Peritoneal dialysis (PD) for renal replacement therapy (RRT) is safe and effective in patients with end-stage renal disease (ESRD). Currently, no data exist for the same in patients at correctional institutions [Department of Corrections (DOC)]. We compared demographic characteristics of, and the efficacy and outcome of self-administered continuous ambulatory peritoneal dialysis (CAPD) in, DOC patients with data from the U.S. Renal Data System for the free-living population (FLP).

We retrospectively reviewed the charts of DOC patients opting for CAPD (n = 10) in the last 7 years. Baseline data (age, race, cause of ESRD, serum chemistries, anemia, bone profiles, and Kt/V) were obtained for dialysis start and 6 – 12 months after dialysis start. Major events, including switches to hemodialysis (HD), hospitalizations, and deaths, were also studied.

The median age of the DOC patients was 45 years. The group was 40% black, 30% white, and 30% Hispanic. Cause of renal failure was diabetes in 30%, HIV-associated nephropathy in 30%, primary glomerular disease in 20%, and hypertension or unknown in 20% of patients. The DOC patients had higher levels of blood urea nitrogen (BUN) at presentation, but better anemia profiles than did the FLP. Complications included peritonitis, fluid leaks, and cardiac events.

Median age at dialysis start is lower for DOC patients, and HIV-associated nephropathy is more common than in the FLP. Levels of BUN/creatinine were much higher in DOC patients, but hemoglobin levels were similar to those in the FLP. Hospitalization rates for peritonitis were comparable; cardiac disease was common in both groups. Self-CAPD can be safely and effectively performed in DOC patients.

Key words
Chronic kidney failure, end-stage renal disease, prisoners, correctional institutions

Introduction
Peritoneal dialysis (PD) is an effective form of renal replacement therapy (RRT) that is widely used throughout the world in the management of end-stage renal disease (ESRD). Over the last 7 years at our institution, we have supported PD as a modality of RRT for patients in the corrections system [Department of Corrections (DOC)] that opt for it.

Data exist concerning the characteristics of patients on PD in the United States, including demographic and biochemical profiles at the onset of RRT and subsequently at various periods of follow-up. However, all those data derive from the free-living population with no specific reference to patients in the corrections system.

Using a Medline search, we performed a literature review to identify data concerning PD in prisoners and found that no such data exist in the worldwide literature. We therefore compared the demographic characteristics of, and the efficacy and outcomes of self-performed continuous ambulatory peritoneal dialysis (CAPD) in, DOC patients with ESRD in correctional institutions with data from the U.S. Renal Data System (USRDS) for the free-living population.

Patients and methods
We performed a retrospective chart review of ESRD patients in the state of Connecticut corrections system who had opted for PD as their modality of RRT in the last 7 years (n = 10). Our review received full Institutional Review Board (University of Connecticut Health Center Human Subjects Committee) approval.

We obtained baseline information, including demographics (age and race), biochemical profiles (serum chemistries, urea and creatinine clearances), and anemia profiles at onset of dialysis. We calculated peritoneal and renal Kt/V data at dialysis onset and at 6 months after dialysis initiation. Causes of ESRD and renal osteodystrophy profiles were identified at dialysis onset. Major intercurrent events—defined as hospitalizations, switches to hemodialysis (HD), and deaths—were also studied.
**Results**

All of the patients in our series were men. Their racial origins were African American (n = 4), Hispanic (n = 3), and Caucasian (n = 3). Causes of ESRD were HIV-associated nephropathy (n = 3), diabetic nephropathy (n = 3), primary glomerular disease (n = 2), hypertensive nephrosclerosis (n = 1), and unknown (n = 1). Table I shows the pertinent demographic and biochemical profiles of the patients.

With regard to complications, peritonitis requiring hospitalization occurred in 3 patients over a follow-up period of 213 patient–months (1 episode per 70 patient–months). One patient with peritoneal fluid leak, scrotal edema, and peritonitis was switched to hemodialysis (HD). One patient required HD in addition to PD for severe calciphylaxis. Two patients died of acute cardiac events, and 2 patients were lost to follow-up (including 1 deported to his native country). Table II compares our patient data with USRDS data.

**Discussion**

Our institution, a university teaching hospital and faculty practice, provides medical care to the inmates of correctional facilities in the State of Connecticut [Correctional Managed Health Care (CMHC)]. Trained dialysis nurses perform renal replacement (in the form of maintenance HD) within the correctional facilities. The medical director of dialysis conducts periodic visits to oversee the facilities and to assure the well-being of prisoners undergoing maintenance HD.

