The most common cause of drop-out from continuous ambulatory peritoneal dialysis (CAPD) therapy is an insufficient dose of dialysis. Several reports and the Dialysis Outcomes Quality Initiative (DOQI) guidelines recommend maintaining a weekly creatinine clearance (CCr) of at least 60 L/1.73 m². Previously, at our center, we found that many patients switched from CAPD to hemodialysis (HD) owing to insufficient solute clearance (less than 50 L/1.73 m²). We attempted to determine whether once-weekly HD would improve solute clearance. We treated 7 cases (6 men, 1 woman; average age: 54.3 ± 4.5 years; mean duration of CAPD: 4.3 ± 1.1 years) with once-weekly HD therapy (3.5 hours; 200 mL/hour). The average CCr was 45 ± 2 L/1.73 m². No ultrafiltration failure was found. Addition of once-weekly HD therapy improved CCr to 66 ± 7 L/1.73 m². That improvement was attributable not only to the addition of HD therapy but also to an increase in peritoneal CCr for 3 consecutive days after completion of once-weekly HD therapy. Creatinine clearance and ultrafiltration were both significantly increased. Other clinical parameters such as blood pressure control, weight control, and dose of erythropoietin were significantly improved after introduction of once-weekly HD therapy. Moreover, uremic symptoms such as pruritus and depression were markedly improved. In conclusion, once-weekly HD therapy in conjunction with regular CAPD therapy improves solute clearance and symptoms related to uremia in CAPD patients with an insufficient dialysis dose.

Key words
Uremic symptoms, dialysis dose, weekly creatinine clearance

Introduction
Recently, continuous ambulatory peritoneal dialysis (CAPD) has been advocated as an initial renal replacement therapy (1,2). If CAPD therapy fails (for whatever reason—usually peritonitis, inadequate dialysis, or patient-related factors), then a switch to hemodialysis (HD) should be considered.

One problem with that approach is that CAPD patients are transferred to HD despite a remaining availability of peritoneal function. Among the factors that lead to discontinuation of CAPD, peritoneal transport status—which may be associated with adverse clinical outcomes (3,4)—is the most important. Moreover, an association exists between peritoneal transport status and weekly creatinine clearance (CCr) (5).

Guidelines for solute clearance targets have now emerged, the most prominent of which are the National Kidney Foundation’s Dialysis Outcomes Quality Initiative (NKF–DOQI) guidelines (6). The NKF–DOQI target for weekly CCr is more than 60 L per 1.73 m².

To achieve adequate weekly CCr, several methods are possible. One is to use automated peritoneal dialysis (APD); however, no decisive data exist regarding the effect of the increased prescription on patient outcome. Because 1 HD session is equivalent to 2 – 3 days of CAPD in terms of CCr, the addition of HD to CAPD in patients who do not achieve the target weekly CCr is an alternative. The considerable obstacles to adopting that approach are almost entirely non medical. They include physician bias and conservative policies, among others. In the present study, we attempted to determine whether once-weekly HD
would improve solute clearance in CAPD patients who had low weekly CCr.

**Patients and methods**

*Patient selection*

Of the CAPD patients attending the Kidney Disease Center of Saitama Medical School between 1998 and 2001, 7 were eligible for the study. (We excluded patients who were unlikely to survive for 6 months or who were planning to have elective living-donor transplant or transfer to another renal center within 6 months.) Informed consent was obtained from all patients.

Baseline data, including age, sex, underlying renal disease, CAPD regimen, duration of CAPD, dialysis regimen, and past history of peritonitis were obtained. All patients were using a standard CAPD regimen of four daily exchanges with 1.5 L or 2 L of dialysate. During the study, all subjects were asked to continue the same dietary and dialysis regimen. Mean daily dietary intake was determined from individual 24-hour food records over a three-day period. The dietary protein intake was 1 g/kg/day, and the energy intake was more than 25 kcal/kg/day. Salt intake was restricted to about 9 g daily. During the study period, the patients had no significant intercurrent illnesses such as infection, surgery, or blood loss. All patients were treated with rHuEPO according to how their anemia responded to that medication. Levels of hemoglobin were maintained in the range 8 – 10 g/dL.

Weekly residual renal function (L/week) was estimated as the mean of renal creatinine and renal urea clearances from a 24-hour urine collection, multiplied by 7 (days in the week). A weekly peritoneal CCr was calculated from a 24-hour collection of spent dialysate and from the concentrations of both serum and peritoneal creatinine. The HD dose was calculated. Creatinine clearance by HD was calculated as

\[
\text{creatinine concentration} \times \text{dialysate flow} \times \text{duration of dialysis} + \text{fluid removed}.
\]

In the present study, to make HD CCr consistent as possible, the same dialyzer was used in all cases, and the duration was fixed at 3.5 hours. Creatinine clearance by HD was 2000 – 2400 mg.

**Statistical analysis**

All data used for statistics were calculated using the average of the data for 6 months before and after the introduction of HD therapy.

All data are presented as mean ± standard deviation. Comparisons of data before and after introduction of HD therapy were performed using the Student t-test. A value of \( p < 0.05 \) was required for statistical significance.

**Results**

*Characteristics of the patients*

Table I shows age, sex, serum creatinine, duration of CAPD, and past history of peritonitis for the patient group. Only 1 of 7 patients was female. The duration of CAPD was less than 5 years. Underlying renal disease was predominantly chronic glomerular nephritis. The frequency of peritonitis was less than two episodes in all patients. The urine volume in each patient was less than 100 mL daily.

