experienced especially severe bilateral pulmonary inflammatory infiltrates, did the initial chest drain insertion not prevent the progression of his respiratory distress leading to intubation and ventilatory support.

ACKNOWLEDGMENT: We thank Dr. K.F. To of the Chinese University of Hong Kong for providing details of the postmortem findings in SARS patients; A. Cheung, Dr. M.T. Hwong, and S.Y.Y. Lam of the Chinese University of Hong Kong for their assistance with statistical analysis; Dr. K.S. Chan of the UCH for coordinating transfer of data between PWH and UCH; and Drs. T.W. Lee and K.H. Thung of the PWH for advice on the preparation of the manuscript.

REFERENCES
8 Tomlinson B, Cockram C. SARS: experience at Prince of Wales Hospital, Hong Kong. Lancet 2003; 361:1486–1487
clearance using vigorous manual chest physical therapy. Our clinical impression is that this technique has resulted in more complete clearing of the lung fields and in longer remissions of the disease process, but we do not have data to substantiate that impression. The purpose of this study was to measure the effectiveness of each component in our WLL process by measuring the dry weight of material obtained during isolated fluid lavage, as well as positional and assisted lung clearance techniques.

**Materials and Methods**

We studied five patients who were underwent a total of six consecutive WLLs performed at the University of Pittsburgh Medical Center between February 2001 and February 2003. These patients required lung lavage based on clinical and physiologic criteria. Spirometry, lung volume measurements, and diffusing capacity of the lung for carbon monoxide (DLco) measurements were performed before and after the lavage procedure using American Thoracic Society standards. The Institutional Review Board of the University of Pittsburgh approved the study, and all patients provided informed consent to participate in this study.

**Lavage Procedure**

The patients were intubated with a double-lumen endotracheal tube, with confirmation of appropriate placement by fiberoptic bronchoscopy. The isolation of each lung was confirmed by water seal testing at 50 to 60 mm Hg pressure. The designated lung was lavaged with warmed normal sterile saline solution (37°C), with total volumes ranging from 45 to 60 L (ie, high-volume lavage). The initial lavages were performed using aliquots of 250 to 500 mL and were gradually titrated up to approximately 50% of the previously measured functional residual capacity. Effluent was collected in sequentially numbered 1.5-L bottles. The lung lavage was performed in three sequential stages. Stage I reflected the initial portion with the patient in the supine position, during which time there was instillation and removal of fluid until the effluent appeared to be clear. Stage II represents assisted clearance with vigorous manual chest percussion until the fluid again was clear. Percussion was administered during both instillation and removal, but more vigorously during effluent drainage. Finally, stage III involved positional clearance in which the patient was placed in the prone position with continuation of chest percussion during lavage and the effluent was collected until it was clear. At that point, the procedure was terminated. The sequentially numbered bottles were marked to identify the transition from one stage to the next. A new bottle was used at each of these points.

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**Weighing Materials**

Since the majority of the solid material in the effluent is surfactant, we used a method based on a previously described technique for isolating surfactant. All bottles of effluent were stored at 4°C until they could be analyzed. The lipoproteinaceous material tends to settle over time due to gravity, so the material was resuspended by vigorously agitating the bottles prior to withdrawing a 250-mL aliquot from each bottle. The aliquot was centrifuged at 27,500 g for 50 min. The supernatant was discarded, and the dry weight of the pellet was measured. The volume of effluent remaining in the bottle was determined using a 2-L graduated cylinder. The total weight for each bottle was calculated by the weight of the pellet multiplied by the ratio of the total volume of fluid in the bottle divided by the aliquot volume (250 mL). We were thus able to estimate the dry weight of material in each bottle.