TABLE I  Characteristics of patients at baseline

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Range</th>
<th>Median±SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>29–61</td>
<td>45</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>113–183</td>
<td>168</td>
</tr>
<tr>
<td>Weight (lbs.)</td>
<td>81–223</td>
<td>183</td>
</tr>
<tr>
<td>BUN at onset (mg/dL)</td>
<td>79–199</td>
<td>116±39</td>
</tr>
<tr>
<td>Serum creatinine (mg/dL)</td>
<td>4.5–25.3</td>
<td>11.1±6.7</td>
</tr>
<tr>
<td>Urea clearance (mL/min)</td>
<td>1.1–8.0</td>
<td>3.65</td>
</tr>
<tr>
<td>Creatinine clearance (mL/min)</td>
<td>1.9–16.0</td>
<td>8.65</td>
</tr>
<tr>
<td>Serum albumin (g/dL)</td>
<td>1.7–3.9</td>
<td>3.2±0.8</td>
</tr>
<tr>
<td>Hemoglobin (g/dL)</td>
<td>5.6–12.0</td>
<td>10.1±2.1</td>
</tr>
<tr>
<td>Serum potassium (mmol/L)</td>
<td>3.1–6.0</td>
<td>4.4±0.8</td>
</tr>
<tr>
<td>Ionized calcium (mmol/L)</td>
<td>0.6–1.37</td>
<td>1.18</td>
</tr>
<tr>
<td>Serum phosphorus (mg/dL)</td>
<td>4.4–12.0</td>
<td>5.9±2.4</td>
</tr>
<tr>
<td>Serum PTH (pg/mL)</td>
<td>15–643</td>
<td>65±183</td>
</tr>
<tr>
<td>Kt/V (at onset)</td>
<td></td>
<td>2.4±0.6</td>
</tr>
<tr>
<td>Kt/V (at 6 months)</td>
<td></td>
<td>2.3±0.5</td>
</tr>
</tbody>
</table>

SD = standard deviation; BUN = blood urea nitrogen; PTH = parathyroid hormone.

Prisoners may opt for peritoneal dialysis (PD)—self-performed with supervision by the nursing staff at their facility. Exchanges are performed daily in the prison infirmary at set times: 0600 h, 1200 h, 1800 h, and 2400 h. A room (11×13 feet) with attached toilet and faucet is allocated for PD supplies; the room has a pristine appearance with glistening floors. Patients arrive in the area and first weigh themselves. They complete their own flow sheets after each exchange. Nurses are available in the infirmary, and the PD nurse and nephrologist are available by telephone for troubleshooting. Follow-up patient visits with the PD nurse and nephrologist occur in the CMHC secure ward at the university hospital. Over the last 7 years, we have successfully initiated a total of 10 patients within the prison system onto self-performed PD.

As evidenced by our data, the prison PD population differs from the free-living USRDS population. The prisoners are younger at dialysis onset, more frequently have HIV-associated nephropathy as the cause of ESRD, and present relatively late in terms of serum chemistries. Notably, the anemia profile in our patient series was comparable to, and even slightly better than, that of the free-living population. A possible explanation is that our patients tend to be younger men. Erythropoietin was not used in our patients before dialysis. The rate of hospitalization for peritonitis has been comparable to that of the USRDS data set. Unfortunately, cardiovascular morbidity and mortality are too common in our patients, who are younger than the free-living population on PD.

The present retrospective chart review has a relatively small sample size. Further evaluation of self-PD in prisoners is necessary to make clinical practice recommendations.

The advantages of self-PD in prisoners include reduced exposure to needles and indwelling vascular catheters, and reduced staff exposure to blood-borne disease. Self-PD also makes inmates responsible for their own health care and well-being, which may benefit them in other areas of life.

Our data also demonstrate that prisoners present significantly later in the course of their kidney disease. Self-performed CAPD can be offered as the primary choice of RRT in appropriate patients, or as the initial choice while a vascular access matures. Transition to HD may occur when residual renal function deteriorates, for ultrafiltration failure, or for complications as discussed earlier. Conversely, self-CAPD...
can be offered to prisoners who have exhausted all their potential sites for vascular access after years of HD. With limited opportunities for renal transplantation, self-performed CAPD offers an effective alternative to HD for incarcerated patients.

Conclusions
Our study demonstrates that PD as a modality of RRT can be performed safely and effectively in a prison population. Incarcerated patients are younger at the onset of dialysis and have a higher incidence of HIV-associated nephropathy as the cause of their ESRD. They tend to present later in the course of their chronic kidney disease, but they have a slightly better anemia profile than that seen in the free-living population—even in the absence of erythropoietin. Complication rates are comparable and cardiovascular morbidity and mortality appear similar between prisoners and the free-living population on PD.