*Dialysis data*

Table II shows the CAPD dialysis dose. Drain volume averaged more than 800 mL daily. The weekly average peritoneal CCr was 45 ± 2 L.

*Effect of add-on HD therapy on peritoneal CCr*

Add-on HD therapy significantly increased the weekly peritoneal CCr to 48 ± 2 L from 45 ± 2 L (\( p < 0.05 \)). Then, adding 24 L of CCr by HD to the 48 L by peritoneal dialysis resulted in a total weekly CCR exceeding 60 L (Figure 1).

*Effect of add-on HD therapy on drain volume*

The daily drain volume increased significantly after addition of once-weekly HD (\( p < 0.05 \); Figure 2).

*Effect of add-on HD therapy on serum creatinine*

Levels of serum creatinine were significantly reduced by addition of once-weekly HD (\( p < 0.05 \); Figure 3).

**Discussion**

In the present study, mild underdialysis by CAPD could be salvaged by once-weekly HD. The average weekly CCr of the patients enrolled in the present study was less than 50 L, indicating that all patients were underdialyzed based on NKF–DOQI guidelines. The
NKF–DOQI targets for CAPD are a weekly Kt/V urea of 2.0 and a weekly CCr of 60 L per 1.73 m². Those guidelines have been modified to lower the targets for CCr in low transporters to 50 L per week, in line with the Canadian guidelines. In Japan, many physicians follow NKF–DOQI; however, no data were available.

### TABLE I Characteristics of the patients in the study

<table>
<thead>
<tr>
<th>Patient</th>
<th>Age (years)</th>
<th>Sex</th>
<th>Underlying disease</th>
<th>Duration of CAPD (years)</th>
<th>Past peritonitis (episodes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>KH</td>
<td>47</td>
<td>Male</td>
<td>CGN</td>
<td>2.5</td>
<td>0</td>
</tr>
<tr>
<td>AS</td>
<td>63</td>
<td>Male</td>
<td>Bechet disease</td>
<td>4.2</td>
<td>1</td>
</tr>
<tr>
<td>HS</td>
<td>56</td>
<td>Male</td>
<td>CGN</td>
<td>3.1</td>
<td>0</td>
</tr>
<tr>
<td>HI</td>
<td>45</td>
<td>Female</td>
<td>CGN</td>
<td>5.2</td>
<td>0</td>
</tr>
<tr>
<td>IM</td>
<td>56</td>
<td>Male</td>
<td>CGN</td>
<td>4.2</td>
<td>1</td>
</tr>
<tr>
<td>TT</td>
<td>67</td>
<td>Male</td>
<td>NS</td>
<td>4.5</td>
<td>1</td>
</tr>
<tr>
<td>YM</td>
<td>39</td>
<td>Male</td>
<td>CGN</td>
<td>4.1</td>
<td>1</td>
</tr>
<tr>
<td>Mean</td>
<td>54±4</td>
<td></td>
<td></td>
<td>4.3±1.1</td>
<td></td>
</tr>
</tbody>
</table>

CAPD = continuous ambulatory peritoneal dialysis; CGN = chronic glomerulonephritis; NS = nephrotic syndrome.

### TABLE II Peritoneal dialysis data

<table>
<thead>
<tr>
<th>Dialysis prescription</th>
<th>Drain volume (mL)</th>
<th>Serum Cr (mg/dL)</th>
<th>Peritoneal CCr (L/week)</th>
</tr>
</thead>
<tbody>
<tr>
<td>KH</td>
<td>2 L 1.5% glucose</td>
<td>950</td>
<td>13.36</td>
</tr>
<tr>
<td>AS</td>
<td>2 L 1.5% glucose</td>
<td>1100</td>
<td>12.66</td>
</tr>
<tr>
<td>HS</td>
<td>2 L 2.5% glucose</td>
<td>650</td>
<td>12.91</td>
</tr>
<tr>
<td>HI</td>
<td>2 L 2.5% glucose</td>
<td>480</td>
<td>16.19</td>
</tr>
<tr>
<td>IM</td>
<td>2 L 1.5% glucose</td>
<td>850</td>
<td>13.35</td>
</tr>
<tr>
<td>TT</td>
<td>2 L 1.5% glucose</td>
<td>1200</td>
<td>8.28</td>
</tr>
<tr>
<td>YM</td>
<td>2 L 2.5% glucose</td>
<td>850</td>
<td>9.55</td>
</tr>
<tr>
<td>Mean</td>
<td>868±93</td>
<td>12.3±0.9</td>
<td>45.8±1.6</td>
</tr>
</tbody>
</table>

Cr = creatinine; CCr = creatinine clearance.

---

**FIGURE 1**  Effect of add-on hemodialysis (HD) therapy on peritoneal creatinine clearance. Add-on HD significantly increased weekly peritoneal creatinine clearance to 48±2 L from 45±2 L (p < 0.05).

