A Comparison of Manual to Mechanical Chest Percussion for Clearance of Alveolar Material in Patients With Pulmonary Alveolar Proteinosis (Phospholipidosis)*

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To our knowledge, there are no studies that compare the effectiveness of manual chest percussion (MN), mechanical chest percussion (MC), and no percussion (NP) for removing the proteinaceous material found in the alveoli of patients with pulmonary alveolar proteinosis (PAP) while undergoing whole-lung bronchopulmonary lavage (BPL). We analyzed the optical densities (OD) of 27 bottles of effluent from three BPLs of a patient with PAP. One technique was used per bottle. The order of techniques was balanced within each nine-bottle series and among the three BPLs. The mean OD for MN (0.933 ± 0.494) was significantly superior to MC (0.477 ± 0.265) (p<0.0005) and NP (0.318 ± 0.242) (p<0.0001). We conclude that MN is superior to MC and NP and increases the therapeutic results of BPL for PAP.

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BPL = bronchopulmonary lavage; MC = mechanical chest percussion; MN = manual chest percussion; NP = no percussion; OD = optical density; PAP = pulmonary alveolar proteinosis; TLC = total lung capacity

Pulmonary alveolar proteinosis (PAP), or phospholipidosis, is a relatively rare disease of unknown etiology that was first described by Rosen et al in 1958. This disease is characterized by the accumulation of periodic acid-Schiff (PAS)-positive lipid material in the alveoli, while the interstitial lung architecture remains normal. The most common symptoms are a nonproductive cough, progressive dyspnea especially with exercise, a "heavy" sensation in the chest, and weight loss. The chest radiograph usually shows bilateral alveolar or nodular infiltrates without mediastinal or hilar lymphadenopathy. The diagnosis is made by open lung biopsy specimen or special staining of segmental bronchial washings obtained through a flexible bronchoscope. Although a number of therapeutic measures have been tried with variable results, bronchopulmonary lavage (BPL) is recognized as the most effective treatment for patients with significant dyspnea on exertion.

Administering manual chest percussion (MN) or mechanical chest percussion (MC) during BPL is reported to increase the amount of particulate material drained into the effluent bottles. However, to date and to our knowledge, there are no studies that have measured the effects of performing chest percussion during this procedure. The purpose of this study was to compare the effectiveness of MN, MC, and no percussion (NP) on draining the proteinaceous material found in the alveoli of a patient with PAP, while undergoing BPL.

METHOD

A 35-year-old woman was studied during therapeutic whole-lung BPL in the operating room on three separate occasions. Her pulmonary function and arterial blood gas data are summarized in Table 1. The lactate dehydrogenase (LDH) measured 291 IU/L before BPL 1 and 230 IU/L before BPLs 2 and 3 (normal <170 IU/L). The lavage technique used at our center has been described in detail elsewhere. The right lung was lavaged twice (BPL 1 and 2) and the left lung once (BPL 3). BPLs 1 and 2 were separated by eight months; BPL 3 was done two days after BPL 2.

The lung was alternately filled with saline solution to total lung capacity (TLC) and drained to the functional residual capacity (FRC) until the procedure was terminated with the effluent almost clear, after using 30 L. To ensure the patency of the system, the first four 1-L bottles were drained without percussion. Beginning with the fifth bottle, either MN (at a rate of 180 to 270/ml), MC using a rotary directional-stroke percussor at 36 Hz (G-5, General Physiotherapy, St Louis) or NP was done over the anterior and anterolateral chest wall of the lung being lavaged. Percussion was applied for 2 min as the lung was drained from TLC. Only one technique was done per bottle. Care was taken not to percuss over the heart or breast tissue.

This study was done according to a protocol that had been approved by the University of Oklahoma Health Sciences Center Institutional Review Board. Maintaining the volume of saline solution constant, nine bottles of fluid were collected during each lavage and saved for analysis, varying the order of these three techniques. The order of techniques was balanced within each nine-bottle series and among the three BPLs (Table 2).