**Data Summary and Statistical Analysis**

The dry weight of the material in each sequential bottle was noted. The dry weight of the bottle prior to and at each transition stage was noted. We summarized the cumulative dry weight of material during each of the three major parts of the procedure. To account for the large variability in the weight of the material being removed, we also expressed this in terms of the percentage of total material for the three stages of the procedure. We summarized the weight of the effluent for each individual bottle vs the sequential bottle number, indicating the points of major intervention, or stages. The mean, SD, and range were determined for volume, weight, and percentage weight at all three stages of the lavage procedure. A paired Student t-test was performed on the data from pulmonary function tests (PFTs) before and after lung lavage. The significance of the difference in terms of the dry weight of the last bottle prior to and after each stage transition was determined using a paired t test. All statistical analyses were performed using a statistical software program (Minitab, release 13.31; Minitab Inc; State College, PA).

**Results**

The average amount of saline solution used, the total amount used, and the amount for each stage used for the 12 WLLs are summarized in Table 1. The right lung lavage in the first lavage set in patient 4 was terminated after the patient was placed in the prone position due to displacement of the bronchial cuff of the endotracheal tube. No additional complications during the lavage of the other patients were recognized. The dry weight of the material collected during the lavage procedures ranged from 30.9 to 387 g, with a mean of 199 ± 104 g. The mean percentage of material being removed in each stage was as follows: stage I, 32.1% ± 21.7%; stage II, 57.4% ± 19.9%; and stage III, 10.5% ± 6.1% (Table 2).

The effluent dry weight was recorded for each bottle, sequentially. This was then graphed with the designation of time points for the initiation of stages I and III. A representative graph from a single lavage is illustrated in Figure 1. We also noted the weight in each bottle prior to and at the initiation of each intervention, and these are shown in Table 3.

Figure 2 shows the PFT changes in FVC and DLco for all the patients before and after lung lavage was per-
formed. All patients noted an improvement in their PFT results after WLL. The p values for the changes in FVC, FEV₁, and DLCO before and after lavage were < 0.01, 0.10, and 0.01, respectively. Note that the fourth patient required two complete sets of bronchopulmonary lavage to produce a complete physiologic remission due to the severity of disease (DLCO changed from 25% to 43% predicted after the first set and 43% to 60% predicted after the second). There was physiologic improvement with both sets of lavages; however, only the second set produced a clinical resolution of dyspnea.

**Discussion**

In this study, we found that the application of different maneuvers is superior to a single maneuver in clearing solid material from the lungs of PAP patients during WLL. A potential limitation of our study was the nonrandom application of the maneuvers. This was mandated by our clinical experience, in which we have observed that initiating chest percussion in the first stage may enhance the removal of material to the extent that the endotracheal tube becomes obstructed or is displaced. In addition, during the initial application of titrated saline solution lavage (ie, stage I) it is essential to establish proper fluid dynamics for the system, and to assure endotracheal tube placement and stability. These issues notwithstanding, our study does provide objective evidence attesting to the benefit of incorporating a variety of clinically relevant maneuvers in the WLL paradigm. We also recognize that our data were derived from a relatively small population. Nonetheless, the patients are highly representative of the PAP phenotype, and the qualitatively similar result across all study participants adds credence to the generalizability of our observations and conclusions.

As shown in Table 2, the weight of the material being removed was highest in almost all patients while chest percussion was being performed. Prone positioning appears to have a small cumulative influence on the amount of material being removed. The wide range of weights obtained is related to variations in the severity of the disease and the diversity of body size in the patients.

The representative graph of bottle number vs material weight (Fig 1) shows that there was a tapering in the amount of material being collected after the initiation of lavage until the initiation of chest percussion. The amount of material increases with the administration of chest percussion therapy, but then again begins to taper. We also noted variations in the weight of material during the time period when chest percussion therapy was used, which we believe is related to variability in the intensity of the manual percussion. Table 3 shows the weight of the material in the individual bottles immediately before and after each intervention. We demonstrated a statistically significant increase in the material being removed after chest percussion and prone positioning each were started. The weight of material in the individual bottles was noted to increase immediately after prone positioning, when compared to the weights just prior to the position change. We used prone positioning because we noted that patients who had significant disease in the posterior segments did not clear these areas when lavage was performed only in the supine position. Even though the weight of the material removed in the prone position is only $10.5 \pm 6.1\%$ of the total, it appears radiographically to make a difference in the clearing of the posterior segments. Our data demonstrate that we are able to improve the amount of material in the effluent with the use of prone positioning.