**FIGURE 2**  Effect of add-on hemodialysis (HD) therapy on drain volume. The daily drain volume increased significantly after addition of once-weekly HD (p < 0.05).
Based on two epidemiologic studies (7, 8), Szeto et al. (9) proposed that dialysis adequacy might be less important for Chinese CAPD patients. In the present study, no patients with diabetes mellitus were included, and all patients had very low residual renal function. Despite a progressive loss of residual renal function, the weekly CCr was relatively well maintained in the patients. Szeto et al. (9) proposed a cut-off value for weekly CCr that was more than 50 L, but not more than 60 L. No patient enrolled in this study had a weekly CCr of more than 50 L. If the daily exchange volume were to rise to more than 8 L, the expected weekly CCr still would not exceed 50 L.

A need exists to develop a method in addition to APD for continuation of CAPD. Failure to achieve long-term CAPD occurs for many reasons. Maiorca et al. (10) found that patient fatigue and psychosocial factors accounted for about half the total number of transfers to HD in long-term CAPD patients. Those findings may in part be related to lower solute clearances. Indeed, in the present study, although we did not evaluate psychological factors, all patients recognized their comparative well-being after introduction of HD therapy. The use of add-on HD therapy may be advantageous in some patients who are relatively underdialyzed. However, the number of patients in our study was small, and that observation must be regarded as suggestive but not confirmed. Patients with loss of ultrafiltration—the most common peritoneal transport abnormality in long-term CAPD (11, 12)—were not included in the present study. Add-on HD therapy would not be effective for those patients, because ultrafiltration failure can be overcome by APD.

Conclusions

Once-weekly HD therapy in conjunction with regular CAPD can improve solute clearance and symptoms related to uremia in CAPD patients with an insufficient dialysis dose.

References


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The influence that the mode of dialysis has on the prognosis of patients with renal disease is controversial. The controversy arises at least in part because of the heterogeneity of patient populations, who may be receiving either continuous ambulatory peritoneal dialysis (CAPD) or hemodialysis (HD). In the absence of randomized trials, epidemiologic investigations present the best method for studying the problem. To determine the influence of the mode of dialysis on prognosis and on the cardiovascular system, erythropoiesis, and calcium metabolism, we selected 36 patients undergoing CAPD and 36 patients undergoing HD for a 3-year follow-up study. Patients were matched for age, sex, and cause of renal disease.

Among the HD patients, 8 deaths occurred from congestive heart failure, 1 death from cerebrovascular accident, and 2 deaths from severe infection. In the HD group, the average age was 63 ± 3 years. Among the CAPD patients, 6 were transferred to HD because of recurrent peritonitis or elevation of serum creatinine. Patients on CAPD had lower blood pressures, and patients on HD had lower total cholesterol levels. Other parameters were not significantly different between the two groups, including dose of erythropoietin and calcium supplements administered.

Our study provides evidence that clinical outcome in renal failure may depend to some extent on the mode of dialysis. Our results suggest that blood pressure level and serum cholesterol should be taken into account for patients treated with either CAPD or HD.

Blood pressure and cholesterol level are both likely to be important contributors to mortality and morbidity in renal patients.

Key words
Blood pressure, lipid metabolism, calcium metabolism, hematopoiesis

Introduction
For more than 20 years, continuous ambulatory peritoneal dialysis (CAPD) has provided an alternative to in-center hemodialysis (HD) in Japan. However the number of patients receiving CAPD has represented fewer than 10% of all patients on dialysis therapy (1). Compared to Western countries and other Asian countries, that percentage seems low.

Japanese patients may possibly prefer HD treatment under the close supervision and care of nurses and doctors in a dialysis clinic, although financial factors may also play a role. The cost of CAPD is equivalent to that of HD; but, because reimbursement for CAPD goes mostly to the companies that provide CAPD fluids (2), the incentive for the medical establishment to carry out the procedure is diminished.

From the clinical standpoint, no studies conclusively compare the effects of CAPD and HD on patient survival, hemodynamics, and calcium and phosphate metabolism in Japanese patients. Several published studies show no difference in patient survival between CAPD and HD (3,4), and other studies have suggested that CAPD is equivalent to HD, or that it may even be superior for certain subgroups (5–8). However, the heterogeneity of the populations
undergoing CAPD and HD increases the difficulty of comparing patient survival for the two modes of treatment, and probably accounts for the variations in the results obtained (9).

In an attempt to further clarify the issue, we studied several factors that may contribute to patient survival with the two modes of treatment. Over a 3-year period, we compared changes in blood pressure and blood pressure control (by number of antihypertensive drugs); serum levels of total cholesterol, high-density lipoprotein (HDL) cholesterol, calcium, phosphate, and intact parathyroid hormone (iPTH); anemia management; and survival rates in patients matched for age, sex, and cause of renal failure, who were receiving CAPD or HD.

**Patients and methods**

All patients gave informed consent to participate in the study. We studied patients with chronic renal failure on CAPD (n = 36) and HD (n = 36) at the Kidney Disease Center of Saitama Medical School, Saitama, Japan. The patients were matched for age [56.5 ± 1.7 years in CAPD patients vs. 56.9 ± 1.8 years in HD patients, mean ± standard error of the mean (SEM)], sex (23 men, 13 women in each group), and cause of chronic renal failure (Table I). In each group, 19 patients had glomerulonephritis, 14 had diabetic nephropathy, 2 had nephrosclerosis, and 1 had anti-myeloperoxidase, anti-neutrophil cytoplasmic antibody–associated glomerulonephritis. Serum creatinine was also similar in both groups (8.9 ± 0.7 mg/dL in CAPD vs. 9.1 ± 0.9 mg/dL in HD).

