], Priscilla Kehoe, PhD [b], Stephanie Fraschilla, MSN, RN [c], Ai Jin Lee, RN [a], Ashley Madsen, RN [a], Taline Marcarian, PhD(c), MSN [a], Kristina Mayol-Ngo, RN [a], Pamela S. Miller, PhD, RN [b], Jay Onga, BSN, RN [c], Betty Rodman, RN [a], David Ross, MD [d], Zeba Shameem, RN [a], Karabi Nandy, PhD [b,e], Joy Toyama, MS [b,e], Susan Sommer, RN [a], Cheryl Tamonang, RN [a], Filma Villamor, RN [a], S. Samuel Weigt, MD, MS [d], Anna Gawlinski, DNSc, RN [b,*]

[a] Department of Nursing, Cardiothoracic Intensive Care Unit, Ronald Reagan–UCLA Medical Center, Los Angeles, California
[b] School of Nursing, UCLA, Los Angeles, California
[c] Transplant Services, Heart and Lung Transplantation, UCLA Health System, Los Angeles, California
[d] Division of Pulmonary and Critical Care Medicine, David Geffen School of Medicine at UCLA, Los Angeles, California
[e] Department of Biostatistics, School of Public Health, UCLA, Los Angeles, California

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ABSTRACT

Purpose: The aim of this study is to compare the effects of chest physiotherapy (CPT) and high-frequency chest wall oscillation (HFCWO) on lung function in lung transplant recipients.
Background: Chest physiotherapy and HFCWO are routinely used after lung transplant to attenuate dyspnea, increase expiratory flow, and improve secretion clearance.
Methods: In a two-group experimental, crossover design with repeated-measures, 45 lung transplant recipients (27 single, 18 bilateral; 64% male; mean age, 57 years) were randomized to receive CPT at 10:00 AM and 2:00 PM followed by HFCWO at 6:00 PM and 10:00 PM ($n = 22$) or vice versa ($n = 23$) on postoperative day 3. Dyspnea (modified Borg score), Spo_2/FiO_2, and peak expiratory flow (PEF) were measured pre-treatment and post-treatment. Data were analyzed using chi-square tests, *t* tests, and linear mixed effects models.
Results: There was no statistically significant treatment effect for dyspnea or PEF in patients who received HFCWO versus CPT. However, there was a significant treatment effect on the Spo_2/FiO_2 ratio ($p < 0.0001$).
Conclusions: Preliminary results suggest that lung function (measured by Spo_2/FiO_2) improves with HFWCO after lung transplantation. Although dyspnea and PEF did not differ significantly between treatment types, HFCWO may be an effective, feasible alternative to CPT.

1. Introduction

Airway complications remain one of the most common causes of morbidity and mortality after lung transplantation (Amesur, Orons, & Iacono, 2004). Lung transplant recipients have significant problems with secretion clearance that require aggressive pulmonary management to prevent or minimize infection and to preserve lung function. Therefore, pulmonary hygiene therapy is an integral part of postoperative care. Conventional chest physiotherapy (CPT) is commonly performed by nurses and has been used for several decades (Oermann, Swank, & Sockrider, 2000) to promote airway clearance and improve lung functions. The CPT consists of a collection of techniques such as postural drainage, vibration, and percussion. This method of airway clearance is inherently an operator-dependent technique that varies among practitioners in terms of frequency, duration, and effectiveness. Additionally, chest physiotherapy is labor-intensive with low treatment adherence rates, hypoxemia,

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* Corresponding author at: UCLA School of Nursing, 700 Tiverton Ave, Factor Bldg. #4-234, Los Angeles, CA 90095. Tel.: +1 310 206 1884; fax: +1 310 794 7482.
E-mail addresses: aesguerra-gonzalez@mednet.ucla.edu (A. Esguerra-Gonzales), mIlagan-honorio@mednet.ucla.edu (M. Ilagan-Honorio), pkehoe@sonnet.ucla.edu (P. Kehoe), sfranschilla@mednet.ucla.edu (S. Fraschilla), leeaijin@gmail.com (A.J. Lee), amadsen@mednet.ucla.edu (A. Madsen), tmarcarian@mednet.ucla.edu (T. Marcarian), kmayol-ngo@mednet.ucla.edu (K. Mayol-Ngo), Pamela.Miller@nursing.ucsf.edu (P.S. Miller), jonga@mednet.ucla.edu (J. Onga), brodman@mednet.ucla.edu (B. Rodman), dross@mednet.ucla.edu (D. Ross), zshameem@mednet.ucla.edu (Z. Shameem), knandy@sonnet.ucla.edu (K. Nandy), jtoyama@sonnet.ucla.edu (J. Toyama), ssommer@mednet.ucla.edu (S. Sommer), ctamonang@mednet.ucla.edu (C. Tamonang), fvillamor@mednet.ucla.edu (F. Villamor), sweigt@mednet.ucla.edu (S.S. Weigt), agawlins@sonnet.ucla.edu (A. Gawlinski).

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and discomfort reported among patients (Arens et al., 1994). As an alternative, contemporary high-frequency chest wall oscillation (HFCWO) may increase rates of lung recovery thanks to its controlled electronic selections of frequency and duration. Administered via an inflatable vest connected to an air-pulse generator, HFCWO creates airflow velocities and cough-like shear forces within the lungs that support the reduction of secretion viscosity as well as the mobilization and expectoration of secretions (King et al., 1983; Oermann et al., 2001). The HFCWO delivers vigorous, consistent, and yet gentle high-quality treatments with selected settings that can be customized to each patient's tolerance.

