PAIN AFTER LUNG TRANSPLANT: HIGH-FREQUENCY CHEST WALL OSCILLATION VS CHEST PHYSIOTHERAPY

By Angeli Esguerra-Gonzalez, RN, BSN, Monina Ilagan-Honorio, RN, BSN, Stephanie Fraschilla, RN, MSN, CCTC, Priscilla Kehoe, PhD, Ai Jin Lee, RN, ADN, Taline Marcarian, RN, MSN, Kristina Mayol-Ngo, RN, BSN, Pamela S. Miller, RN, PhD, Jay Onga, RN, BSN, CCTC, Betty Rodman, RN, BSN, David Ross, MD, Susan Sommer, RN, BSN, Sumiko Takayanagi, PhD, Joy Toyama, MS, Filma Villamor, RN, BSN, CCRN, S. Samuel Weigt, MD, and Anna Gawlinski, RN, DNSc

Background  Chest physiotherapy and high-frequency chest wall oscillation (HFCWO) are routinely used after lung transplant to facilitate removal of secretions. To date, no studies have been done to investigate which therapy is more comfortable and preferred by lung transplant recipients. Patients who have less pain may mobilize secretions, heal, and recover faster.

Objectives  To compare effects of HFCWO versus chest physiotherapy on pain and preference in lung transplant recipients.

Methods  In a 2-group experimental, repeated-measures design, 45 lung transplant recipients (27 single lung, 18 bilateral) were randomized to chest physiotherapy (10 AM, 2 PM) followed by HFCWO (6 PM, 10 PM; group 1, n = 22) or vice versa (group 2, n = 23) on postoperative day 3. A verbal numeric rating scale was used to measure pain before and after treatment. At the end of the treatment sequence, a 4-item patient survey was administered to assess treatment preference, pain, and effectiveness. Data were analyzed with χ² and t tests and repeated-measures analysis of variance.

Results  A significant interaction was found between mean difference in pain scores from before to after treatment and treatment method; pain scores decreased more when HFCWO was done at 10 AM and 6 PM (P = .04). Bilateral transplant recipients showed a significant preference for HFCWO over chest physiotherapy (11 [85%] vs 2 [15%], P = .01). However, single lung recipients showed no significant difference in preference between the 2 treatments (11 [42%] vs 14 [54%]).

Conclusions  HFCWO seems to provide greater decreases in pain scores than does chest physiotherapy. Bilateral lung transplant recipients preferred HFCWO to chest physiotherapy. HFCWO may be an effective, feasible alternative to chest physiotherapy. (American Journal of Critical Care. 2013;22:115-125)
Pulmonary complications remain one of the most common causes of morbidity and mortality following lung transplant surgery. Lung transplant recipients have marked problems with clearance of secretions, and aggressive pulmonary management is required 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 to promote airway clearance and improve lung function. CPT includes postural drainage, vibration, and percussion techniques.

This method of airway clearance is inherently dependent on the human operator and varies among practitioners in terms of frequency, duration, and effectiveness. Additionally, CPT is labor-intensive, and low treatment adherence rates, hypoxemia, and discomfort have been reported among patients. Evidence indicates that CPT can provide effective airway clearance, preserving pulmonary function and minimizing complications. Researchers in many studies have reported small-scale benefit of CPT on pulmonary end points. Novoa et al recently reported that CPT reduced postoperative pulmonary morbidity (eg, respiratory insufficiency, atelectasis, and pneumonia) in patients undergoing lung resection for cancer. Although these findings are encouraging, current recommendations for perioperative CPT have been driven largely by quasi-experimental, nonexperimental, and expert opinion, and further evaluation through large-scale studies is needed.

As an alternative, contemporary high-frequency chest wall oscillation (HFCWO) may increase rates of lung recovery thanks to the technique’s controlled electronic selections of frequency and pressure amplitude. Previous comparative studies have shown HFCWO to be as effective as CPT in clearing pulmonary secretions among patients with chronic pulmonary disease in mostly outpatient settings. Additionally, HFCWO is not operator-dependent, does not require specialized positions, and may be less painful than CPT. Thus, HFCWO may be the method of therapy preferred by patients. Disadvantages of HFCWO have been largely overshadowed by its reported advantages. However, when compared with CPT, the perceived disadvantages of HFCWO may be inherently related to longer duration of therapy sessions, unknown cost benefit, and portability of the equipment (as a larger device). Overall, little evidence supports the idea that oscillation such as HFCWO is more effective than CPT among patients with cystic fibrosis.