The CAPD treatment consisted of 4 daily 2-L exchanges using a dialysate containing lactate and 1.5 g/dL or 2.5 g/dL dextrose. All patients were treated using a disconnect system.

Hemodialysis was carried out over a 4-hour period 3 times weekly, using a high-flux synthetic membrane (polysulphone or polyacrylonitrile). Bicarbonate was used as the buffer. Water quality was regularly monitored to ensure tight bacteriologic standards.

Administration of rHuEPO was carried out weekly by the subcutaneous route in patients on CAPD and by the intravenous route at the end of each session in patients on HD. Doses were adjusted monthly. A patient was defined as being resistant to rHuEPO if a hematocrit of 30% could not be achieved despite weekly administration of a dose of rHuEPO greater than 200 UI/kg (10,11). Patients were given oral iron supplementation if they were diagnosed as having iron deficiency.

During each 6-month period, laboratory values were recorded. Six-month means were calculated for blood urea nitrogen (BUN), serum creatinine, electrolytes, calcium and phosphate, alkaline phosphatase, hemoglobin, and hematocrit. Parathyroid hormone levels [intact molecule assay (iPTH)] and serum cholesterol were measured once every 6 months.

Patients with iPTH levels greater than 200 pg/mL were treated with 1,25-(OH)2 D3 and CaCO3 supplements; patients with levels lower than 70 pg/mL were treated with CaCO3 to reduce the degree of hyperphosphatemia. Doses were adjusted according to serum levels of calcium and phosphate. Lipid-lowering drugs, primarily statin derivatives, were administered if serum cholesterol levels exceeded 240 mg/dL.

In HD patients, pre-dialysis and post-dialysis blood pressures were calculated as the average value of all recordings taken over a 1-month period. Three

<table>
<thead>
<tr>
<th>Continuous ambulatory PD</th>
<th>Hemodialysis</th>
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<tbody>
<tr>
<td><strong>CGN</strong> (n=19)</td>
<td><strong>DM</strong> (n=14)</td>
</tr>
<tr>
<td><strong>Age (years)</strong></td>
<td>56±3</td>
</tr>
<tr>
<td><strong>Systolic BP (mmHg)</strong></td>
<td>163±6</td>
</tr>
<tr>
<td><strong>Diastolic BP (mmHg)</strong></td>
<td>94±5</td>
</tr>
<tr>
<td><strong>Serum Cr (mg/dL)</strong></td>
<td>10.4±1.2</td>
</tr>
<tr>
<td><strong>Hemoglobin (g/dL)</strong></td>
<td>7.0±0.2</td>
</tr>
<tr>
<td><strong>iPTH (pg/mL)</strong></td>
<td>257±95</td>
</tr>
<tr>
<td><strong>Serum Ca (mg/dL)</strong></td>
<td>7.1±0.4</td>
</tr>
<tr>
<td><strong>Serum P (mg/dL)</strong></td>
<td>5.3±0.2</td>
</tr>
</tbody>
</table>

**CGN** = chronic glomerulonephritis; **DM** = diabetes mellitus; **NS** = nephrosclerosis; **RPGN** = rapidly progressive glomerulonephritis; BP = blood pressure; Cr = creatinine; iPTH = plasma intact parathyroid hormone; P = phosphate.
measurements per week (12 per month) were made. When the systolic pressure exceeded 140 mmHg or the diastolic pressure 90 mmHg, therapy with antihypertensive agents was initiated.

In CAPD patients, blood pressure values were obtained by averaging home blood pressure measurements (10 – 20 measurements per month), and antihypertensive therapy was carried out as in HD patients.

Statistics
Statistical analysis was performed using the Student t-test (or the Mann–Whitney test when applicable) for comparing the means of unpaired variables. Analysis of variance was used to compare serial values of means. Patient survival curves were calculated by the Kaplan–Meier life-table analysis method, and differences between the groups were evaluated by the log-rank test. Results are expressed as mean ± SEM, as appropriate. A p value of less than 0.05 was considered significant.

Results

Effect of CAPD and HD on blood pressure
Blood pressure (Figure 1) was lower in CAPD patients as compared with HD patients from the second year to the end of the study (p < 0.01). Significant differences were observed between the patients on CAPD and those on HD in both systolic and diastolic pressures. Although no significant differences were seen between the two groups in the average number of antihypertensive drugs administered in the first year (1.7 ± 0.5 for CAPD vs. 1.5 ± 0.3 for HD) or at the end of the study (2.1 ± 0.6 for CAPD vs. 1.6 ± 0.4 for HD), the results did indicate that control of blood pressure was carried out more effectively in the CAPD patients.

Effect of CAPD and HD on serum creatinine
No significant differences in serum creatinine levels were seen between the two groups (Figure 2). The levels in both groups increased toward the end of the study, reaching significance as compared with baseline in both groups.

Effect of CAPD and HD on hemoglobin and dose of rHuEPO
In the two groups, no significant differences were observed in levels of hemoglobin, and the doses of rHuEPO administered were similar (Table II). Hemoglobin levels increased significantly (p < 0.01) from the first year onward and remained above 9 g/dL throughout the study.

Effect of CAPD and HD on calcium and phosphate metabolism
At 1 year of treatment, serum levels of calcium were significantly increased in both groups (p < 0.01), and those levels remained steady throughout the study.