**TABLE II** Comparison of Department of Corrections (DOC) patient data to data from the U.S. Renal Data System (USRDS)

<table>
<thead>
<tr>
<th>DOC self-PD patients</th>
<th>USRDS 2003</th>
</tr>
</thead>
<tbody>
<tr>
<td>Median age at onset of PD (years)</td>
<td>45</td>
</tr>
<tr>
<td>Cause of ESRD</td>
<td></td>
</tr>
<tr>
<td>Diabetic nephropathy</td>
<td>30%</td>
</tr>
<tr>
<td>HIV-associated nephropathy</td>
<td>30%</td>
</tr>
<tr>
<td>Hypertensive nephrosclerosis</td>
<td>—</td>
</tr>
<tr>
<td>Glomerulonephritis</td>
<td>20%</td>
</tr>
<tr>
<td>Median BUN/creatinine at onset (mg/dL)</td>
<td>116/11.1</td>
</tr>
<tr>
<td>Median hemoglobin at onset (g/dL)</td>
<td>10.1</td>
</tr>
<tr>
<td>Hospitalizations for peritonitis (per 1000 patient–years)</td>
<td>160</td>
</tr>
</tbody>
</table>

PD = peritoneal dialysis; ESRD = end-stage renal disease; HIV = human immunodeficiency virus; BUN = blood urea nitrogen.

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E-mail: adams@nso.uchc.edu
In the present study, we evaluated the clinical course and outcome of chronic peritoneal dialysis (PD) in a group of elderly patients. We enrolled 60 elderly patients (37 men, 23 women) starting PD over a 4-year study period and assessed outcomes.

The mean age of our patients was 61 ± 7 years; mean PD duration was 16 months (range: 3–40 months). Primary diseases were mainly diabetic nephropathy (54%) and glomerulonephritis (20%). In most patients, the PD modality was chosen because of cardiac instability. Complications during PD included peritonitis (1 episode per 9 patient–months) and exit-site infection (1 episode per 26 patient–months). Technique survival was 89% at 1 year. Patient survival was 83% and 32% at 1 and 4 years respectively. The most frequent causes of death were cerebrovascular accident, cardiac complications, and sepsis.

We also compared predialysis parameters to final parameters for 20 deceased patients. Mean age in this group was 62 ± 8 years, and mean PD duration was 13 ± 8 months. Body mass index (BMI) was 23 ± 3 kg/m² predialysis versus 22 ± 3 kg/m² at the end of dialysis ($p < 0.01$); residual renal creatinine clearance was 4.4 ± 2 mL/min versus 2.3 ± 2 mL/min ($p < 0.003$), and weekly total $Kt/V$ was 2.1 ± 0.3 versus 1.8 ± 0.3 ($p < 0.002$). Albumin showed positive correlations with BMI ($r = 0.40$, $p < 0.02$) and with creatinine ($r = 0.40$, $p < 0.01$).

We conclude that survival of elderly patients on continuous ambulatory peritoneal dialysis is reasonable in the first year, and that further improvement may be achieved by initiating dialysis early, by increasing the dialysis dose, and by improving the patients’ nutrition status.

**Key words**
End-stage renal failure, diabetic nephropathy, peritonitis, survival

**Introduction**
Because of continuous improvement in the various modalities of renal replacement therapy (RRT), elderly patients with end-stage renal failure (ESRF) are increasingly being accepted for dialysis (1). Data from the European Renal Association/European Dialysis and Transplant Association (ERA–EDTA) show that 48% of new patients starting dialysis therapy are older than 65 years of age (2). Comorbidities such as diabetes, coronary artery disease (CAD), and cerebrovascular disease (CVD) are more frequent in elderly patients, and therefore peritoneal dialysis (PD) becomes a better choice for many.

In general, worldwide use of PD is low as compared with hemodialysis (HD), accounting for 14% of the ESRF patient population (3). Multiple factors are involved. Reports compiled from the U.S. Renal Data System show that the number of ESRF patients on PD is much smaller in comparison with other modalities because of unfavorable outcomes over the longer duration (4).

In Bangladesh, the general attitude is to use the limited dialysis facilities to provide HD to younger patients. This approach often leaves PD as the only choice for elderly patients (5). In the present study, we retrospectively analyzed the outcomes of PD in a group of elderly ESRF patients. Our objective was to compare events during PD in this group of patients to events documented in other published reports.
Patients and methods

We enrolled into the study elderly patients attending the nephrology department of BSM Medical University, Bangladesh, for PD therapy over a period of 4 years. “Elderly” was considered to be 50 years of age or older.