To date, most studies have compared HFCWO with CPT in patients with chronic pulmonary diseases, mainly cystic fibrosis, in both inpatient and outpatient settings. Two studies used a randomized design to compare HFCWO and CPT on outcome variables of comfort and preference. According to the literature, patients with cystic fibrosis and a variety of thoracic surgery patients reported little or no discomfort during therapy and preferred HFCWO to conventional CPT. However, in 1 study, patients preferred their usual airway clearance technique (percussion) to HFCWO.

No published studies have investigated which treatment is less painful and preferred by lung transplant recipients. These outcomes are important...
informed consent, 45 patients who underwent SLT or BLT surgery participated in this study. Figure 1 displays a flowchart of patients’ enrollment and randomization to treatment groups.

Criteria for selection of participants included (1) diagnosis of SLT or BLT, (2) men or women from 18 to 80 years old, (3) fluent in English, (4) alert and oriented, and (5) hemodynamically stable. 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.

Data Collection Procedure

Patients were randomly assigned to 1 of 2 groups by using a table of random numbers. Group 1 (n = 22) received CPT during the first half of postoperative day 3 (time 1 at 10 AM; time 2 at 2 PM) followed by HFCWO for the second half of postoperative day 3 (time 3 at 6 PM; time 4 at 10 PM). Group 2 (n = 23) received HFCWO at time 1 and time 2 followed by CPT at time 3 and time 4. Pulmonary hygiene treatment and data collection were performed by trained registered nurses who had successfully completed the clinical competencies for administration of CPT and HFCWO. Registered nurses followed clinical practice issues because determining which pulmonary hygiene method is less painful and preferred can influence patients’ adherence with this therapy and maximize patients’ outcomes. Given the lack of evidence supporting the effectiveness of HFCWO and CPT among lung transplant recipients, the purposes of this pilot, feasibility study were to (1) explore the effect of HFCWO versus CPT treatment on patient’s pain patterns by measuring pain scores before and after treatment and (2) compare lung transplant recipients’ preference for HFCWO versus CPT.

Methods

Design

A 2-group experimental, repeated-measures design was used to compare HFCWO versus CPT with respect to lung transplant recipients’ pain and preference. Group 1 received CPT as the first treatment followed by HFCWO. Group 2 received HFCWO as the first treatment followed by CPT.

Sample and Setting

The study site was a university-affiliated, public medical center and major referral center for lung transplant surgery with approximately 50 to 55 patients per year receiving either a single lung transplant (SLT) or bilateral lung transplants (BLT). A sample size of 26 patients was estimated by power analysis to achieve 70% power to detect a medium effect size at a significance level of .05. After approval by the institutional review board and provision of written informed consent, 45 patients who underwent SLT or BLT surgery participated in this study. Figure 1 displays a flowchart of patients’ enrollment and randomization to treatment groups.

Criteria for selection of participants included (1) diagnosis of SLT or BLT, (2) men or women from 18 to 80 years old, (3) fluent in English, (4) alert and oriented, and (5) hemodynamically stable. 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.

Pain scores were assessed immediately before and after treatment, and 15 minutes after treatment.
structured (quantitative self-report and objective data) and semistructured (open-ended question on Patient Preference Questionnaire) data collection procedures outlined in the study and treatment protocols.

Pain scores were assessed immediately before treatment, immediately after treatment, and 15 minutes after treatment. After the last treatment was completed at time 4, preference for one method of treatment over the other was measured. Table 1 illustrates the time sequence for data collection on the variables of pain and preference. These time points were chosen because they most likely corresponded to the maximal effect after treatment for the study variables and, therefore, were times when a difference from baseline level may be detected. Both treatments were conducted 1 hour before meal time. Sociodemographic and clinical information including age, preoperative comorbid conditions, and medications were abstracted from the patient’s bedside chart and electronic medical record.

