Damage to large arteries is a major contributory factor to the high cardiovascular morbidity and mortality of patients with end-stage renal disease. Among the methods for assessment of arterial damage, measurements of pulse wave velocity (PWV) are considered to predict cardiovascular risk. In the present study, we compared changes in the PWV of patients on hemodialysis (HD) and on continuous ambulatory peritoneal dialysis (CAPD).

Patients were eligible for entry into the study if they had been on HD or CAPD for at least 3 months, but for fewer than 5 months, and if they had had no clinical cardiovascular disease during the 6 months preceding study entry. We followed a total of 22 patients (average age: 57.9 ± 9.8 years) on HD and 22 patients (average age: 59.7 ± 11.4 years) on CAPD for 1 year. Baseline PWV was determined, and a second measurement was performed 1 year after the baseline PWV had been obtained.

Systolic and diastolic blood pressures in the two groups were similar [144.8 ± 18.4 mmHg over 83.2 ± 8.7 mmHg (CAPD) vs. 147.4 ± 18.8 mmHg over 87 ± 12.3 mmHg (HD)]. In the patients on CAPD, urine volume was fairly constant at about 546.1 ± 365 mL daily; however, urine volume for most of the patients on HD was less than 100 mL daily. Although no significant difference was observed in baseline PWV [1726.2 ± 374 m/s (CAPD) vs. 1774.2 ± 531.3 6 m/s (HD)], a significant difference in PWV was seen between the two groups at 1 year [1631.9 ± 380.8 m/s (CAPD) vs. 1853.2 ± 434.2 m/s (HD), p < 0.05]. With the exception of level of serum cholesterol [256 ± 24 mg/dL (CAPD) vs. 187 ± 25 mg/dL (HD), p < 0.05], other laboratory data were not significantly different between the two groups.

Despite higher serum cholesterol in the patients on CAPD, PWV was faster in the patients on HD. There may be less arterial damage in patients on CAPD than in patients on HD.

Key words
Pulse wave velocity, arterial damage, hemodialysis, continuous ambulatory peritoneal dialysis, angiotensin, blood pressure, cholesterol

Introduction
Studies in which the mortality rates for patients undergoing hemodialysis (HD) are compared with the mortality rates for patients undergoing continuous ambulatory peritoneal dialysis (CAPD) have yielded conflicting results (1–3). Previously, we reported that blood pressure (BP) and serum cholesterol level should be taken into account for patients treated with either CAPD or HD (4). Both factors induce vascular abnormalities such as vascular calcification, arteriosclerosis, and severe atherosclerosis lesions in patients with end-stage renal disease (ESRD).

Theoretically, compared with HD, CAPD possesses several hemodynamic advantages: it is a continuous depuration process, and it maintains a stable intravascular volume with minimal electrolyte shifts and minimal changes in BP. However, few studies have
compared the prevalence of vascular abnormalities between patients on HD and those on CAPD.

Cardiovascular disease is the most important determinant of mortality in patients on CAPD and HD, accounting for about 50% of deaths on dialysis in Japan (5) and the United States (6). Arterial disease is one of the principal risk factors (7). The most common methods used to evaluate the arterial stiffness in clinical practice are based on the study of pulse wave velocity (PWV) along a given large artery (8).

Recently, measures of aortic stiffness proved to be powerful predictors of survival on HD (9). However, very few studies have focused on comparing arterial wall properties between patients on CAPD and on HD. Recently, Covic et al. (10) demonstrated that patients on CAPD had stiffer arteries and more profoundly abnormal endothelial-dependent vasomotor function than did matched subjects on HD. However, that study was carried out in a cross-sectional design, and the possibility remains that some of the differences may have already been present at dialysis initiation. Therefore, to try to further clarify the issue, we compared differences in BP and PWV both before start of dialysis therapy and 1 year after the start of dialysis therapy 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. The study was performed in patients with chronic renal failure on CAPD \( (n = 22) \) and on HD \( (n = 22) \) at the Kidney Disease Center of Saitama Medical School or at the Kidney Disease Center of Kubojima Medical Clinic, Saitama, Japan. The patients were matched for age [59.0 ± 9.9 years in CAPD patients vs. 58.1 ± 10.1 years in HD patients (mean ± standard deviation)], sex (17 men, 5 women), and cause of chronic renal failure. In each group, 10 patients had chronic glomerulonephritis, 8 had diabetic nephropathy, and 4 had nephrosclerosis. Serum creatinine was also similar in both groups (8.3 ± 2.7 mg/dL in CAPD vs. 8.8 ± 3.7 mg/dL in HD).