Samples were collected during an earlier lavage of this patient, and a linear regression was performed to determine the predictive value of optical density (OD) (diluted 1/25) for dry weight. A significant relationship (p = 0.0001) existed (predicted dry

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weight = 0.042724 × OD + 0.005978), and we chose to use the OD measurements for this study. A 1-ml aliquot was taken from each well shaken bottle and diluted 1:25 with normal saline solution for OD measurements of relative turbidity by a spectrophotometer at 280 nm. The measurements were recorded for statistical analysis. An analysis of variance appropriate for a one-factoral repeated measure experimental design was performed to test the null hypothesis of no difference among the three percussion techniques.

**RESULTS**

Rejection of the null hypothesis was indicated by a significant (p = 0.0001) F statistic. Subsequent pairwise comparisons determined a significant difference between MN (0.933 ± 0.494) and MC (0.477 ± 0.265) at p<0.0005. Manual chest percussion was also significantly different from NP (0.318 ± 0.242) at the p<0.0001 level. Mechanical chest percussion and NP were not significantly different (p<0.1726).

Manual chest percussion was almost twice as effective as the MC, according to the mean OD measurements. Only bottles of material obtained by MN exceeded an OD reading of 1.0. In BPLs 2 and 3, the highest three measurements of the nine bottles studied were those in which MN was administered. In BPL 1, three of the four highest OD readings were obtained by MN. Only once did the highest MC measurement within a BPL exceed the lowest MN reading (BPL 1 bottle 6 vs bottle 12).

Manual chest percussion was significantly superior to this type of mechanical percussor (Fig 1 through 3). This was also apparent when comparing each three-bottle series within BPLs 1 through 3. In each of the series, MC measurements never equaled or exceeded the manual technique. Rather, MN consistently removed from 1.6 to 2.9 times as much material per bottle as MC, regardless of the order of the techniques.

During the collection of each bottle of effluent, the turbidity of the saline solution increased as the lung drained down to FRC. The dense material that remained in the clamped tubing at the end of MN tended to enhance the reading of the bottle that followed it. However, a comparison of the OD measurements of the two percussion techniques that followed bottles of NP (to eliminate this enhancement) further supports the superiority of MN. For example, within BPL 1, bottle 10 (manual) had an OD 1.6 times greater than bottle 8 (mechanical), even though it occurred later in the lavage when a diminished amount of proteinaceous material would be expected from the lung. In BPL 2 this was even larger, as bottle 7 (manual) removed 2.2 times the material bottle 5 (mechanical) did (bottles 1 through 4 were NP). Within BPL 3, the OD of bottle 6 (manual) was 2.9 times that of bottle 11 (mechanical), due in part to occurring earlier in the procedure when more particulate material was present in the alveoli. Mechanical chest percussion was similar to NP, except at the end of BPL 3 (bottle 11) when it was more than twice as effective as the preceding bottle.

Both BPL 1 and BPL 2 were performed on the right lung (eight months apart). The similar group values of the ODs from BPL 1 (mean, 0.723; median, 0.620; range, 1.683 to 0.225 = 1.458) and BPL 2 (mean, 0.784; median, 0.692; range, 1.448 to 0.208 = 1.24) indicate a similar amount of alveolar material was present. If the percussion techniques were equally

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**Table 1—Pulmonary Function Tests and Arterial Blood Gases**