In all patients, a Tenckhoff double-cuff, straight catheter was inserted surgically. The patients used various types of PD connection systems (single/double/ultra). All patients were evaluated for clinical and biochemical parameters. Outcomes were assessed from technique and patient survival. We also separately evaluated parameters at the start and end of PD for 20 patients who died, trying to identify factors that influenced survival.

Results

We enrolled 60 ESRF patients (37 men, 23 women) into the study. Mean age of the patients was 61 ± 7 years. Primary renal diseases were diabetic nephropathy (54%), glomerulonephritis (20%), hypertension (9%), and 17% other diseases (polycystic kidney disease, obstructive uropathy, renal stone disease, etc.). Comorbid illnesses present included hypertension in 94% of patients, CAD in 64%, and CVD in 23%. Indications for PD were cardiovascular instability (angina, myocardial infarction, refractory heart failure, etc.) in 51%, unavailability of an HD facility in 22%, patient’s choice in 22%, and access (fistula) failure in 5%. Tables I and II show the various clinical and biochemical parameters for the patients before the start of PD.

At the time of evaluation, mean duration of PD was 16 months (range: 3 – 40 months). Table III shows peritonitis-related and technique survival data for that period. The causative organisms of peritonitis were gram-positive bacteria (staphylococcus and streptococcus species) in 36% of cases, and gram-negative bacteria (Escherichia coli, Klebsiella, and Pseudomonas species) in 42%. Exit-site infection was caused by gram-positive organisms in 58% of cases and gram-negative organisms in 42%. In 6 patients, the PD catheter was removed for unresolved peritonitis. Other mechanical complications—leaks, malposition, herniation, blockage, and membrane failure—were encountered in only a few patients.

Patient survival was 83% at 1 year and 32% at 4 years. The most frequent cause of death was CVD. The others were sepsis (peritonitis related), CAD, and other causes (chronic debilitation, sudden death, discontinuation of dialysis therapy, etc.; Table IV).

We evaluated 20 of the deceased patients for clinical and biochemical parameters at the start and end of dialysis. The mean age of those patients was 62 ± 8 years, and the mean duration of dialysis was 13 ± 8 months. At the end of dialysis, those patients showed a lower total Kt/V associated with a decrease in residual renal function (Table V).

---

**Table I**  Demographics of the patients (n = 60)

<table>
<thead>
<tr>
<th>Age (years)</th>
<th>61±7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male/female</td>
<td>37/23</td>
</tr>
<tr>
<td>Primary renal disease</td>
<td></td>
</tr>
<tr>
<td>Diabetic nephropathy</td>
<td>54%</td>
</tr>
<tr>
<td>Glomerulonephritis</td>
<td>20%</td>
</tr>
<tr>
<td>Hypertension</td>
<td>9%</td>
</tr>
<tr>
<td>Others</td>
<td>17%</td>
</tr>
</tbody>
</table>

**Table II**  Baseline characteristics of the patients (n = 60)

<table>
<thead>
<tr>
<th>BP (mmHg)</th>
<th>161±11</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diastolic BP (mmHg)</td>
<td>89±9</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>22±3</td>
</tr>
<tr>
<td>Hemoglobin (g/dL)</td>
<td>8±1</td>
</tr>
<tr>
<td>Serum creatinine (µmol/L)</td>
<td>1023±188</td>
</tr>
<tr>
<td>Creatinine clearance (mL/min)</td>
<td>5±2</td>
</tr>
<tr>
<td>Serum K⁺ (mmol/L)</td>
<td>4.4±0.6</td>
</tr>
<tr>
<td>Serum Ca²⁺ (mmol/L)</td>
<td>1.7±0.2</td>
</tr>
<tr>
<td>Serum PO₄⁻ (mmol/L)</td>
<td>1.9±0.3</td>
</tr>
<tr>
<td>Serum albumin (g/L)</td>
<td>31±4</td>
</tr>
</tbody>
</table>

**Table III**  Dialysis complications observed

<table>
<thead>
<tr>
<th>Peritonitis</th>
<th>1/9 patient-months</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infective organisms:</td>
<td></td>
</tr>
<tr>
<td>Gram-positive</td>
<td>36%</td>
</tr>
<tr>
<td>Gram-negative</td>
<td>42%</td>
</tr>
<tr>
<td>Fungus</td>
<td>6%</td>
</tr>
<tr>
<td>Culture-negative</td>
<td>16%</td>
</tr>
<tr>
<td>Exit-site infection</td>
<td>1/26 patient-months</td>
</tr>
<tr>
<td>Infective organisms:</td>
<td></td>
</tr>
<tr>
<td>Gram-positive</td>
<td>58%</td>
</tr>
<tr>
<td>Gram-negative</td>
<td>42%</td>
</tr>
</tbody>
</table>