![Figure 1](image)

**FIGURE 1** Serial changes in (A) systolic and (B) diastolic blood pressure in patients on continuous ambulatory peritoneal dialysis (CAPD) and hemodialysis (HD). In patients on CAPD, systolic and diastolic blood pressure both decreased significantly at 2 and 3 years after the initiation of dialysis therapy as compared with basal values. In HD, only systolic blood pressure declined. Also, the changes were significantly different between patients on CAPD and on HD at 2 and 3 years after the start of dialysis therapy. * p < 0.01 as compared with basal values. # p < 0.01 as compared with HD. ## p < 0.05 as compared with HD.
In contrast, serum levels of phosphate did not change significantly throughout the study. The level of iPTH and the dose of 1,25-(OH)2 D3 were not significantly different between the two groups throughout the study.

**Effect of CAPD and HD on serum cholesterol levels**

Serum total cholesterol was significantly higher (p < 0.01) in CAPD patients than in HD patients from 1 year after the initiation of dialysis therapy onward. The difference was maintained until the end of the study (Figure 3). Other variables such as HDL cholesterol and triglycerides were not significantly different between the two groups (data not shown).

### Table II Serial changes of clinical parameters in patients on hemodialysis (HD) and continuous ambulatory peritoneal dialysis (CAPD).

Throughout the study, no significant difference was observed between the two groups for any parameter.

<table>
<thead>
<tr>
<th></th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
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</thead>
<tbody>
<tr>
<td>Hemoglobin (g/dL)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>HD</td>
<td>6.9±0.2</td>
<td>9.0±0.2a</td>
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<td>8.9±0.1a</td>
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<td>9.0±0.2a</td>
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<td>9.8±0.4a</td>
<td>9.4±0.4a</td>
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<tr>
<td>Erythropoietin consumption (IU/week)</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>HD</td>
<td>6000±418</td>
<td>4371±440</td>
<td>4157±421</td>
<td>4382±415</td>
<td>3913±405</td>
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<tr>
<td>CAPD</td>
<td>4832±438</td>
<td>3535±439</td>
<td>4181±465</td>
<td>3966±542</td>
<td>4580±540</td>
<td>4700±539</td>
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<tr>
<td>Serum calcium (mg/dL)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HD</td>
<td>7.8±0.1</td>
<td>8.8±0.1a</td>
<td>8.6±0.1a</td>
<td>8.8±0.1a</td>
<td>9.0±0.1a</td>
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<tr>
<td>CAPD</td>
<td>7.7±0.2</td>
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<td>9.0±0.1a</td>
<td>9.1±0.3a</td>
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<tr>
<td>Serum phosphate (mg/dL)</td>
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<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>HD</td>
<td>5.3±0.2</td>
<td>5.4±0.2</td>
<td>5.5±0.2</td>
<td>5.7±0.2</td>
<td>5.6±0.2</td>
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<tr>
<td>CAPD</td>
<td>5.4±0.3</td>
<td>4.5±0.3</td>
<td>4.9±0.3</td>
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<tr>
<td>Plasma intact parathyroid hormone (pg/mL)</td>
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<tr>
<td>HD</td>
<td>146±10</td>
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<td>173±13</td>
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<td>260±33</td>
</tr>
<tr>
<td>CAPD</td>
<td>231±58</td>
<td>160±63</td>
<td>163±63</td>
<td>158±42</td>
<td>182±57</td>
<td>274±64</td>
</tr>
</tbody>
</table>

* a p < 0.01 as compared with basal values in each group.
Cause of death in both groups
A total of 16 deaths occurred over the 5-year study period, 5 in the CAPD group and 11 in the HD group [p = nonsignificant (NS)]. Among the CAPD patients, 3 deaths were attributable to congestive heart failure, 1 to myocardial infarction, and 1 to pulmonary infection. In the CAPD group, the average age was 58 ± 3 years, and 1 patient had diabetes. Among the HD patients, 8 deaths were attributable to congestive heart failure, 2 to infection, and 1 to cerebrovascular accident. In the HD group, the average age was 63 ± 3 years, and 8 of the patients had diabetes.

Transfer to the other modality
Six CAPD patients were transferred to HD because of recurrent peritonitis or elevation of serum creatinine. No patients on HD were transferred to CAPD.

Discussion
In the present study, we found that more patients on CAPD than on HD were alive at the end of the study period; however, the difference was not statistically significant. That finding could be due to the small number of patients in both groups. A larger series would be required to test that point. The causes of death were not dissimilar in the two groups, and our study agrees with several prior investigations (12) showing that increasing age and diabetes mellitus may have an adverse effect on survival in the HD population.

The heterogeneity that is so commonly observed in CAPD and HD populations increases the difficulty of comparing patient survival for the two methods. Heterogeneity probably accounts for much of the variation noted in previous studies, even when attempts were made to study paired populations (9). The controversy regarding the mode of dialysis that provides the greatest patient survival therefore remains (13), although many studies have suggested that CAPD may be equivalent to HD, or may even be more advantageous for certain subgroups (3–8).

The underlying cause of renal disease is also well known to be a powerful prognosticator in end-stage renal disease, and selection bias related to cause of renal failure may be responsible for the varying results that have been obtained in unpaired studies. In the present study, we attempted to match as closely as possible the causes of the underlying renal disease in our CAPD and HD patients, including diabetic and non diabetic renal disease. It is therefore less likely that that type of heterogeneity in CAPD and HD populations played a major role in our study.