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Prelavage (%) pred</th>
<th>Postlavage (%) pred</th>
<th>Prelavage (%) pred</th>
<th>Postlavage (%) pred</th>
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</thead>
<tbody>
<tr>
<td>FVC, L</td>
<td>1.42 (40)</td>
<td>2.05 (58)</td>
<td>1.70 (48)</td>
<td>2.19 (62)</td>
</tr>
<tr>
<td>FEV&lt;sub&gt;1&lt;/sub&gt;, L</td>
<td>1.26 (45)</td>
<td>1.78 (63)</td>
<td>1.54 (55)</td>
<td>1.88 (67)</td>
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<tr>
<td>FEV/FVC, %</td>
<td>89</td>
<td>87</td>
<td>91</td>
<td>96</td>
</tr>
<tr>
<td>FEF25-75, L/s</td>
<td>1.72 (52)</td>
<td>2.30 (70)</td>
<td>2.49 (76)</td>
<td>2.36 (72)</td>
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<tr>
<td>VC, L</td>
<td>1.45 (41)</td>
<td>2.05 (58)</td>
<td>1.79 (50)</td>
<td>2.22 (63)</td>
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<tr>
<td>TLC, L</td>
<td>2.92 (60)</td>
<td>3.21 (65)</td>
<td>2.92 (60)</td>
<td>3.44 (70)</td>
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<tr>
<td>RV, L</td>
<td>1.46 (50)</td>
<td>1.16 (76)</td>
<td>1.14 (74)</td>
<td>1.21 (79)</td>
</tr>
<tr>
<td>FRC, L</td>
<td>1.76 (62)</td>
<td>1.70 (59)</td>
<td>1.77 (63)</td>
<td>—</td>
</tr>
<tr>
<td>Dsb, ml/min/mm Hg</td>
<td>6.9 (33)</td>
<td>12.8 (63)</td>
<td>6.4 (31)</td>
<td>13.9 (67)</td>
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<td>7.43</td>
<td>7.43</td>
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<tr>
<td>PaCO&lt;sub&gt;2&lt;/sub&gt;, mm Hg</td>
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<tr>
<td>PaO&lt;sub&gt;2&lt;/sub&gt;, mm Hg</td>
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<td>85</td>
<td>54</td>
<td>86</td>
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<td>FIO&lt;sub&gt;2&lt;/sub&gt;</td>
<td>0.21</td>
<td>0.21</td>
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</tbody>
</table>

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**Table 2—Order of Techniques**

<table>
<thead>
<tr>
<th>Bottle No.</th>
<th>BPL 1</th>
<th>BPL 2</th>
<th>BPL 3</th>
</tr>
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<tbody>
<tr>
<td>5</td>
<td>MN</td>
<td>MC</td>
<td>NP</td>
</tr>
<tr>
<td>6</td>
<td>MC</td>
<td>NP</td>
<td>MN</td>
</tr>
<tr>
<td>7</td>
<td>NP</td>
<td>MN</td>
<td>MC</td>
</tr>
<tr>
<td>8</td>
<td>MC</td>
<td>NP</td>
<td>MN</td>
</tr>
<tr>
<td>9</td>
<td>NP</td>
<td>MN</td>
<td>MC</td>
</tr>
<tr>
<td>10</td>
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<td>MN</td>
<td>MC</td>
</tr>
<tr>
<td>12</td>
<td>MN</td>
<td>MC</td>
<td>NP</td>
</tr>
<tr>
<td>13</td>
<td>MC</td>
<td>NP</td>
<td>MN</td>
</tr>
</tbody>
</table>

*BPL = bronchopulmonary lavage; MN = manual chest percussion; MC = mechanical chest percussion; NP = no chest percussion.
OPTICAL DENSITIES OF ALIQUOTS READ AT 280 nm

(BILTED 1/25)

BPL 1

ABSORBANCE

0
0.5
1
1.5
2

MN  MC  NP  MC  NP  MN  NP  MN MC  NP
5   6   7   8   9   10  11  12  13

OPTICAL DENSITIES OF ALIQUOTS READ AT 280 nm

(DILUTED 1/25)

BPL 2

ABSORBANCE

0
0.5
1
1.5
2

MC  NP  MN  MC  NP  MN  MC  NP  MN  MC  NP
5   6   7   8   9   10  11  12  13

OPTICAL DENSITIES OF ALIQUOTS READ AT 280 nm

(DILUTED 1/25)

BPL 3

ABSORBANCE

0
0.1
0.2
0.3
0.4
0.5

NP  MN  MC  NP  MC  NP  MN  MC  NP  MN  MC
5   6   7   8   9   10  11  12  13

Effective, it would be expected that the same num-
bered bottles during the course of the lavage would
have similar measurements. Because the order of
techniques was varied between BPLs 1 and 2, both
MN and MC occurred only during the collection of
bottles 5, 10, and 12. In both BPLs, bottle 5 was

FIGURE 1. A comparison of the turbidity (light
absorbance) of samples taken from effluent bottles
using the three techniques in bronchopulmonary
lavage 1 (BPL 1).