**Table IV**  Causes of death

<table>
<thead>
<tr>
<th>Causes of death</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>CVD</td>
<td>32%</td>
</tr>
<tr>
<td>Sepsis</td>
<td>12%</td>
</tr>
<tr>
<td>Other</td>
<td>36%</td>
</tr>
</tbody>
</table>

**Table V**  Dialysis parameters at start and end of dialysis

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Start</th>
<th>End</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Kt/V</td>
<td>2.2±0.5</td>
<td>1.9±0.4</td>
</tr>
<tr>
<td>Residual renal function</td>
<td>18±6</td>
<td>12±5</td>
</tr>
</tbody>
</table>
Correlation studies in all patients showed that serum albumin was positively correlated with body mass index (albumin vs. BMI: \( r = 0.40 \), \( p < 0.02 \)) and with serum creatinine (albumin vs. Cr: \( r = 0.40 \), \( p < 0.02 \)). Also, increased hemoglobin levels were associated with lower serum creatinine levels (Hb vs. Cr: \( r = 0.50 \), \( p < 0.01 \)). In the 20 deceased patients, a reduction in total PD clearance (Kt/V) was inversely correlated with dialysis duration (Kt/V vs. duration: \( r = -0.60 \), \( p < 0.01 \)).

## Discussion

In the present study, half of the patients were diabetic, and most were referred to PD because of cardiac instability. Decompensated cardiac status is common in elderly patients, especially those with diabetes, and it renders HD difficult to perform. Higher rates of cardiovascular complications are related chiefly to high blood pressure. In older patients, CVD has been found to be influenced by systolic hypertension in many situations (6). Our study patients had a higher mean systolic blood pressure at the start of PD, which might contribute to the complications present at dialysis onset.

Technique survival in our study group at 1 year was about 89%. Technique failure was attributable mostly to unresolved infection leading to catheter removal. Other reports have shown that technique survival can vary from 96% after 1 year to 64% at 2 years (7,8).

The incidences of peritonitis and exit-site infection were relatively high in the present study. Carey et al. (9) and Anderson (10) reported similar findings. Proposed possible factors are increased age, poor nutrition status (low albumin), and diabetes. Those factors were all present in our study patients.

The various PD connection systems used by the patients may also be partly responsible for the rates of infection. In this study, the causative organisms of peritonitis were predominantly gram-negative bacteria. With the introduction of the twin-bag system, the incidence of gram-positive infections are decreasing. Also, some studies have found that elderly patients are more prone to gram-negative peritonitis (5). That finding may be attributable to an increased incidence of transmural migration of microbes from the gut rather than from intraluminal spread.

Survival on dialysis is lower among elderly patients than among younger patients. Our patient group had a 1-year survival of 83% and a 2-year survival of 54%. The ERA–EDTA registry analysis of elderly patients showed similar survival rates (2). Reports from some other Asian patient groups also showed similar survival (11).

Many studies show confounding results regarding survival of PD patients in comparison with HD patients. In some studies, HD appears superior; other studies found equivocal results (12).

When we compared various clinical and biochemical parameters at the start and end of PD in 20 of our deceased patients, we found that those patients had a lower Kt/V and a reduction in residual renal function over the dialysis period. Alterations in those two parameters are recognized as being related with poorer dialysis outcomes. A large cohort study found that mortality was higher among patients who lost residual renal function (13). A reduction in residual function must be compensated by an increased dialysis dose—that is, an increased PD exchange volume. But Kt/V was found not to be further increased in our deceased patients. That situation might be a contributing factor to their poorer survival.

<table>
<thead>
<tr>
<th>TABLE IV Dialysis outcomes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patient survival</td>
</tr>
<tr>
<td>1 year</td>
</tr>
<tr>
<td>2 years</td>
</tr>
<tr>
<td>3 years</td>
</tr>
<tr>
<td>4 years</td>
</tr>
<tr>
<td>Cause of death</td>
</tr>
<tr>
<td>Cerebrovascular</td>
</tr>
<tr>
<td>Cardiac</td>
</tr>
<tr>
<td>Sepsis</td>
</tr>
<tr>
<td>Others</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>TABLE V Comparison of various parameters in deceased patients (n = 20) before start of dialysis and just before death</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td>Systolic BP (mmHg)</td>
</tr>
<tr>
<td>Diastolic BP (mmHg)</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
</tr>
<tr>
<td>Hemoglobin (g/dL)</td>
</tr>
<tr>
<td>Serum creatinine (µmol/L)</td>
</tr>
<tr>
<td>Residual CCr (mL/min)</td>
</tr>
<tr>
<td>Serum albumin (g/L)</td>
</tr>
<tr>
<td>Kt/V (total)</td>
</tr>
</tbody>
</table>