Chest Physiotherapy. 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 (Smiths Medical ASD, Inc). The CPT was performed by registered nurses as a 3-minute treatment (1.5 minutes on each side of the lungs) according to established competency. This treatment time is consistent with published treatment times, which range from 2 to 3 minutes. Only 1 patient required a frequency adjustment to 12 Hz. Patients were encouraged to cough and deep breathe after HFCWO and CPT therapy.

Training was implemented to ensure reliability across data collectors for performing HFCWO and CPT treatment. Interrater reliability was measured at baseline and quarterly during the course of the study. Two advanced practice nurses with combined experience in critical care and cardiology evaluated video recordings of registered nurses performing CPT and graded each nurse by using a competency scoring sheet. Interrater reliability was randomly evaluated among 10% of the recordings, with at least 90% agreement achieved.

Pain was measured on a verbal numeric rating scale of 0 to 10.

Measures

Pain. Pain was measured on a verbal numeric rating scale (VNRS) of 0 to 10 without visual cues immediately before and after treatment and at 15 minutes after treatment. Patients reported the number that best represented their treatment-related pain (where 0 = no pain and 10 = most intense pain imaginable). The VNRS is used routinely as a pain assessment and management tool for lung transplant recipients in this research setting. The instrument is well established and its scores have been reported to correlate strongly ($r = 0.95$) with scores on a visual analog scale in an adult population with acute pain. The VNRS has been used in previous studies of lung transplant recipients. Patients are more familiar with the VNRS, which is commonly used in clinical practice to assess pain intensity.

Preference. Patients’ preference regarding HFCWO and CPT was measured by using an abridged version of the Chest Physiotherapy Satisfaction Survey developed by Oermann and colleagues. The 4-item survey (Table 2) was completed by patients at the end of the treatment sequence on postoperative day 3. Subjects were asked about their treatment preference and which of the 2 methods of pulmonary hygiene they perceived as less painful and more effective. The

<table>
<thead>
<tr>
<th>Variables</th>
<th>Before treatment</th>
<th>Immediately after treatment (1 min)</th>
<th>After treatment (15 min)</th>
<th>End of treatment sequence</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Verbal numeric rating scale</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pain</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Preference</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Pain</td>
<td></td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Effectiveness</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>

### Table 1

Data collection timeline for verbal numeric rating scale and Patient Preference Questionnaire at time 1 (10 AM) and time 3 (6 PM)
survey included an open-ended question to determine the patients’ rationale for treatment preference.

**Data Analysis**

Descriptive statistics were used to summarize the overall sample demographics and clinical characteristics. Subgroup analyses were conducted according to transplant type (SLT and BLT). Differences in baseline demographic and clinical characteristics between both subgroups were determined by using t and F tests for continuous variables and \( \chi^2 \) test for categorical variables. Because of missing data at the 2 PM and 10 AM time points, data were analyzed and reported for only the 10 AM and 6 PM time points. In the cases with missing data, the patient did not complete data collection because of scheduled procedures (eg, imaging study, lung biopsy) at 2 PM or refused participation at the 10 PM time point because of fatigue. Patients included in the analyses had completed treatment using CPT and HFCWO as previously described.

To determine the potential confounding effect of analgesia on VNRS pain scores, patients were categorized into 2 groups based on administration of analgesics 2 hours before data collection (yes = received analgesics; no = did not receive analgesics) at time 1 and time 3. Four patients received patient-controlled analgesia and were included in the analgesic medication group if they had self-administered pain medication within the 2-hour period before data collection began.

A mixed-model analysis of variance was conducted to compare the effects of the 2 treatments by using the VNRS to measure differences in pain scores from before treatment to 15 minutes after treatment. The interaction effect was also tested to determine whether there was a differential treatment effect. Patients’ preference for the methods of treatment was examined by using a \( \chi^2 \) test. For descriptive purposes only, content analysis of the open-ended comments was performed to identify meaning and recurring themes.

Data were analyzed with SPSS version 17 statistical software. All tests of significance were 2-tailed, and the level of statistical significance was set at .05. Data are presented as means, standard deviations, and percentages.