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

The HD treatments were carried out over a 3- to 4-hour period 2 – 3 times weekly using a high-flux synthetic membrane (polysulfone or polyacrylonitrile). Bicarbonate was used as a buffer. Water quality was regularly monitored to ensure strict bacteriologic standards.

Administration of recombinant human erythropoietin (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. Patients were given oral iron supplementation if they were diagnosed as having iron deficiency.

Patients were treated with 1,25-(OH)_2 D_3 and CaCO_3 supplements if needed. Doses were adjusted according to serum levels of calcium and phosphate.

In HD patients, predialysis and post-dialysis BPs were calculated as the average value of all recordings taken over a 1-month period. When the systolic pressure exceeded 140 mmHg, or the diastolic pressure exceeded 90 mmHg, therapy with antihypertensive agents was initiated or continued. All patients enrolled in the study received angiotensin converting enzyme inhibitor (ACEI) or angiotensin receptor blocker (ARB) based on our previous observations (11–13).

In CAPD patients, BP was determined in the clinic. When the systolic pressure exceeded 140 mmHg, or the diastolic pressure exceeded 90 mmHg, therapy with antihypertensive agents was initiated or continued.

Study design
All patients were followed for 1 year. The study was started 3 – 5 months after initiation of dialysis therapy. Before the start and 1-year after the start of the study, PWV was measured. During follow-up, BP and laboratory values were recorded on a routine basis.

Measurements of BP and PWV
Brachial artery BP was measured using a conventional sphygmomanometer at the arm without the fistula. Phase V Korotkoff sounds were taken for diastolic BP. The mean of three readings was used.

Brachial-ankle PWV was determined (14) using an automated polygraph device (AT-Form: Nippon Colin, Komaki, Japan). Pulse waves were recorded using sensors placed on the posterior tibial and brachial arteries. Time intervals of pulse waves between
the posterior tibial and brachial arteries were obtained, and the distances from the brachial artery to the posterior tibial artery were estimated from the patient’s height. The best consecutive 10 pulses were analyzed, and the average PWV from the brachial artery to the posterior tibial artery was calculated by dividing the distance by the time interval. To reduce the possibility of variations in PWV due to operator variation, one person performed all PWV measurements. The reproducibility of this method is high (13).

In CAPD patients, the PWV measurement was performed with an empty abdomen, 2 hours after the first morning drain; in HD patients, it was performed post-dialysis (midweek dialysis session).

**Statistical analysis**

Statistical analysis used the Student t-test for comparing means of unpaired variables. A simple regression analysis was performed for correlations among the variables. Data were expressed as mean ± standard deviation. A value of $p < 0.05$ was considered statistically significant.

**Results**

Table I summarizes the results of the study.

**Effect of CAPD and HD on BP**

At the end of the study, the mean BP of CAPD patients was lower than that of HD patients, but the difference did not achieve statistical significance. In patients on HD, the mean systolic BP before the dialysis session was significantly higher than that seen at the time of measurement of PWV after the dialysis session.

**Effect of CAPD and HD on serum creatinine, hemoglobin, and serum total cholesterol**

No significant differences in serum creatinine and hemoglobin levels were seen between the two groups. However, at the end of the study, mean serum total cholesterol was significantly higher in CAPD patients than in HD patients.

**Effect of CAPD and HD on PWV**

In patients on CAPD, PWV was slightly, but not significantly, lower at the end of the study than at the start. In contrast, in patients on HD, PWV was slightly, but not significantly, higher at the end of the study than at the start. At the start of the study, no significant difference in PWV was observed between the two groups; however, at the end of the study, the two groups showed a significant difference in PWV.

**Correlations between PWV, BP, and pulse rate**

Correlations between PWV, BP, and pulse rate in the two patient groups were calculated at the start and 1 year after the start of the study. Figures 1 – 5 show the results. At the start of the study, the relationship between PWV, BP, and pulse rate were similar between patients on CAPD and those on HD. However, at 1 year, some differences in the relationships appeared. Moreover, the degree of increase in PWV in the patients on HD was significantly associated with the changes in systolic BP before and after HD sessions ($p < 0.05$).

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**Table I** Changes in clinical parameters for patients on continuous ambulatory peritoneal dialysis (CAPD) and hemodialysis (HD)