Our data show that, in the first 3 years of treatment, blood pressure control improved in patients on CAPD as compared with patients on HD. Those results seem to agree with previous findings that CAPD may provide better extracellular volume and blood pressure control (14). However, our findings contrast with other studies that suggest that patients on CAPD may have higher blood pressure and greater volume expansion than do patients on HD (15). The discrepancy may be related to the duration of CAPD, given that Faller and Lameire (16) found, in a cohort of long-term CAPD patients, that after the first 2 years of treatment, the number of antihypertensive drugs had to be progressively increased to maintain blood pressure control. Their observation is supported by a recent report by Cocchi et al. (17), which showed that 88% of a population of 504 patients on long-term CAPD (average duration of treatment: 32 months) were hypertensive. Thus, initiation of CAPD may lead to short-term control of blood pressure; but, as time advances and residual renal function is lost, dialysis therapy may fail to control extracellular volume, resulting in elevation of blood pressure. Administration of erythropoietin has also been noted to be associated with hypertension in dialysis patients (18). However, we observed no differences in total dose of rHuEPO or level of hemoglobin between patients on CAPD and on HD.

Some particularly troubling methodology issues arise in studies that assess blood pressure control in dialysis patients. Those issues are the confounding factors of blood pressure measurements and the effects of concurrent use of antihypertensive agents. In the present study, we employed home blood pressure measurements in CAPD patients and average values of pre-dialysis and post-dialysis blood pressure measurements in HD patients. In HD patients, pre-dialysis and post-dialysis blood pressure measurements may not accurately reflect average blood pressure during the intradialytic interval. Some investigators (19) propose the importance of pre-dialysis blood pressure values; others (20) prefer the 20-minutes post-dialysis reading. Recently, Agarwal and Lewis (21) reported that sensitivity and specificity of 80% or better were achieved with a pre-dialysis blood pressure of 150/85 mmHg and 150/90 mmHg, respectively. Post-dialysis blood pressure values 20/10 mmHg lower
gave the same sensitivity and specificity. Based on those data, the values employed in the present study might be found to be useful for evaluating hypertension, indicating that the blood pressure comparison would be valid.

Regarding lipid disorders, patients undergoing CAPD have been described as having a more atherogenic profile than that found in patients undergoing HD—which may contribute to atherosclerotic cardiovascular morbidity and mortality (13, 22). During the first year of CAPD, serum triglycerides and serum cholesterol both typically increase, at least during the initial months of treatment. The changes are attributable to concurrent increases in the very-low-density lipoprotein (VLDL) and low-density lipoprotein (LDL) fractions (changes in HDL being typically less marked). Those changes are more marked in patients who are already hyperlipidemic at the start of CAPD (23).

It is probably reasonable to assume that the risks associated with hyperlipidemia and the benefits of correcting lipoprotein abnormalities in dialysis patients are comparable to the risks and benefits accruing to the general population. Whether existing clinical guidelines for the treatment of lipoprotein abnormalities—which take into account multiple risk factors for cardiovascular disease, and which target desirable lipoprotein levels—are applicable to dialysis patients is not known. A pre-dialysis serum cholesterol value of 200 – 250 mg/dL is associated with the lowest mortality risk in dialysis patients. Low serum cholesterol values, especially values below 150 mg/dL, are associated with an elevated mortality risk in dialysis patients, probably because they reflect poor nutritional status.

In the present study, significant differences were observed in serum levels of total cholesterol between patients on CAPD and patients on HD. Those results agree with previous evidence that the prevalence of increased total serum cholesterol and LDL cholesterol is relatively high in patients treated with CAPD, but is lower in patients undergoing chronic HD (24). In large population studies, many of those changes have been associated with increased cardiovascular risk. Treatment of LDL cholesterol abnormalities in the general population has been shown to reduce morbidity and mortality from cardiovascular disease in primary and secondary prevention trials alike. Therefore, to reduce the cardiovascular morbidity and mortality that is a major complication of dialysis, it seems rational to attempt to lower the higher level of total cholesterol in patients on CAPD.

It might be suspected that CAPD would present fewer problems with respect to renal osteodystrophy than does HD, because CAPD provides more consistent steady-state biochemical control and permits a less restrictive diet. However, reports of control and development of osteodystrophy in CAPD have produced varying results, with some studies showing improvement and others showing deterioration (25, 26). In the present study, no significant differences were seen in serum levels of calcium, phosphate, and iPTH between patients on CAPD and patients on HD.

Many patients on CAPD are able to maintain a higher hematocrit than are patients on HD. Patients on CAPD have also been shown to have a good response to erythropoietin. However, the data from the present study show no significant differences in the level of hemoglobin and the dose of erythropoietin between patients on CAPD and patients on HD. Why the present data differ from the results obtained in other studies is uncertain.

Conclusion
The present study provides some clinical guidelines for selection of patients who are being evaluated for dialysis using CAPD or HD. In patients with end-stage renal failure who have higher blood pressure, CAPD might be the best choice. In patients with higher serum levels of cholesterol, HD might be a better choice. Because high blood pressure and high levels of serum cholesterol both contribute to mortality and morbidity from cardiovascular accident during dialysis therapy, patients should be carefully evaluated with those factors in mind.