**Results**

**Characteristics of the Sample**

Demographic and clinical characteristics are reported in Table 3. Of the total sample of 45 patients, 27 (60%) had SLT and 18 (40%) had BLT. The mean age of the total sample was 57 (SD 12.9) years. The BLT patients were significantly younger than the SLT patients (mean age, 46 years vs 65 years; \( F = 47.33; P < .001 \)). Twenty-nine transplant recipients (64%) were male and 16 (36%) were female. The most common diagnosis was pulmonary fibrosis (58%). SLT and BLT recipients differed significantly on the preoperative diagnosis of cystic fibrosis (\( \chi^2 = 6.59; P = .01 \)). All 4 patients with a preoperative diagnosis of cystic fibrosis underwent BLT. Other diagnoses included emphysema/chronic obstructive pulmonary disease (18%), pulmonary hypertension (33%), and sarcoidosis (2%). In terms of psychosocial diagnoses, 11% of patients had a history of depression, 7% anxiety, and 49% smoking. Use of pain medication within the 2 hours preceding data collection at 10 AM and 6 PM did not differ significantly between the 2 treatment groups (Table 4, \( P > .20 \)). Analyses showed no significant difference in other baseline demographic and clinical characteristics between the HFCWO and CPT groups.

Table 5 illustrates examples of comments on the effectiveness of the treatments. “Improved airway clearance” emerged as a common theme on the basis of comments from BLT recipients addressing the effectiveness of HFCWO. Among the SLT recipients, 2 common themes explained the effectiveness of HFCWO and CPT. One theme was “human touch” in support of CPT. The other common theme was “consistency and length of treatment,” which support the effectiveness of HFCWO.

### Table 2 Survey items relating to preference, pain, and effectiveness of treatment in the Patient Preference Questionnaire

<table>
<thead>
<tr>
<th>Question</th>
<th>Options</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Which method of chest therapy do you prefer?</td>
<td>• Inflatable vest • Patting chest and back with rubber percussors</td>
</tr>
<tr>
<td>2. Which method of chest therapy was less painful?</td>
<td>• Inflatable vest • Patting chest and back with rubber percussors</td>
</tr>
<tr>
<td>3. Which method of chest therapy do you think is more effective?</td>
<td>• Inflatable vest • Patting chest and back with rubber percussors</td>
</tr>
<tr>
<td>4. Why do you think that the above choice is more effective?</td>
<td></td>
</tr>
</tbody>
</table>

*Questionnaire derived from an abridged version of the Chest Physiotherapy Satisfaction Survey by Oermann et al.*

The greatest decrease in pain scores occurred with high-frequency chest wall oscillation treatment in both groups.
Table 3
Demographic and clinical characteristics of the total sample and by single and bilateral lung transplant type

<table>
<thead>
<tr>
<th>Variable</th>
<th>All patients (n = 45)</th>
<th>Single transplant (n = 27)</th>
<th>Bilateral transplant (n = 18)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, mean (SD), y</td>
<td>57 (12.89)</td>
<td>65 (5.24)</td>
<td>46 (12.76)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Sex, No. (%) of patients</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>29 (64)</td>
<td>18 (67)</td>
<td>11 (61)</td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>26 (36)</td>
<td>9 (33)</td>
<td>7 (39)</td>
<td>.70</td>
</tr>
<tr>
<td>Preoperative diagnoses, No. (%) of patients</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pulmonary hypertension</td>
<td>15 (33)</td>
<td>7 (26)</td>
<td>8 (44)</td>
<td>.20</td>
</tr>
<tr>
<td>Cystic fibrosis</td>
<td>4 (9)</td>
<td>0 (0)</td>
<td>4 (22)</td>
<td>.01</td>
</tr>
<tr>
<td>Pulmonary fibrosis</td>
<td>26 (58)</td>
<td>18 (67)</td>
<td>8 (44)</td>
<td>.14</td>
</tr>
<tr>
<td>Emphysema/chronic obstructive pulmonary disease</td>
<td>8 (18)</td>
<td>4 (15)</td>
<td>4 (22)</td>
<td>.52</td>
</tr>
<tr>
<td>Sarcoidosis</td>
<td>1 (2)</td>
<td>0 (0)</td>
<td>1 (6)</td>
<td>.22</td>
</tr>
<tr>
<td>Depression</td>
<td>5 (11)</td>
<td>3 (11)</td>
<td>2 (11)</td>
<td>&gt;.99</td>
</tr>
<tr>
<td>Anxiety</td>
<td>3 (7)</td>
<td>3 (11)</td>
<td>0 (0)</td>
<td>.14</td>
</tr>
<tr>
<td>Smoking history</td>
<td>22 (49)</td>
<td>13 (48)</td>
<td>9 (50)</td>
<td>.90</td>
</tr>
</tbody>
</table>

