Serial Studies of Pulmonary Function in Continuous Ambulatory Peritoneal Dialysis*

A Prospective Study

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Continuous ambulatory peritoneal dialysis (CAPD) produces a nearly continuous state of iatrogenic ascites which may interfere with respiratory excursions of the diaphragm and compromise ventilatory function. Sitting and supine studies of pulmonary function and arterial blood gas analyses done serially in 13 patients undergoing CAPD showed a significant decline in pulmonary volumes immediately after the institution of CAPD; however, the decline was not accompanied by abnormalities in gas transfer. Pulmonary volumes returned to baseline values within two weeks in all patients, including those with preexisting mild chronic obstructive pulmonary disease (COPD). It is concluded that CAPD does not compromise pulmonary function in patients with normal pulmonary function or in those with mild COPD.

Since the introduction of continuous ambulatory peritoneal dialysis (CAPD) by Popovich and associates in 1976, the number of patients treated by peritoneal dialysis has grown steadily. Peritoneal dialysis has been reported to compromise ventilatory function; however, these studies were done in patients who were either acutely ill with terminal renal failure or who were being treated intermittently. Therefore, these reports have little bearing on stable patients undergoing CAPD. The recent popularity of CAPD has aroused fresh interest in the effects of peritoneal dialysis on ventilatory function. With the exception of the report dealing with our preliminary results, these reports are a one-time study of patients who have been undergoing CAPD for a variable length of time. Since CAPD produces a nearly continuous state of iatrogenic ascites, it may conceivably compromise pulmonary function in its recipient. To test this hypothesis, we carried out a prospective serial study of pulmonary function in patients undergoing CAPD. Our results show that although there is a significant decrease in pulmonary volumes immediately after institution of CAPD, this is not associated with any significant defect in gas exchange in the lung and that pulmonary volumes return to baseline values within two weeks after the initiation of CAPD.

Material and Methods

Thirteen patients undergoing CAPD participated in this study. An informed consent was obtained from all of the participants. All subjects were men between 40 and 71 years of age, with a mean age of 55 years. There were four cigarette smokers, four ex-smokers, three nonsmokers, and three pipe smokers; one of these was an ex-cigarette smoker. The current smokers had a mean of 41 pack-years of smoking, with a range of 27 to 50 pack-years. The ex-smokers had quit smoking between 4 and 26 years prior to the study and had smoked a mean of 31 pack-years. Three patients gave a history of cough in the morning with production of small amounts of mucoid sputum. None had shortness of breath or wheezing; however, five patients had mild chronic obstructive pulmonary disease (COPD) on the basis of baseline tests of pulmonary function (ratio of forced expiratory volume in one second over the forced vital capacity [FEV/FVC] of less than 70 percent in sitting and supine positions). Several causes were responsible for end-stage renal failure in these patients (hypertensive nephrosclerosis in five, chronic glomerulonephritis in three, poly cystic kidney disease and diabetic glomerulosclerosis in two each, and obstructive nephropathy in one). Serum creatinine levels were similar at the beginning (13.4 ± 1.1 mg/100 ml) and end (12.5 ± 1.3 mg/100 ml) of the study; however, blood urea nitrogen levels, as expected, were significantly lower at the end of the study (57 ± 3 mg/100 ml), as compared to the baseline levels (79 ± 3 mg/100 ml). The schedule of CAPD consisted of four daily exchanges of 2 L each. The mean change in body weight during the period of study was a gain of 0.31 ± 0.10 kg.

The following tests of pulmonary function were done: pulmonary volumes; expiratory flow rates; and diffusing capacity for carbon monoxide (D) using an automatic analyzer (SRL Automated Pulmonary Function Laboratory M100B). In addition, arterial blood gas levels were determined simultaneously in six of the 13 patients (Radiometer Acid Base Laboratory ABL 2).

A baseline study was obtained before the insertion of a Tenckhoff catheter for CAPD. Following insertion of the catheter, patients were placed on intermittent peritoneal dialysis for eight to ten hours every other day (starting exchange volume of 1 L and increasing gradually to 2 L) for two weeks before starting CAPD. Repeat tests of pulmonary function were obtained on days 1, 8, and 15 on CAPD. All studies except the baseline (pre-CAPD) were carried out with 2 L of dialysate in the peritoneal cavity. The patients were studied in

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Pulmonary Function in Peritoneal Dialysis (Singh et al)
supine and sitting positions on each occasion. The patients were free of acute respiratory illness and fluid overload and refrained from smoking on the day of study. The results on days 0 (pre-CAPD), 1, 8, and 15 (on CAPD) were compared by using Scheffé's multiple comparisons procedure at $\alpha = 0.05$ level of significance and are expressed as the mean ± SE.