We should point out, however, that at the start of the current study, no significant differences were observed in blood pressure or serum cholesterol readings between our two groups. Previous use of antihypertensive and cholesterol-lowering drugs might have already had an effect upon blood pressure and serum total cholesterol. Moreover, in the present study, no techniques were employed to provide independent verification of the presence of cardiovascular disease (for example, echocardiography for detection of atheromatous plaque in the internal jugular artery, pulse wave velocity measurements, etc.). Evaluating the effects of blood pressure and cholesterol on vas-
cular damage in these patients over the 3-year study period was therefore difficult.

In conclusion, the mode of dialysis therapy should be carefully selected based on blood pressure and serum cholesterol levels, in addition to other criteria that may be employed for the purpose.

References

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Peritoneal dialysis (PD) is an effective renal replacement therapy; however, its penetration rate in China is rather low. In the present study, we investigated the opinions and attitudes of Chinese chief nephrologists about dialysis modality selection. We asked 51 chief nephrologists from various university hospitals to answer 8 questions about their attitudes toward PD and about the factors that affect their selection of dialysis modality.

Hemodialysis (HD) was available in all of the hospitals where the surveyed chief nephrologists worked. Peritoneal dialysis was available in 68.6% of the hospitals, and renal transplantation was available in 54.9%. Of the surveyed nephrologists, 5.9% believed that PD was more advantageous than HD, and 29.4% of them believed that HD was better. However, most of the nephrologists (64.7%) thought that the advantages of each modality depended on the individual patient and therefore that modality selection should be individualized accordingly. About 70.6% of the nephrologists expressed confidence in PD, and 88% were interested in PD. Overall, 90.2% of the nephrologists said that they would start or expand a PD program in the future. More than half of the nephrologists (52.9%) thought that the proportion of PD in China should be 30% – 50%. [The actual percentage is less than 10% in most areas (58.8%) of China.] Most nephrologists indicated that the major reasons for such low use of PD were the low profit from PD treatment and insufficient patient and professional education about PD. A few nephrologists said that peritonitis, the high PD dropout rate, and patient preference also affected the penetration of PD.

Our findings suggest that many of the chief nephrologists in China are confident about PD treatment. The major obstacles to PD expansion in China are the lack of incentive (profit) for PD treatment and insufficient education for professionals and patients alike.

Key words
Nephrologists, modality selection

Introduction
Dialysis, including hemodialysis (HD) and peritoneal dialysis (PD), is the main renal replacement therapy for end-stage renal disease (ESRD) patients the world over. Owing to its simplicity, effectiveness, and lower general cost, continuous ambulatory peritoneal dialysis (CAPD) has become an established form of renal replacement therapy. During the past three decades, PD has undergone dramatic improvements and has been shown to provide similar or even superior patient survival as compared with HD therapy—at least during the first 2 years of treatment (1). Therefore, in Hong Kong, almost 80% of dialysis patients are on PD (2). However, in mainland China, the PD penetration rate is only about 10% of the total dialysis population. The objective of the present study was to identify the factors that most influence dialysis modality selection in China.

Methods
From August 12 to 24, 2002, a training course for chief nephrologists in China was held at the First Hospital, Peking University. The course was endorsed by the Ministry of Health of the Chinese government. One of the objectives of the course was to update the nephrologists with recent advances in dialysis treatment. After the course, we conducted a questionnaire survey on the opinions and attitudes of Chinese chief nephrologists about dialysis modality selection.

The questionnaire comprised 8 questions:

1. What kinds of renal replacement therapy are available in your hospital?
2. Is one dialysis modality better than the others?
3. Do you have confidence in PD?
4. Are you interested in PD?
5. Will you develop your PD program in your hospital?
6. What is the ideal PD penetration rate in China?
7. What is the actual PD penetration rate in your area?
8. What are the factors that affect PD penetration in your area?

Requested demographic details included age, sex, years of practice in nephrology, and geographic region.

The course was attended by 51 chief nephrologists from 18 provinces in China. All of the chief nephrologists came from university hospitals, and all of them responded to the questionnaire.

All data were processed using Microsoft Excel and SPSS-PC version 10. The data are expressed as simple descriptive statistics.

**Results**

Among the 51 nephrologists, 19 were men and 32 were women. The mean age was 41.6 ± 4.9 years. Most of the chief nephrologists were the leading figures in nephrology in their own provinces.

In all of the hospitals, HD was available. Peritoneal dialysis was available in only 68.6% of the hospitals, and transplantation was available in 54.9% of the hospitals. In 7 hospitals both HD and transplantation were provided, but not PD. In 14 hospitals both HD and PD were provided, but not transplantation. Another 9 hospitals provided only HD service.

Of the 51 nephrologists, 3 (5.9%) believed that PD was superior to HD, and 15 (29.4%) believed that HD was better in general than PD. The nephrologists who believed that HD was superior had practiced only HD. On the other hand, most of the nephrologists (64.7%) thought that the various dialysis modalities had their own advantages and disadvantages, and therefore that modality selection should be individualized accordingly. Among the 51 chief nephrologists, 70.6% expressed their confidence in PD, and 88% expressed a strong interest in PD. Overall, 90.2% of the nephrologists indicated that they would start or expand a PD program immediately after they got back to their own hospitals.