Table 4
Characteristics of the total sample and treatment groups who received analgesic medications

<table>
<thead>
<tr>
<th>Time when received analgesics</th>
<th>Total sample (n = 44)</th>
<th>Group 1 CPT-HFCWO (n = 22)</th>
<th>Group 2 HFCWO-CPT (n = 22)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time 1 (10 AM)</td>
<td>26 (59)</td>
<td>14 (64)</td>
<td>12 (55)</td>
</tr>
<tr>
<td>Time 3 (6 PM)</td>
<td>17 (39)</td>
<td>6 (27)</td>
<td>11 (50)</td>
</tr>
<tr>
<td>Total (Time 1 + Time 3)</td>
<td>43 (49)</td>
<td>20 (45)</td>
<td>23 (52)</td>
</tr>
</tbody>
</table>

Abbreviations: CPT, chest physiotherapy; HFCWO, high-frequency chest wall oscillation.

Table 5
Descriptive summary of themes from patients’ comments on the effectiveness of treatment using high-frequency chest wall oscillation (HFCWO) and chest physiotherapy (CPT) from the Patient Preference Questionnaire

<table>
<thead>
<tr>
<th>Single lung transplants</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Theme 1. Human touch (CPT)</td>
<td>“Human touch is always the best.” (favoring CPT)</td>
</tr>
<tr>
<td>Theme 2. Consistency and length of treatment (HFCWO)</td>
<td>“Vest is consistent; treatment is longer than CPT.” (favoring HFCWO)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Bilateral lung transplants</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Theme Improved airway clearance (HFCWO)</td>
<td>“I don’t know why but all I know is that when “vest” is done, I feel clearer.”</td>
</tr>
<tr>
<td></td>
<td>“I feel that the vest gives more of an overall average to help with secretions especially since not having to force a cough while doing it, which proves difficult with chest tubes.”</td>
</tr>
<tr>
<td></td>
<td>“It causes more sputum to come.”</td>
</tr>
</tbody>
</table>

VNRS Pain Scores
Medians and interquartile ranges for VNRS pain scores are shown in Table 6 for the total sample and for each treatment group. Figure 2 illustrates mean differences in pain scores from before to after treatment at 10 AM and 6 PM for group 1 and group 2. Pain scores did not differ significantly from before to after treatment among patients who received CPT in group 1 at 10 AM and group 2 at 6 PM (P > .05). Group 1 had a tendency toward a significant decrease in pain scores from before to after treatment with HFCWO at 6 PM (F = 3.06; P = .10). Patients who received HFCWO in group 2 at 10 AM showed a significant decrease in pain scores from before to after treatment (F = 15.70; P = .001). Overall, the greatest decrease in pain scores occurred with HFCWO treatment in both groups at 10 AM and at 6 PM.

Further analyses were done to determine mean difference scores (score 15 minutes after treatment minus score before treatment) for pain by using repeated measures at 10 AM and 6 PM. The independent variable was treatment method (order). A significant interaction effect of time and treatment order on the mean difference in pain scores from before to after treatment was noted (F = 4.79, P = .04; Figure 3). Regardless of order and treatment, greater reduction in pain scores occurred with HFCWO treatment in both groups at 10 AM and at 6 PM.

When intake of pain medication was used in the model as the controlled variable, the effect observed was slightly attenuated to a borderline significance (F = 4.048, P = .05). This finding suggests that use of pain medication may slightly decrease the effect of the interaction of time and treatment order (HFCWO vs CPT).

No difference was found between single and bilateral transplant types (P = .66), so both subgroups
were combined. When transplant type was included in the same model, the results showed a nonsignificant trend toward greater pain reduction with HFCWO compared with CPT ($P = .07$). A post hoc power analysis of differences in pain scores for the within-between interaction revealed a power of 0.57 with a significance level of .05 (2-tailed). A total sample of 140 subjects would have been required to obtain 80% power given the small effect size (0.12).