**RESULTS**

The FVC decreased significantly on day 1 of CAPD when compared to the pre-CAPD value, but returned to baseline on days 8 and 15 in the sitting position and on day 15 in the supine position (Fig 1). The FEV$_1$ showed a similar pattern, but the changes were not statistically significant. The FEV$_1$/FVC ratio did not show any significant change at any time in either position. The decrease observed in the maximum voluntary ventilation (MVV) on the first day undergoing CAPD was not statistically significant, and the values returned to baseline or slightly higher on days 8 and 15.

Vital capacity (VC) showed a significant decline on day 1 in the sitting position and on days 1 and 8 in the supine position, but returned to baseline subsequently (Fig 2). The functional residual capacity (FRC) and total lung capacity (TLC) measured in the sitting position showed a significant decline on days 1 and 8 on CAPD, but were not different from the baseline on day 15; however, no significant changes were seen when these measurements were made in the supine position. The changes in expiratory reserve volume (ERV) and residual volume (RV) followed a similar pattern but failed to reach statistical significance at any time.

No significant changes in the carbon monoxide diffusing capacity (D), arterial oxygen and carbon dioxide tensions (PaO$_2$ and PaCO$_2$), and pH were observed in either sitting or supine positions following institution of CAPD (Table 1).

Five patients had mild COPD based on the baseline pulmonary function tests (FEV$_1$/FVC ratio <70 percent in sitting and supine positions). None of these patients had significant symptoms referable to the respiratory system. The results of serial pulmonary function tests were also analyzed separately in this group. These results were similar to those for the entire group as described previously.

**DISCUSSION**

Our results indicate that instillation of 2 L of fluid into the peritoneal cavity causes a temporary change in ventilatory function, as measured by a decline in the FVC and VC in the sitting and supine positions and a reduction in the FRC and TLC in the supine position only. Changes observed in other measures of pulmonary function (FEV$_1$, ERV, MVV, FEV$_1$/FVC, and RV/TLC ratios) are not significant. Also, no significant changes in D, PaO$_2$, PaCO$_2$, and pH are present. The measurements manifesting a significant decline on day 1 undergoing CAPD return back to the baseline values in most of the patients on day 8 and in all of them on day 15 of CAPD.

Peritoneal dialysis has been reported to compromise ventilatory function when the treatment was used intermittently for acute$^{a}$ or chronic renal failure; however, these results have no relevance to stable patients who are undergoing ambulatory peritoneal dialysis continuously. The English literature contains four reports dealing with the ventilatory function in patients undergoing CAPD,$^{a, b, c, d}$ however, with the exception of the one dealing with our preliminary results,$^{a}$ these reports are a one-time study of the patients who have been undergoing CAPD for a variable length of time. Although Winchester et al$^{a}$ did study some patients late in the course of CAPD, only...
three of them had previously been studied soon after institution of CAPD. Moreover, all of these studies excluded patients with preexisting pulmonary disease. The present study, on the other hand, is a prospective serial study. A baseline was obtained before insertion of the Tenckhoff catheter to avoid interference in performing various breathing maneuvers from a sore belly. The patients were free of fluid overload and acute respiratory problems and refrained from smoking on the day of study. Only those who completed all four studies under these tightly defined conditions were included in the final analysis.