More than half of the nephrologists (52.9%) thought that the ideal proportion of PD in China should be 30% – 50%. [The actual penetration rate for PD is less than 10% in most areas (58.8%) of China, and 10% – 20% in some areas (21.6%).]

Most nephrologists thought that the major reasons for such a low PD penetration rate were low reimbursement rates to the hospital and physician for PD treatment (51%) and insufficient patient and professional education about PD (27.5%). A few nephrologists thought that peritonitis (21.7%), a high PD drop-out rate (15.7%), patient preference (7.8%), and the difficulty of PD follow-up (3.9%) also affected the penetration of PD in China. Malnutrition, lack of insurance, and a HD-first policy in the hospital were cited by 1 chief nephrologist.

**Discussion**

The present study found that PD is underutilized in China and that the low PD penetration rate is mainly attributable to non medical factors.

Recent studies indicate that the number of patients in need of dialysis will continue to increase, because, in recent years, the criteria under which patients are offered dialysis have been expanded, and elderly patients and patients with other comorbid diseases are now being treated.

Dialysis treatment requires considerable resources. Many patients with chronic renal failure can be successfully treated with either HD or PD. The decision about whether to treat a patient with HD or PD is thus often made using implicit criteria. The argument about whether HD is superior to PD (or vice versa) continues, and the literature shows conflicting results (3–5).

Owing to the simplicity and cost effectiveness of PD, many authorities favor that less costly service. A recent cost–utility analysis by Sennfalt et al. (6) showed that PD should be regarded as the primary method of treatment for patients eligible for both PD and HD. Health care service resources are rather limited in China, and PD, an effective renal replacement therapy, should theoretically be the first choice for chronic renal failure patients as it is in Hong Kong (2,7). However, HD is the predominant treatment in China. Recent Chinese registry data showed that the PD penetration rate is only around 10% (7).

The present survey among chief nephrologists in China showed that HD is available in all hospitals; PD is not. In most places, the PD penetration rate is less than 10%, similar to the percentage in the registry data. Although only 51 chief nephrologists were included in the present study, all of those nephrologists are directors of nephrology in various university hospitals. They are in charge of nephrology development...
in their respective provinces. Their opinions are therefore highly representative and reflect the current practice regarding dialysis modality selection in China.

Our survey found that non medical factors are the major reason for the low PD penetration rate in China. We found that, despite the fact that most of the chief nephrologists did not consider HD to be superior to PD, or vice versa, and that most of the nephrologists are interested in PD and confident in PD, reimbursement to hospitals and nephrologists prevent use of PD in their regions.

Few studies have addressed the relationship of non medical factors to modality assignment (8,9). In a recent review that summarized PD development in Asian countries, Wang et al. (7) found that reimbursement policies significantly affect the use of PD in Asia. The reimbursement system in Asia typically favors HD over PD, except in Hong Kong (and there, PD usage is high). In mainland China, the high cost of PD solution and the low cost for HD staff mean that PD lacks a cost advantage. Actually, at the present time, the cost of PD is similar or only slightly less expensive than the cost of HD. Reimbursement to the hospital and physicians is much better for HD than for PD, and reimbursement is therefore the most important factor limiting the use of PD.

In the current health care system, most hospitals in China are run under fee-for-service models. Each HD session is performed in the hospital, and so the hospital can profit from the service provided. Because PD patients perform dialysis exchanges at home, by themselves, most of the payment for treatments goes to medical companies instead of hospitals in many regions. The high profit associated with HD treatment has driven the fast growth of that modality in China over the past 20 years, and many hospitals have adopted a HD-first policy.

Interestingly, we found that most nephrologists believe that the ideal penetration rate for PD should be 30% – 50%. That percentage is similar to the percentage reported in North America (10,11), suggesting that PD is underutilized in China. We believe that, with the increase in HD cost owing to the increased cost of human resources, with a decrease in the cost of PD solution, and with reform of reimbursement in China, the cost advantage of PD will be significant, and the penetration rate for PD will increase.

Another important reason shown in this survey for low PD usage in China is insufficient patient and staff education about PD treatment. That situation is similar to the situation in other Asian countries (7). Some senior nephrologists have not been well educated in current PD knowledge and still hold that PD is a second-class therapy. That situation leads to a possible lack of awareness about PD therapy among patients who are starting renal replacement therapy. Our finding that those who believe HD is superior are those who have experience only with HD is therefore not surprising. The PD society must understand the importance of education and put effort into creating opportunities for nephrologists, nurses, and patients to receive education and to acquire updated knowledge about PD.

Although the proportion was not significant, some chief nephrologists pointed out that fear of peritonitis and a high PD drop-out rate affected their selection of PD for their patients. The peritonitis rate has dropped dramatically in recent years in China owing to wide use of the Y-disconnect system, but peritonitis remains a cause of drop-out. The high PD drop-out rate may give nephrologists and patients the impression that PD can be used only as a “bridging therapy” (7). We therefore believe that reducing PD drop-out by reducing the peritonitis rate and that achieving a better understanding of the factors that predict long-term PD treatment are important areas of PD research in China.

Conclusions
Our survey among Chinese chief nephrologists suggests that PD in China is underutilized. The most important factor that limits use of PD is the low reimbursement rate to hospitals and physicians for PD treatment. Insufficient patient and professional education and fear of the high PD drop-out rate have all contributed to the low penetration rate of PD in China.

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