**Survey Data: Preference, Pain, and Effectiveness**

**Preference.** Overall, no significant preference for HFCWO over CPT was found in lung transplant recipients. However, BLT recipients showed a significant preference for HFCWO over CPT at the end of the treatment sequence (85% vs 15%; Figure 4). Among SLT recipients, no difference in preference was found between HFCWO and CPT (42% vs 54%). One patient had no preference between the 2 therapies.

**Pain.** In response to a question about which technique was less painful, similar degrees of painfulness were reported for HFCWO and CPT (50% vs 50%, $P > .05$). Interestingly, 4 SLT recipients reported both methods as less painful and 2 SLT recipients reported that neither treatment was less painful.

**Effectiveness.** Overall, SLT and BLT recipients’ reported the 2 treatments to be similar in effectiveness. Among SLT recipients, the 2 treatment methods did not differ significantly in terms of effectiveness. Five SLT recipients reported both methods as more effective, and 1 reported neither treatment as more effective. BLT recipients reported HFCWO as significantly more effective than CPT (77% vs 23%, $P = .05$).

**Discussion**

This study is the first to compare the effect of HFCWO and CPT on outcome measures of pain and preference in lung transplant recipients. We hypothesized that significantly less pain would be reported by patients receiving HFCWO than by patients receiving CPT and that significantly more patients would prefer HFCWO than would prefer CPT. Overall, both SLT and BLT recipients reported significantly less pain with HFCWO. Collectively, no significant difference in preference was apparent. However, the BLT patients significantly preferred HFCWO over CPT. The SLT recipients reported no difference in preference between HFCWO and CPT.

**Pain**

We are the first to assess the effect of HFCWO and CPT on pain scores by using a valid and reliable VNRS that is routinely used in the clinical setting. Our data provide strong evidence that pain scores as measured by using a VNRS are lower for HFCWO than for CPT in lung transplant recipients. Pain control is an important clinical parameter among lung transplant recipients. During the postoperative period, adequate pain control allows mobilization of secretions, proper expectoration of sputum, and better ventilation. Thoracic pain prevents deep breathing and can result in atelectasis and infection. In addition, lung transplant recipients are immediately administered immunosuppressants and steroids, which places them at a greater risk for infection. Pulmonary hygiene is imperative postoperatively, because airway complications are the most common causes of morbidity and mortality after lung transplantation.

**Table 6**

<table>
<thead>
<tr>
<th>Time relative to treatment</th>
<th>Pain score, median (interquartile range)</th>
<th>Total sample</th>
<th>Group 1 CPT-HFCWO</th>
<th>Group 2 HFCWO-CPT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time 1 (10 AM)</td>
<td>Before</td>
<td>3.0 (2.0-5.0)</td>
<td>4.0 (0.0-5.5)</td>
<td>3.0 (2.0-5.0)</td>
</tr>
<tr>
<td></td>
<td>15 min after</td>
<td>2.0 (0.13-4.0)</td>
<td>3.0 (0.25-4.0)</td>
<td>2.0 (0.0-3.0)</td>
</tr>
<tr>
<td>Time 3 (6 PM)</td>
<td>Before</td>
<td>3.0 (0.25-4.75)</td>
<td>3.0 (0.0-4.0)</td>
<td>3.0 (1.5-5.0)</td>
</tr>
<tr>
<td></td>
<td>15 min after</td>
<td>2.0 (0.0-3.75)</td>
<td>0.5 (0.0-3.0)</td>
<td>2.0 (1.0-4.0)</td>
</tr>
</tbody>
</table>

Abbreviations: CPT, chest physiotherapy; HFCWO, high-frequency chest wall oscillation.

**Figure 2**

Mean differences in pain scores on verbal numeric rating scale between groups from before to 15 minutes after treatment at 10 AM and 6 PM. A significant decrease in mean pain scores occurred in group 2 with the high-frequency chest wall oscillation (HFCWO: 3.50 to 2.08 at 10 AM; $P = .001$). A trend toward improvement in pain scores was seen in group 1 with HFCWO (2.62 to 1.74 at 6 PM; $P = .10$). No differences were reported in either group with chest physiotherapy (CPT).
A significant time by treatment type interaction was observed for VNRS pain scores. Regardless of time and order of treatment, these data suggest that HFCWO may be more effective than CPT in lowering pain severity from before to after treatment. A HFCWO-CPT difference may be apparent in patients with higher pain levels. We cannot exclude the presence of low variability among VNRS pain scores. However, pain scores in group 1 with a higher versus lower pain level before treatment shows a somewhat stronger reduction in pain level with HFCWO than with CPT, supporting the likelihood that HFCWO may be particularly useful in patients with higher pain levels before treatment. Increasing a parameter (medication variable) generally decreases the power to detect the effect. Therefore, the medication effect is rather inconclusive. Further study is warranted in a larger sample to evaluate the use of pain medication as a mediating or moderating variable.