Since 2004, HFCWO and CPT have been used in combination as part of routine postoperative treatment to improve respiratory efficiency, promote airway clearance, and strengthen respiratory muscles among lung transplant recipients in the cardiothoracic intensive care unit (CTICU) at university-affiliated medical center. Previous comparative studies have shown that HFCWO is as effective as CPT for clearing pulmonary secretions in patients with chronic pulmonary disease, mostly in outpatient settings (Arens et al., 1994; Scherer et al., 1998; Varekojis et al., 2003; Warwick & Hansen, 1991). The existing evidence, however, is based largely on randomized and quasi-experimental designs in patients with cystic fibrosis. Given the paucity of data on the effects of HFCWO and CPT in lung transplant recipients, it is unclear whether one of these techniques is more effective than the other in reducing patients' dyspnea and improving physiological indicators of lung function.

This study expands on previously published work by our research team who investigated the effects of HFCWO and CPT on patients' perceived pain and their preference (Esguerra-Gonzalez et al., 2013). The purpose of this current pilot study was to evaluate the effectiveness of HFCWO compared with CPT in reducing patients' shortness of breath (dyspnea) and improving lung function (peak expiratory flow [PEF] and ratio of oxygen saturation to fraction of inspired oxygen [Sp_{O_2}/FiO_2]) among postoperative lung transplant recipients. This study had two specific goals. First, we examined the difference in shortness of breath (dyspnea) in patients receiving HFCWO and patients receiving CPT therapy. It was hypothesized that patients treated with HFCWO would report significantly less shortness of breath than would patients receiving CPT therapy. Second, we sought to determine whether lung function, as measured by PEF and Sp_{O_2}/FiO_2, differed between patients receiving HFCWO and patients receiving CPT therapy. We speculated that lung function measured in that way would not differ among patients treated with HFCWO and patients receiving CPT therapy.

2. Methods

2.1. Study population

A two-group, experimental, crossover design with repeated-measures was used to examine the effect of HFCWO and CPT on dyspnea and lung function in lung transplant recipients. Patients listed for lung transplant were screened in the pulmonary clinic, and lung transplant recipients were screened in the CTICU on postoperative day 2 at the university-affiliated medical center. Patients who were planning to undergo single or bilateral lung transplant, 18 to 80 years old, fluent in English, alert and oriented, and hemodynamically stable were considered eligible for enrollment and participation in the study. Exclusion criteria were as follows: (1) intubation, (2) tracheostomy, (3) active bleeding, (4) hemodynamic instability, (5) unstable head and neck injury, (6) dementia or physical/mental incapacity to perform study requirements, (7) open chest, and (8) myopathy affecting diaphragmatic movement. Forty-five lung transplant recipients participated in the study. The study procedures were approved by the institutional review board. Each patient provided informed consent in order to participate (Esguerra-Gonzalez et al., 2013).

2.2. Procedures

Patients were randomly assigned to one of two groups that differed in the sequence of the pulmonary hygiene methods. Group 1 ($n = 22$) received CPT twice during the first half of postoperative day 3 (period 1 at 10:00 AM and 2:00 PM), followed by HFCWO during the second half of postoperative day 3 (period 2 at 6:00 PM and 10:00 PM). Group 2 ($n = 23$) received HFCWO during the first half of postoperative day 3 (period 1 at 10:00 AM and 2:00 PM), followed by CPT during the second half of postoperative day 3 (period 2 at 6:00 PM and 10:00 PM). Trained registered nurses who had successfully demonstrated clinical competency in administration of CPT and HFCWO performed the pulmonary hygiene treatments. Dyspnea scores were collected immediately before treatment, immediately after treatment, and 15 minutes after treatment. Physiological dependent measures of lung function (peak expiratory flow [PEF] and Sp_{O_2}/FiO_2) were recorded and collected before treatment and 30 minutes after treatment. The time sequence for data collection on the variables of dyspnea and lung function is illustrated in Table 1. These time points were chosen because they most likely corresponded to the maximal effect after treatment for the study variables of interest and therefore were times when a difference from baseline level might be detected. Both treatments were conducted 1 hour before mealtime. Socio-demographic and clinical information including age, preoperative co-morbid conditions, and medications were abstracted from the patient's bedside chart and electronic medical record.

2.2.1. CPT

For the purpose of this study, CPT included percussion, coughing, and deep breathing. Percussion was defined as rhythmically striking the chest wall with a rubber percussor. Registered nurses performed CPT as a 3-minute treatment according to established procedure. This treatment time is consistent with the times reported in published studies, which range from 2 to 3 minutes (Kirilloff, Owens, Rogers, & Mazzocco, 1985) up to 7 to 20 minutes (Reisman et al., 1988). The treatment consisted of the following: (1) positioning the patient in a chair, leaning over a bedside table with one pillow. (2) Percussing by using Palm Cups rubber percussors (Smiths Medical ASD, Inc, Keene, New Hampshire), beginning at the bases of the lungs. Working toward the upper lobes of the lungs in a circular motion. (3) Percussing 1.5 minutes on each side of the lungs, with a 1-minute rest period between the therapies for each side. (4) Instructing the patient to deep breathe and cough and attempt to clear secretions. (5) Repeating the procedure on the other side.

2.2.2. HFCWO

Patients received HFCWO via The Vest Airway Clearance System (Hill-Rom, St Paul, Minnesota). The HFCWO was performed with patients wearing a cloth-like vest that covers the entire thorax (front and back) and the upper part of the abdomen. The device is an inflatable vest connected by tubes to an air-pulse delivery system. The HFCWO was conducted as a 15-minute treatment, which consisted of

Table 1
Timeline for data collection before and after treatment.

Outcome measures	Before treatment	1 minute after treatment	15 minutes after treatment	30 minutes after treatment
Tolerability				
Dyspnea	X	X	X	
Lung function				
Sp_{O_2}/FiO_2	X		X	X
Peak expiratory flow (PEF)	X			X