It is reasonable to assume that the initial decline in some of the parameters of pulmonary function in these patients is due to iatrogenic ascites of CAPD. Indeed, Abelman and associates$^9$ described significant impairment of pulmonary function in patients with ascites of varying causes (congestive heart failure, hepatic cirrhosis, and malignant neoplasms) which improved significantly following therapeutic paracentesis. These investigators$^9$ ascribed the abnormalities to the elevation and decreased excursion of the diaphragm. The return of pulmonary function to baseline within two weeks of starting CAPD may be due to adaptation to the presence of fluid in the abdomen. The stretching of the abdominal wall in response to ascites may allow normal excursions of the diaphragm which now has returned to its usual resting position. This is inconsistent with the report by Abelman and associates$^9$ showing persistent decline in pulmonary function in long-

Table 1—Arterial Blood Gas Levels and D in Patients on CAPD

<table>
<thead>
<tr>
<th>Days on CAPD</th>
<th>PsO$_2$, mm Hg</th>
<th>PsCO$_2$, mm Hg</th>
<th>pH</th>
<th>D, percent predicted</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sitting</td>
<td>Supine</td>
<td>Sitting</td>
<td>Supine</td>
</tr>
<tr>
<td>0</td>
<td>90.8±4.4</td>
<td>88.3±2.7</td>
<td>32.1±2.2</td>
<td>33.0±2.3</td>
</tr>
<tr>
<td>1</td>
<td>88.2±2.7</td>
<td>91.2±3.9</td>
<td>34.2±1.6</td>
<td>33.5±2.9</td>
</tr>
<tr>
<td>8</td>
<td>91.2±4.4</td>
<td>85.8±4.0</td>
<td>35.8±1.5</td>
<td>33.1±2.3</td>
</tr>
<tr>
<td>15</td>
<td>88.2±2.4</td>
<td>89.0±1.8</td>
<td>35.4±1.6</td>
<td>31.3±2.7</td>
</tr>
</tbody>
</table>

*Table values are means ± SE. Arterial blood gas levels were obtained in six of 13 patients. Changes were not statistically significant in any category.
standing ascites; however, their patients had massive ascites, mean volume drained at paracentesis being 10.4 L, compared to 2 L of dialysate in our patients. It is entirely possible that this adaptation does not occur in the face of massive ascites. The other possibility is that with the introduction of fluid into the peritoneal cavity and the consequent increase in intraperitoneal pressure, the diaphragm probably becomes more curved. The muscle then becomes more effective in generating increased force due to altered length-tension relationship.10

In a study of ten patients, Thieler et al found no change in pulmonary function when patients undergoing CAPD were studied with or without dialysate in the abdomen. Since these patients were studied after they had already been undergoing CAPD for several weeks, one would predict no change based upon our findings that any decline in pulmonary function occurs early and is mitigated within two weeks. Epstein and associates,7 in a similar study, found no change in pulmonary volumes measured by plethysmograph, but observed a statistically significant decrease when pulmonary volumes were measured by the helium-dilution technique with the abdomen filled with 2 L of dialysate, when compared to the empty state. They did not state the reason for the difference with the two techniques.

Winchester and coauthors6 studied pulmonary function early (day 3 or 4 on CAPD) and late in CAPD (7.6 ± 4.1 months following the initiation of CAPD). They observed a significant fall in FRC in both sitting and supine positions when the abdomen was filled with 2 L of dialysate, as compared to the empty state, both during early CAPD, as well as several months later. This is consistent with our findings of diminished FRC at the beginning of CAPD; however, contrary to their report, we observed a return of FRC to baseline values within two weeks after institution of CAPD. Winchester et al6 also found significant hypoxemia in the supine but not in the sitting position upon instillation of 2 L of dialysate into the abdomen early in CAPD (PaO2 of 92 ± 7 mm Hg in the empty state vs 84 ± 8 mm Hg following instillation of 2 L dialysate). They attributed it to ventilation-perfusion mismatch due to a decrease in FRC with no change or an increase in closing capacity. Although these changes in FRC and closing capacity were still observed in patients studied several months later, hypoxemia was no longer observed. We did not observe significant hypoxemia in our studies in either the sitting or supine positions in patients with normal pulmonary status as well as those with mild COPD. This is consistent with our findings of no significant changes in pulmonary volumes and flow rates in these patients.

Our results show that changes in pulmonary function, if any, occur early in CAPD. The values return to baseline levels within two weeks of starting CAPD. This is also true of the patients with mild COPD. We conclude that CAPD does not cause significant compromise of pulmonary function in patients with normal pulmonary function or in those with mild COPD. We believe that these results may be extrapolated to the patients with moderate degrees of COPD who may desire to go on CAPD; however, we recommend that baseline studies of pulmonary function should be obtained under optimal conditions before insertion of the Tenckhoff catheter and repeat measurements should be obtained on CAPD to document the validity of this assumption.

REFERENCES

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