We have shown that measurable amounts of lipoproteinaceous material were removed at all stages of lung lavage. The most effective adjunct to lavage is manual chest percussion therapy, removing $57 \pm 19.9\%$ of the total amount of material. Previous studies have suggested that manual chest percussion was superior to both mechanical percussion and no-percussion techniques using optical density changes. However, these authors did not measure the dry weight of lipoproteinaceous material in the effluent, so a direct comparison to our results cannot be made. The effect of prone positioning in facilitating the removal of lipoproteinaceous material was not as dramatic as that during stages I and II, but was still noted to be significant. This finding may be a result of using the technique at the terminal end of the procedure and not at the beginning.

To our knowledge, no studies have been performed comparing low-volume to high-volume lung lavage. Removing larger amount of material would presumably improve the patient's physiologic parameters and gas exchange. Other authors have published single case reports on variations in lavage technique, such as fiberoptic bronchoscopy and partial ventilation of the lavaged lung. The semi-quantitative technique that we have described would provide a method for future investigators to examine the relationship between the volume and the dry weight of material removed during WLL. Such a technique could eventually be used to study outcome variables such as pulmonary function, roentgenographic clearing, and length of remission. The current study is too
small to address outcome, but when we compared the dry
weight of the material removed to the change in DLCO,
there was a modest correlation ($r = 0.55$), suggesting
that as more material is removed, the DLCO increases. In
this group of patients, none have required a repeat lavage
during a follow-up period ranging from 10 to 36 months,
although patient 4 required two complete sets of lavages
before he had maximum clinical improvement.

Granulocyte-macrophage colony-stimulating factor
(GM-CSF) has been postulated\textsuperscript{16–20} to be a useful treat-
ment of PAP, based on the presence of antibodies to
GM-CSF in patients with PAP. Studies\textsuperscript{21–23} have shown
that some patients experience clinical and physiologic
improvement after the administration of GM-CSF. These
studies are promising in the pursuit of a less invasive, more
readily available treatment for PAP. However, in order to
make valid comparisons among outcomes of WLL, GM-
CSF, or any other treatment modality, a standardization of
the WLL technique would be required. As we have
shown, substantial amounts of lipoproteinaceous material
are removed at the latter stages of the procedure, and the
amount of material removed varies with adjunctive proce-

*See Table 1 for abbreviations not used in the text.