Previous studies comparing HFCWO with CPT used outcome measures such as comfort and tolerability. For example, in a qualitative study of thoracic surgery patients, 84% of the patients had little or no discomfort with HFCWO, as compared with conventional CPT. Osman and colleagues found no significant differences between HFCWO and the usual airway clearance method with respect to scores for comfort measured on a visual analog scale. Conversely, Oermann et al. reported that the Flutter, a portable device that provides positive expiratory pressure, was better tolerated and more comfortable than HFCWO and postural drainage, percussion, and vibration. One possible explanation for our results may be that the vest is clothlike and covers the entire thorax and the upper part of the abdomen, whereas CPT involves striking over the chest wall with rubber percussors. The HFCWO may be less painful because it involves less focused contact on the incisional area.

Our finding that neither HFCWO nor CPT was considered less painful among both treatment groups was counterintuitive. It is possible that the measurement of pain in the survey was not sufficient to adequately capture which treatment was less painful. Individual evaluation of each treatment by using a 4-point Likert scale of descriptor categories (eg, less painful) may better capture differences. Anderson et al. surveyed pain (using none, mild, moderate, and severe categories) during HFCWO in a sample of patients with thoracic blunt trauma and found it to be well-tolerated, with most patients reporting no pain to mild pain. Moreover, patients’ fatigue and timing of the survey at the end of the last treatment may have been contributory factors.

Preference
To date, this study is the only experimental research in which treatment preference was examined in lung transplant recipients. Until now, lung transplant recipients’ preference among airway clearance
techniques such as HFCWO and CPT was relatively unknown. Preference is an important clinical variable because it can influence patients’ adherence to the pulmonary care regimen.

We found that BLT patients preferred HFCWO to CPT. In a previous study, Arens et al. reported that HFCWO was preferred over CPT in patients with cystic fibrosis. However, the investigators did not report on possible explanations for this greater preference among patients with cystic fibrosis. Similar findings were observed in the study by Allan and colleagues, where thoracic surgery patients preferred HFCWO to routine CPT. The investigators proposed that the preference for HFCWO over CPT was because the oscillatory impulses from the HFCWO are non-focally distributed across the thorax in contrast to the focal impulse of manual percussion. On the contrary, Varekojis et al. found no significant difference in preference among hospitalized patients with cystic fibrosis for 3 techniques: postural drainage and percussion, intrapulmonary percussive ventilation, and HFCWO. Moreover, in another study, researchers observed greater preference (55%) among patients with cystic fibrosis for their usual airway clearance technique than for HFCWO. We also theorize that the nonfocal nature of the oscillatory impulses in HFCWO may result in less concentrated pressure, less discomfort, and greater preference.

Significant differences in age were observed between SLT and BLT patients, indicating that BLT patients were younger than SLT patients. This difference is most likely due to the selection criteria for bilateral transplants, with an upper age limit of 60 years at the study site. In select cases, patients more than 60 years of age may undergo BLT for preoperative elevated pulmonary artery pressure and bronchiectasis. No such age limit is used for SLT recipients. We presume that the anatomy of the surgery, as opposed to age of the patients, is a contributing factor related to BLT recipients’ preference for HFCWO. The BLT maintains chest tubes on both sides. The HFCWO may splint the chest in a way that provides a sense of chest stability, while simultaneously oscillating and mobilizing secretions across all lobes of the lung.

Findings in favor of HFCWO as it relates to efficacy/effectiveness domains of preference or satisfaction have been mixed. In the current study, “improved airway clearance” emerged as a common theme addressing the BLT recipients’ rationale for effectiveness of HFCWO. This theme may explain why BLT recipients preferred HFCWO to CPT. Among the SLT recipients, preferences were equally distributed between HFCWO and CPT. Two common themes emerged from the effectiveness question.