<table>
<thead>
<tr>
<th></th>
<th><strong>CAPD (n = 22)</strong></th>
<th></th>
<th><strong>HD (n = 22)</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>At start</td>
<td>1 Year after</td>
<td>At start</td>
<td>1 Year before</td>
</tr>
<tr>
<td>PWV (m/sec)</td>
<td>1726±374</td>
<td>1631±380</td>
<td>1774±531</td>
<td>—</td>
</tr>
<tr>
<td>SBP (mmHg)</td>
<td>144±18</td>
<td>138±18</td>
<td>147±19</td>
<td>158±20</td>
</tr>
<tr>
<td>DBP (mmHg)</td>
<td>83±9</td>
<td>85±12</td>
<td>87±12</td>
<td>85±11</td>
</tr>
<tr>
<td>Pulse rate (/min)</td>
<td>58±13</td>
<td>65±17</td>
<td>61±11</td>
<td>58±13</td>
</tr>
<tr>
<td>RRF (mg/dL)</td>
<td>760±423</td>
<td>680±526</td>
<td>220±185</td>
<td>108±255a,c</td>
</tr>
<tr>
<td>Serum Cr (mg/dL)</td>
<td>8.3±2.7</td>
<td>9.1±3.2</td>
<td>8.8±3.4</td>
<td>11.2±4.3</td>
</tr>
<tr>
<td>Hemoglobin (g/dL)</td>
<td>9.3±3.3</td>
<td>9.1±3.9</td>
<td>8.8±3.7</td>
<td>9.0±2.1</td>
</tr>
<tr>
<td>Total cholesterol (mg/dL)</td>
<td>202±38</td>
<td>234±47d</td>
<td>227±44</td>
<td>199±38</td>
</tr>
</tbody>
</table>

* $p < 0.05$ compared with 1 year after start of CAPD.
* $p < 0.05$ compared with predialysis.
* $p < 0.05$ compared with start of HD.
* $p < 0.05$ compared with start of CAPD.

PWV = pulse wave velocity; SBP = systolic blood pressure; DBP = diastolic blood pressure; RRF = residual renal function; Cr = creatinine.
Discussion

As expected, our study found that PWV was significantly associated with BP and pulse rate in patients on HD and CAPD. In addition to those findings, changes in PWV in the patients on HD were associated with the fluctuations in BP before and after dialysis therapy sessions.

In previous studies (11–13), we showed that inhibition of the renin–angiotensin system using ACEIs or ARBs produced regression of left ventricular hypertrophy and attenuated progression of arterial stiffness in patients receiving dialysis therapy. Hence, we did not discontinue administration of those drugs in patients who were introduced to dialysis therapy because of ESRD. In the present study, systolic BP levels were significantly associated with PWV in patients on both CAPD and HD—which was not the case in the previous studies. This difference might be attributable to the study design. In the present study, all patients received ACEIs or ARBs before the start of the study. In addition, for the present study, we enrolled patients with and without left ventricular hypertrophy.

Recently, Covic et al. performed a cross-sectional comparative study (10) that demonstrated...
that CAPD is associated with stiffer arteries and increased arterial pulse wave reflections, and that CAPD patients exhibit a higher incidence of abnormal vasomotor function as compared with matched HD subjects.

In the present study, measurements of PWV in the patients on HD were carried out immediately after their dialysis therapy session. In contrast, in the study by Covic et al., PWV measurements were performed before dialysis. Moreover, the mean levels of systolic BP before the HD session were lower than those seen in our study (130 mmHg vs. 149 mmHg before dialysis and 141 mmHg post dialysis). Indeed, the level of increase in PWV was associated with changes in BP predialysis and post-dialysis.

In contrast to the findings by Covic et al., Konings et al. reported that the distensibility coefficient of the right common carotid artery was similar in PD patients and controls, but was significantly lower in HD patients (15). These discrepancies might be explained by the study design, the underlying renal diseases, and comorbid conditions.

Compared to those two studies that were performed in a cross-sectional analysis, the present study was designed to match age, sex, underlying renal diseases, and levels of BP, serum creatinine,
and hemoglobin in the two groups. Additionally, all patients received ACEIs or ARBs. Despite numerous potentially relevant factors contributing to arterial stiffness (arteriosclerosis, vessel calcifications, etc.), the present study suggests that greater fluctuations in BP predialysis and post-dialysis might be involved in the progression of arterial stiffness in patients on HD.

In addition to fluctuations in BP, beneficial effects on residual renal function might account for the inhibition of increases in PWV in the patients on CAPD, because deterioration of residual renal function induces greater fluctuations in the circulating levels of toxic substances such as angiotensin II. In the present study, the residual renal function of patients on CAPD was well preserved as compared with that in the patients on HD at 1 year after the initiation of dialysis therapy. Similar observations have been reported elsewhere (16–18).

Our study has some limitations. The number of patients was too small to predict the effects of PWV on the mortality rate in patients on HD and CAPD. Despite careful antihypertensive treatment and dialysis therapy, BP levels were not reconciled. The possibility therefore remains that elevated BP may have produced increased PWV in the patients on HD.

Conclusions
A greater degree of BP fluctuation in patients on HD than in patients on CAPD may contribute to prevention of arterial stiffness as evaluated by PWV.

References
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