FIGURE 2. A comparison of the turbidity (light
absorbance) of samples taken from effluent bottles
using the three techniques in bronchopulmonary
lavage 2 (BPL 2).

FIGURE 3. A comparison of the turbidity (light
absorbance) of samples taken from effluent bottles
using the three techniques of bronchopulmonary
lavage 3 (BPL 3).
preceded by NP and yet the OD of the manual bottle was 2.61 times greater than the mechanical bottle. Even though bottles 10 and 12 in BPL 2 were enhanced by directly following bottles of MN, the manual technique in BPL 1 still had 1.49 and 1.62 times greater turbidity than did the mechanical percussor in BPL 2.

The importance of including MN during lavages for PAP can be seen by comparing the ODs between the bottles of NP and MN. In each of the three-bottle series, from 1.8 to 4.8 times more the amount of alveolar material was removed by doing MN.

**DISCUSSION**

This study was undertaken after our clinical observation during BPLs that MN produced a visible increase in the amount of particulate material removed from the lungs of these patients, as evidenced by increased turbidity in the effluent bottles. We wanted to quantify this difference and also determine if the mechanical percussor might further improve the lavage results.

The ODs indicate that the disease was more extensive in the right lung than the left. This correlates well with the patient's chest radiograph and oxygen uptake prior to the lavages. Even with a reduced amount of material in the left lung, MN remained proportionately superior to MC.

A number of centers doing BPLs for PAP have recognized the value of adding chest percussion to the procedure.2,3,5-5 Some have advocated the manual technique5,6 while at least one has used a mechanical percussor,7 although it is a device different from the model that we evaluated in this study.

Manual percussion has been compared with MC in only three previous studies. All used a vertical stroke percussor rather than the rotary stroke percussor we studied. In a group of 14 patients with cystic fibrosis, Maxwell and Redmond8 found there was no significant difference between the FEV1, FVC, and sputum volume produced by the two types of percussion. Pryor et al10 used a randomized cross-over design over 4 days to study 12 patients with cystic fibrosis. These patients did self-administered MC or MN along with postural drainage and the forced expiratory technique. There was no significant difference in the weight of sputum cleared by either technique. However, with MN, there was a statistically significant improvement of FEV1 and FVC at 5, 15, 30, and 45 min posttreatment. Flower et al11 used tracheal or esophageal balloons to evaluate intrathoracic pressure changes produced by MN and MC in 22 adult cadavers and 9 volunteers. The mechanical percussor maintained a higher and more constant intrathoracic pressure of 25 to 30 cm H2O, whereas three therapists generated pressures of 5, 12, and 15 cm H2O. While the mechanical percussor may cause greater intrathoracic pressure changes, these studies indicate MN is equal or superior to MC for draining sputum and improving spirometry in patients with cystic fibrosis. The present study also supports the superiority of MN over MC for removing alveolar material from patients with PAP during BPLs.

The use of MN during BPL in the operating room reduces the length of the procedure and clearly increases the therapeutic results in patients with PAP. Others have reported a more complete clearing of the chest radiographs2,3,5 and our experience supports this. We recommend MN be included as an important part of BPL of patients with PAP. Further study is needed to compare MN with manual vibration, as well as how the training and experience of the therapist performing these techniques may affect the amount of particulate material removed. Also, additional study is needed to determine whether one of the numerous other models of mechanical percussors available might perform better than the manual techniques.

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**REFERENCES**