One theme was “human touch” in support of CPT; another theme was “consistency and length of treatment” in support of HFCWO. Although adherence was not explored in this study, we presume that patients’ preference would positively influence treatment adherence. Patients’ preference is an important part of the clinical decision-making process to ensure adherence to the postoperative regimen and optimize clinical outcomes.

**Limitations**

Our study had several limitations. First, the relatively small sample size may have precluded the detection of small-group differences between HFCWO and CPT on targeted outcome variables and warrants cautious interpretation of the findings. In spite of the low statistical power, our exploratory pilot data provide support for the possibility of differences in pain and preference for lung transplant recipients using CPT and HFCWO and estimates for a larger study.

Second, lung transplant recipients are a unique population of critically ill patients with the most severe lung disease and greatest risk for postoperative pulmonary complications compared with other thoracic surgical patients. This, in turn, limits the generalizability of observed findings to this highly specialized population of lung transplant recipients. However, the potential applicability and benefit of these airway clearance methods holds promise for other surgical populations.

Third, residual confounding factors (eg, analgesics and anxiolytics) may mediate the relationship between HFCWO and CPT on targeted outcome variables and leads to pain and preference outcomes. Therefore, future studies should consider the effect of medications on pain and preference. Of note, nearly all patients in this study were naïve with respect to past experience with the airway clearance treatments, particularly HFCWO. Furthermore, issues to be addressed by future studies include treatment effectiveness and adherence. In addition, future studies should assess patients’ outcomes that might address whether there is a difference in patient benefit when HFCWO is used rather than CPT.

Fourth, treatment times varied between HFCWO and CPT (15 minutes vs 3 minutes, respectively). It is plausible that this variation may have influenced patients’ ratings of pain and preference. For the purpose of this study, the investigators followed the routine standards of care regarding duration of therapy

For lung transplant recipients with higher levels of pain, high-frequency chest wall oscillation may be used as the initial airway clearance therapy.
that were stated in the intensive care unit’s policy. Thus, future studies should explore the effects of treatment time on pain and preference.

Fifth, although the registered nurses followed a strict protocol for data collection and received competency training, bias could have occurred during data collection. Given the nature of the interventions, we were unable to blind patients or nurses collecting data to group treatment order. However, to minimize bias further, data collection instruments were checked to ensure proper coding, and nurses who collected data were not assigned or responsible for the care of the patient on the day of data collection. Finally, the study was conducted at a single facility. Replication with a larger sample and in a multicenter study is warranted.

Conclusions

This study was conducted as a pilot investigation to determine the feasibility of design and procedures for comparing HFCWO versus CPT on measures of pain and preference in lung transplant recipients. Overall, HFCWO produced greater decreases in pain scores than did CPT. The BLT recipients preferred HFCWO to CPT. We speculate that HFCWO is an effective and feasible alternative to CPT. For lung transplant recipients who are experiencing higher levels of pain, HFCWO may be used as the initial method of airway clearance therapy. Further investigation is warranted to explore the influence of analgesics and anxiolytics on outcome variables between these 2 methods of therapy and to extend this research to include a larger sample from multisite settings.

ACKNOWLEDGMENTS

The authors thankfully acknowledge the contributions of Charles Burchette, RN, Alisse Chan, RN, MSN, Seve Madrona, RN, Ashley Madsen, RN, Michelle Mekpongstorn, RN, Allison Parker, RN, Julia Porter, RN, MSN, Aliza Richman, RN, and Zeba Shameem, RN, members of the Research Institute and staff from the cardia-thoracic intensive care unit; and Irena Var-tapetian, RRT, from the respiratory therapy department at Ronald Reagan University of California, Los Angeles, Medical Center. The authors are grateful to the patients who participated in this study and their families.

FINANCIAL DISCLOSURES

This study was funded by grants from the American Association of Critical-Care Nurses, the American Nurses Foundation, and Sigma Theta Tau International, Gamma Tau Chapter.

REFERENCES


To purchase electronic or print reprints, contact The InnoVision Group, 101 Columbia, Aliso Viejo, CA 92656. Phone, (800) 899-1712 or (949) 362-2050 (ext 532); fax, (949) 362-2049; e-mail, reprints@acin.org.