BP = blood pressure; BMI = body mass index; CCr = creatinine clearance.
In the same patients, serum albumin was also lower at the beginning of PD and further decreased until the end of dialysis. A higher albumin level at enrollment in dialysis therapy may confer better survival (14). In the CANUSA study (15), patients with the highest serum albumin had the lowest risk of death.

Conclusions
We found that our elderly ESRF patients were often referred to PD because of associated comorbidities. Duration of survival in elderly patients on continuous ambulatory peritoneal dialysis may be acceptable in the first year. Further improvement may be achieved by initiating dialysis early, by increasing the dialysis dose, and by improving the patients’ nutrition status.

References

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We have developed a new telemedicine system that uses a cellular telephone and Internet Web site to monitor changes of blood pressure (BP) in patients on continuous ambulatory peritoneal dialysis (CAPD). An I-converter data collection system directly transmits all data on BP and heart rate (HR) measured by a fully automatic device (HEM-705IT: Omron Life Science, Tokyo, Japan) to a cellular telephone. The cellular telephone then sends the data directly to the main server at the NTT DoCoMo data center. All data, including BP and HR from each patient, are accumulated in the server. Application service provider technology (ASP) connects that system directly to the Internet.

Any time and anywhere, each patient can use a cellular telephone or the Internet Web site to monitor, in graph form, changes in their data. The average data at each collection point are calculated and shown on the Web site. All data collected by cellular telephone are also calculated and sent directly, in real time, to the physician’s office. Currently, we are using this telemedicine system for 44 hypertensive patients on CAPD at our center.

In the present study, we used the telemedicine system to evaluate changes in 24-hour BP. We followed 20 CAPD patients, monitoring changes in BP for 3 months. At the end of study, we found that the average daytime home BP was 137 ± 8 mmHg over 80 ± 4 mmHg and that the average nighttime BP was 128 ± 7 mmHg over 72 ± 4 mmHg. The overall average home BP was 132 ± 7 mmHg over 76 ± 3 mmHg. The average outpatient clinic BP was 155 ± 9 mmHg over 86 ± 5 mmHg.

The measured systolic and diastolic BP at the outpatient clinic were significantly higher than those measured at home. As measured at the outpatient clinic, BP indicated that 7 CAPD patients (35%) were hypertensive (>160/95 mmHg). However, as measured at home, BP indicated that only 4 CAPD patients (20%) were truly hypertensive (>135/85 mmHg). We were therefore able to determine that 43% of our hypertensive patients had “white coat” hypertension.

Our new telemedicine system that monitors BP by cellular telephone provides great advantages in monitoring BP at home in patients on CAPD.

Key words
Blood pressure, telemedicine, cellular telephone, continuous ambulatory peritoneal dialysis

Introduction
Information and telecommunications technologies have developed rapidly over the last few decades, and many of the resulting techniques have found applications in the medical field. Computers are assisting medicine more and more in many areas, not the least of which are nephrology and dialysis, given the particular characteristics of those fields, including number of patients, complexity of cases, follow-up length, and economic cost (1).

Previously, we reported developing a telemedicine system that uses a cellular telephone to collect data on continuous ambulatory peritoneal dialysis (CAPD) patients (2,3). Our telemedicine system has two separate parts: (A) a data collection and monitoring system based on cellular telephone technology, and (B) an Internet Web site accessible by computer.
The system has been very useful for monitoring the data of CAPD patients. When our telemedicine patients have trouble with their CAPD treatment, we can contact them by cellular telephone and offer advice. We expected the telemedicine system to have great advantages for maintaining patients on CAPD, especially handicapped and elderly patients (2,3). However, patients using our system had to input their data—including body weight, ultrafiltration volume, blood pressure (BP), heart rate (HR), and urine volume—by themselves. Some patients, especially elderly ones, could not input the data by themselves. We therefore began to develop a new telemedicine system that can directly collect data from any fully automatic device, including BP monitors, weight scales, glucose meters, and automated peritoneal dialysis (APD) systems.

In the present study, we report on our new data collection system, called “I-converter.” We used this new system to monitor changes of BP in hypertensive patients on CAPD.