### Table 2—Dry Weight and Percentage of Material Removed During WLL According to Stage of Lavage*

<table>
<thead>
<tr>
<th>Patient/ Side</th>
<th>Stage I</th>
<th></th>
<th>Stage II</th>
<th></th>
<th>Stage III</th>
<th></th>
<th>Total Weight, g</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Weight, g</td>
<td>% of Total</td>
<td>Weight, g</td>
<td>% of Total</td>
<td>Weight, g</td>
<td>% of Total</td>
<td>Total Weight, g</td>
</tr>
<tr>
<td>1/L</td>
<td>37.1</td>
<td>19.7</td>
<td>121</td>
<td>64.2</td>
<td>30.3</td>
<td>16.1</td>
<td>189</td>
</tr>
<tr>
<td>1/R</td>
<td>14.8</td>
<td>12.6</td>
<td>93.9</td>
<td>79.8</td>
<td>9.0</td>
<td>7.7</td>
<td>118</td>
</tr>
<tr>
<td>2/L</td>
<td>4.3</td>
<td>15.5</td>
<td>19.0</td>
<td>68.0</td>
<td>7.9</td>
<td>4.6</td>
<td>31.0</td>
</tr>
<tr>
<td>2/R</td>
<td>20.2</td>
<td>11.8</td>
<td>143</td>
<td>83.6</td>
<td>4.6</td>
<td>4.6</td>
<td>171</td>
</tr>
<tr>
<td>3/L</td>
<td>31.9</td>
<td>17.1</td>
<td>110</td>
<td>59.0</td>
<td>44.6</td>
<td>23.9</td>
<td>187</td>
</tr>
<tr>
<td>3/R</td>
<td>55.6</td>
<td>14.4</td>
<td>292</td>
<td>75.4</td>
<td>39.6</td>
<td>10.2</td>
<td>387</td>
</tr>
<tr>
<td>4/L</td>
<td>225</td>
<td>68.9</td>
<td>77.7</td>
<td>23.8</td>
<td>23.7</td>
<td>7.3</td>
<td>327</td>
</tr>
<tr>
<td>4/R</td>
<td>204</td>
<td>71.3</td>
<td>78.3</td>
<td>27.3</td>
<td>3.9</td>
<td>1.4</td>
<td>287</td>
</tr>
<tr>
<td>4-2/L</td>
<td>47.2</td>
<td>51.3</td>
<td>32.5</td>
<td>35.3</td>
<td>12.3</td>
<td>13.4</td>
<td>92.0</td>
</tr>
<tr>
<td>4-2/R</td>
<td>46.2</td>
<td>39.8</td>
<td>61.2</td>
<td>52.6</td>
<td>8.8</td>
<td>7.6</td>
<td>116</td>
</tr>
<tr>
<td>5/L</td>
<td>60.6</td>
<td>24.7</td>
<td>166</td>
<td>68.0</td>
<td>17.7</td>
<td>7.2</td>
<td>245</td>
</tr>
<tr>
<td>5/R</td>
<td>51.8</td>
<td>30.7</td>
<td>160</td>
<td>58.7</td>
<td>27.3</td>
<td>11.4</td>
<td>199</td>
</tr>
<tr>
<td>Mean</td>
<td>69.92 ± 71.58</td>
<td>32.1 ± 21.7</td>
<td>109.91 ± 71.85</td>
<td>57.4 ± 19.9</td>
<td>18.93 ± 13.71</td>
<td>10.5 ± 6.1</td>
<td>198.8 ± 103.74</td>
</tr>
</tbody>
</table>

\*See Table 1 for abbreviations not used in the text.

![Representative graph from a single lavage showing the weight of the effluent in each individual bottle arranged sequentially over the time period of the lung lavage. This illustrates the improvement in effluent dry weight after each intervention and the variability during chest percussion. CPT Start = chest percussion therapy initiation time; Prone Start = prone positioning initiation time.](http://journal.publications.chestnet.org/pdaccess.ashx?url=/data/journals/chest/22010/)
Table 3—Effectiveness of Manual Chest Percussion and Prone Positioning: Dry Weight in Bottles Prior to and After Initiation of Manual Chest Percussion and Prone Positioning*

<table>
<thead>
<tr>
<th>Patient/Side</th>
<th>Manual Chest Percussion: Stage I → Stage II</th>
<th>Prone Positioning: Stage II → Stage III</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre, g</td>
<td>Post, g</td>
</tr>
<tr>
<td>1/L</td>
<td>2.71</td>
<td>8.82</td>
</tr>
<tr>
<td>1/R</td>
<td>0.89</td>
<td>13.1</td>
</tr>
<tr>
<td>2/L</td>
<td>0.92</td>
<td>3.08</td>
</tr>
<tr>
<td>2/R</td>
<td>2.34</td>
<td>14.3</td>
</tr>
<tr>
<td>3/L</td>
<td>8.99</td>
<td>6.47</td>
</tr>
<tr>
<td>3/R</td>
<td>7.50</td>
<td>30.0</td>
</tr>
<tr>
<td>4-1/L</td>
<td>3.06</td>
<td>24.4</td>
</tr>
<tr>
<td>4-1/R</td>
<td>3.89</td>
<td>12.9</td>
</tr>
<tr>
<td>4-2/L</td>
<td>3.46</td>
<td>10.1</td>
</tr>
<tr>
<td>4-2/R</td>
<td>3.46</td>
<td>3.10</td>
</tr>
<tr>
<td>5/L</td>
<td>1.41</td>
<td>4.44</td>
</tr>
<tr>
<td>5/R</td>
<td>14.3</td>
<td>11.8</td>
</tr>
</tbody>
</table>

Mean ± SD: 4.43 ± 3.97 12.1 ± 8.21 2.58 ± 1.91 3.57 ± 2.09

p value: 0.006 0.012

*See Table 1 for abbreviations not used in the text.