Patients and methods

I-converter data collection system
Figure 1 shows our newly developed telemedicine system. First, BP is measured by a fully automatic device (HEM-705IT: Omron Life Science, Tokyo, Japan). The I-converter is then connected between the BP measuring device and a cellular telephone. When the green signal indicates that a connection has been established, a press of the I-converter switch downloads the BP, HR, and time data directly from the BP measuring device to the cellular telephone memory (Figure 2). The data are then sent directly to the main server at the NTT DoCoMo company data center.

The server accumulates all data collected from each patient. Application service provider (ASP) technology connects the server data to an Internet Web site. Averages for the patient data are calculated and shown at the Web site. Any time and anywhere, participating patients can access the Internet Web site for hypertensive patients. All participating patients can use a cellular telephone or the Internet Web site to check the changes in their own data in graph form.

Self-measurement of BP at home
Patients were asked to measure their BP at home, once in the morning within 1 hour of awaking (after micturition) and once in the evening before sleep (twice daily in total). Each measurement was to be taken in a sitting position after 3 minutes of rest. Morning BP was to be measured before breakfast, before drug ingestion, and before the first CAPD exchange of the day. Evening BP was to be measured after the last CAPD exchange, just before bedtime.
In principle, home BP measurements were to be performed every day throughout the observation and treatment period using the HEM-705IT, which meets the criteria of the Association for the Advancement of Medical Instrumentation. The HEM-705IT uses the cuff oscillometric method. The BP and HR data measured by the device were transmitted directly to the cellular telephone by the I-converter collection system. The data were then sent directly to the NTT DoCoMo server by the cellular telephone.

**Web site for hypertensive patients**
When patients wanted to check their data, they could log onto the Internet and visit the Web site or dial into the server using their cellular telephone. Patients can access the i-mode site to view their data whenever they want. They can monitor the actual data, averages, and graphs. All data from hypertensive patients are collected by the ASP technology and calculated by computer. If the medical staff want to check the data for the hypertensive patients, they also can access the Web site. If our hypertensive patients encounter problems, an emergency signal on the Web site alerts the medical staff. Someone then calls and consults with the patient over the cellular telephone.

**Patients**
We used the new telemedicine system to monitor 20 hypertensive patients (12 men; 8 women) who were undergoing CAPD. The average age of the patients was 43.6 ± 3.4 years. The average duration of CAPD was 3.2 ± 0.3 years. All patients were already receiving antihypertensive drugs. The causes of renal insufficiency were chronic glomerulonephritis \((n = 14)\), diabetic nephropathy \((n = 2)\), and unknown causes \((n = 4)\). Previously administered antihypertensive drugs were withheld before the start of the study.

All patients gave their informed consent to participation in the study. The study was performed in accordance with the Second Helsinki Declaration and was approved by the local ethics committee. After a run-in period, patients started to receive their antihypertensive drugs once daily. Patients were assessed at 4, 8, and 12 weeks.

During the study, all subjects were asked to undergo the same dietary and dialysis regimen. The CAPD treatment consisted of 4 daily 2-L exchanges of dialysate containing lactate and 1.5 g/dL or 2.5 g/dL dextrose. Mean daily dietary intake was determined from individual 24-hour food records during a 3-day period. Dietary protein intake was at least 1 g/kg daily, and energy intake was about 25 kcal/kg daily. Salt intake was restricted to about 7 g daily or less.

**Statistical analysis**
All data are shown as mean ± standard error of mean. Multiple comparisons were analyzed by analysis of variance (ANOVA) with the Kruskal–Wallis test and subsequent Dunn test. A simple regression analysis was performed for correlations among the variables. A \(p\) value < 0.05 was required for statistical significance.

**Results**
We followed 20 CAPD patients to monitor changes in BP over 3 months. Figure 3 shows the data for BP taken at home and in the outpatient clinic in those 20 hypertensive patients. The data reveal that, when measured at home, the average daytime BP was 137 ± 8 mmHg over 80 ± 4 mmHg and the average nighttime BP was 128 ± 7 mmHg over 72 ± 4 mmHg. The overall average home BP was 132 ± 9 mmHg over 76 ± 3 mmHg. The average outpatient clinic BP was 155 ± 9 mmHg over 86 ± 5 mmHg.

The measured systolic and diastolic BP at the outpatient clinic were significantly higher than those at home.
measured at home. Figure 4 shows the correlation between home BP and outpatient clinic BP. Home BP and outpatient clinic BP were strongly correlated (systolic: $r^2 = 0.815, p < 0.0001$; diastolic: $r^2 = 0.745, p < 0.0001$).