Fluorodeoxyglucose Positron Emission Tomography and CT After Talc Pleurodesis

Boon Han Kwek, FRCP; Suzanne L. Aquino, MD; and Alan J. Fischman, MD, PhD

Background: Talc pleurodesis is widely performed for the management of persistent pneumothorax or pleural effusion, particularly malignant effusions. However, there are very few data characterizing fluorodeoxyglucose (FDG)-positron emission tomography (PET) and CT findings after treatment.

Methods: We retrospectively evaluated the FDG-PET and CT studies of nine patients who underwent talc pleurodesis for the treatment of malignant pleural effusions or persistent air leak.

Results: FDG-PET studies were performed on average 22 months after talc pleurodesis, and the mean CT follow-up period was 25 months. There was moderate-to-intense plaque-like or focal nodular-increased FDG uptake in the pleura on PET with mean standardized uptake value (range, 2.0 to 16.3). The FDG uptake was either diffuse (two patients) or focal (seven patients), and most commonly occurred in the posterior costophrenic angles (five patients), followed by the apical regions (three patients), anterior costophrenic angle (one patient), and the anterior chest wall (one patient). On CT, high-density areas of pleural thickening or nodularity (mean, 230 Hounsfield units [HU]) corresponded to regions of increased FDG uptake. These pleural foci had an average thickness of 1.2 cm and measured up to 8.2 cm (mean, 7.1 cm) in length. Rounded pleural nodules were as large as 3.1 cm (mean, 1.5 cm).

Conclusions: Talc pleurodesis produces increased FDG uptake on PET and high-density areas of pleural thickening on CT that remain unchanged on serial imaging. When PET detects increased uptake in the pleural space, correlation with CT is recommended to detect the presence of pleural thickening of increased attenuation that suggests talc deposits rather than tumor.

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Key words: CT; pleural cavity; pleurodesis; positron emission tomography; talc

Abbreviations: FDG = fluorodeoxyglucose; HU = Hounsfield units; PET = positron emission tomography; SUV = standardized uptake value

Talc pleurodesis was first employed by Bethune in 1935 as a preoperative procedure to anchor the lung during lobectomy. Since then, talc pleurodesis has been widely employed in the management of recurrent pneumothoraces and pleural effusions, with a success rate > 90%. In 1997, Murray et al described increased fluorodeoxyglucose (FDG) uptake in a 66-year-old man who underwent positron emission tomography (PET) 10 months after talc pleurodesis for persistent postthoracotomy air leak. The areas of increased FDG uptake corresponded to high-density plaques on CT that were attributed to talc pleurodesis.

FDG-PET is widely employed in the management of patients with malignancy. However, increased uptake of FDG by a chronic inflammatory process in the pleura, such as talc pleurodesis, may lead to a false-positive interpretation of malignant pleural disease. To our knowledge, with the exception of the case reported by Murray et al, there are no previous reports in the medical literature that describe the FDG-PET findings in patients following talc pleurodesis. Similarly, there is a paucity of medical literature on the CT appearance of the pleura after talc pleurodesis. The only report on the CT appearance after talc pleurodesis is by Murray et al, who describe pleural thickening and nodularity with high-attenuation areas. We present the FDG-PET and CT findings in our series of nine patients, all of whom underwent multiple follow-up scans after talc pleurodesis.

Materials and Methods

The study was approved by the Human Research Committee of our institution. Over a 3-year period, nine patients who underwent both talc pleurodesis and FDG-PET were identified, and a retrospective review of their clinical and radiologic records was performed. There were eight women and one man in the study group. Their mean age was 58 years (range, 26 to 73 years). All patients had a history of malignancy, five had lung carcinomas (one each in stage IA, IB, IIA, IIB, and IV), and one each had treated breast carcinoma, ovarian carcinoma (stage IV), Ewing sarcoma (metastatic), and pulmonary neuroendocrine tumor.