By outpatient clinic BP measurement, 7 (35%) of the 20 CAPD patients were hypertensive (>160/95 mmHg). However, by home BP measurement using our telemedicine system, only 4 (20%) of the 20 CAPD were truly hypertensive (>135/85 mmHg). We were therefore able to determine that 43% of our hypertensive patients had “white coat” hypertension.

**Discussion**

We are currently using our new telemedicine system with hypertensive patients undergoing CAPD. We expect the system of monitoring home BP to have great advantages for these patients—especially the handicapped and elderly ones. When these patients have trouble at home, we can contact with them by cellular telephone and provide advice.

In addition, we can use the telemedicine system to network between our hypertensive patients and the hospital. Patients who live remote from the main hospital can periodically attend an affiliated hospital for routine follow-up: examination of physical condition, blood chemistry, chest X-ray, electrocardiogram, and so on. A nephrologist in the main hospital can obtain all of a patient’s data—including BP, medications, and blood chemistry—through the telemedicine system. In future, patient will be able to receive drugs prescribed by the nephrologist as required. Furthermore, our system can be used as an emergency alarm system. In the case of an emergency call, all data for the patient are available at the main hospital, and the nephrologist can order the necessary medication.

In the past, the most useful BP information related to hypertension was believed to come from outpatient clinic measurements. Information on BP for epidemiologic study was also usually obtained in a medical environment such as that used for mass screening. Recently, questions have been posed regarding the true meaning of BP measured in the outpatient clinic. Research has therefore focused on other ways of measuring BP, such as ambulatory BP (ABP) monitoring and home BP measurement. Both of those new techniques for measuring BP have several advantages over measurements taken at the outpatient clinic. One advantage is the ability to take multiple BP measurements over a given period (4). The ABP monitoring technique, for example, provides more than 50 measurements during the course of a day. Home BP monitoring provides more than 60 measurements during the course of a month. Such detailed information permits the derivation of many BP parameters. Data from ABP and home BP can monitor the circadian variation in BP and the morning rise in BP.

Circadian variation in BP is usually observed in normotensive and hypertensive patients alike (5,6).
Some reports have noted that, under several conditions, variation in circadian BP is diminished and inverted, with nocturnal elevation of BP (5,6). The clinical significance of a high morning BP was suggested by the results of previous studies (7,8). The higher the morning BP in relation to the evening BP, the greater the relative hazard ratio for cardiovascular mortality. Controlling morning BP seems to yield a better prognosis in the hypertensive patient (7,8).

In the past, patients checking their BP by themselves at home had to write the resulting data in a notebook. So that staff could monitor the home BP, patients had to bring their notebooks to the outpatient clinic. For patients and the medical staff alike, using our telemicine system to monitor home BP is easier and more reliable. The system has great advantages for hypertensive patients and reforms the monitoring of home BP (9).

“White coat” hypertension is defined as reproducible hypertension in the medical setting and normotension in the non medical setting. By using home BP measurements, the Ohasama study (5) revealed the prognostic significance of “white coat” hypertension. According to the Cox proportional hazards model, the relative risk in “white coat” hypertension is similar to that seen in true normotensive patients. True hypertension and “reverse white coat” hypertension carry a significantly higher relative risk of cardiovascular mortality.

In the present study, we measured BP both at the outpatient clinic and at home. The BP measured at the outpatient clinic was significantly higher than that measured at home—for both the systolic and diastolic readings.

Hypertension is a common finding in CAPD patients and undoubtedly contributes to the development of cardiovascular events. Approximately 80% of patients are hypertensive at dialysis initiation; however, in CAPD patients, the prevalence of hypertension falls to 40% by the end of year 1 largely because of volume control (10).

Previously, we reported changes in 24-hour ABP before and after introduction of CAPD (11,12). Analysis of those 24-hour ABP readings revealed a predominant daytime reduction in BP and a lesser reduction at night after introduction of CAPD. In the present study, BP measured at the outpatient clinic showed that 35% of patients on CAPD were hypertensive (>160/95 mmHg). However, BP measured at home by our telemicine system showed only 20% of patients to be truly hypertensive (>135/85 mmHg). We were able to determine that 43% of hypertensive patients had “white coat” hypertension.

Conclusions
Our results suggest that home-measured BP has more predictive power and is more representative of individual BP than is conventionally measured outpatient clinic BP. If home BP measurements become the “gold standard” because of their predictive power and reliability, our telemicine system will be the best system to monitor home BP. Our new telemicine system—with our new I-converter data collection system that connects to a cellular telephone—has great advantages for monitoring home BP in hypertensive patients on CAPD.

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