Obesity shortens survival in the general population. In hemodialysis (HD), obesity is associated with improved short-term survival (around 3 years). The discrepancy in the survival of obese patients between HD and the general population may be attributable to survival bias. (Only a small percentage of patients with renal failure survive until HD, and they may have certain survival advantages, including obesity.) Bias is introduced through the mixture of prevalent and incident HD patients in most studies, better nutrition in obese HD patients, malnutrition–inflammation complex syndrome causing weight loss, or other reasons.

In studies of peritoneal dialysis (PD), obesity has been associated with decreased patient survival, no noticeable effect on survival, and increased survival. Potential reasons for the differences include bias in the selection of PD for obese patients, effects of race, chronic inflammation in obese PD patients, differences in nutrition and adequacy of PD, adverse effects of the increased PD dose needed to achieve adequate small-solute clearances, differences in body composition, and time discrepancies among risk factors having opposite effects on PD patient survival.

Some evidence exists that in the long term (>10 years), obesity is a risk factor for death in both HD and PD. Further studies are needed to identify the short- and long-term risks and benefits of obesity in the two dialysis modalities.

Key words
Obesity, patient survival, hemodialysis

Introduction
Obesity is a risk factor for diabetes, heart disease, stroke, hypertension, gallbladder disease, osteoarthritis, sleep apnea and other respiratory diseases, and certain cancers (uterus, breast, colorectal, kidney, gallbladder); obesity is also associated with hypercholesterolemia, complications of pregnancy, menstrual irregularities, hirsutism, stress incontinence, depression, and increased surgical risk (1). In the general population, obesity leads to shortened survival (2–5). Studies have also shown a J- or U-curve effect, with underweight as well as overweight subjects exhibiting an increased risk of death as compared with normal weight subjects (5).

Analyses of large series of patients on chronic dialysis have identified several risk factors in the general population—for example, hypertension (6) and hypercholesterolemia (7)—that, at least in the short term, have beneficial effects on the survival of dialysis patients. Obesity is one of the conditions associated with varying survival trends in dialysis patients. Differences in the effects of obesity on patient survival have been found between hemodialysis (HD) and the general population, between peritoneal dialysis (PD) and the general population, between HD and PD, and between various centers or registries analyzing PD patient survival.

The present report summarizes the major survival studies on obese dialysis patients and analyzes the potential causes of the survival differences found in those studies.

Discussion

Obesity and survival in HD
To our knowledge, no study of the effect of obesity on HD patient survival has reported measuring body fat by one of the standard methods of body composition. All studies used surrogate “height/weight” methods of estimating body fat content, usually the body mass index (BMI), which is advocated by the National Institutes of Health (NIH) guidelines (8). (One study used the weight-for-height percentile.)

The BMI is a reasonable, but not perfect, indicator of body fat content. Across age, sex, and nationality groups, substantial differences in body fat content can be found among subjects with the same BMI (9). Also, substantial discrepancies in the classification of the degree of obesity have been found between BMI and other “height/weight” indices, both in the general
population (10) and in PD patients (11). The relationship between BMI and body fat in dialysis patients needs further study and may be one of the causes of reported survival discrepancies, as will be discussed later in this presentation.

Reservations about the use of BMI to characterize body fat content notwithstanding, large registry-type studies have invariably shown an adverse effect of low BMI and a beneficial effect of high BMI (or high weight-for-height percentile) on short-term (usually around 3 years) HD patient survival (12–17). The reasons for the difference in survival between obese patients on HD and the general population are not entirely clear. We next discuss some of the suggested reasons.

**Potential causes of the discrepancy in survival between obese patients on HD and the general population**

Table I shows the major reasons suggested for the discrepancy in survival between obese patients on HD and the general population. A detailed analysis of the reasons can be found in the report of Kalantar–Zadeh and coauthors (18).

The reasoning for the existence of survival bias is based on the discrepancy between the number of patients with known renal failure and the number of patients with end-stage renal disease (ESRD), and on the finding in several studies that elevated serum creatinine is an independent risk factor for cardiovascular mortality. Patients who survive to the ESRD stage are thought to have a survival advantage—a “resistance” that could be related in some unknown way to obesity—in regard to the traditional cardiovascular risk factors that are frequently present in patients with renal failure.

The mixture of prevalent patients and incident patients in studies of HD survival may also perpetuate the survival bias. Most studies analyze a mixture of prevalent and incident HD patients. However, one large study that analyzed incident patients only also found a strong beneficial effect of high BMI on HD patient survival (19).

The argument about competing risk factors with different time courses states that traditional risk factors with relatively long-term effects on survival (such as obesity) are operative in HD patients, but that they compete with other factors that are particular to HD and have a beneficial effect on patient survival over the short term. Better nutrition is the most prominently discussed short-term beneficial factor for obese HD patients.

In a prospective analysis, survival of HD patients was lowest in the lowest-weight BMI tertile (<23.2 kg/m²), intermediate in the middle tertile (23.2 – 28.5 kg/m²), and highest in the highest tertile (>28.5 kg/m²). Patients in the highest-weight tertile had significantly higher serum creatinine and prealbumin than did patients in the other two tertiles. At the same time, in agreement with several other studies, serum albumin did not differ between the three weight groups (20).

The concept of competing risk factors with varying time effects suggests that the risks of obesity are manifested by shortened long-term survival. In a Japanese study with a 12-year follow-up, survival was worse for patients whose BMI was <16.9 kg/m² or >23.0 kg/m². The survival curves for the underweight and overweight groups were both separated from the curve for the medium-weight group after the 6th year of follow-up (21). However, the number of patients in each weight category was small. In Chinese patients who survived on dialysis for more than 12 years, mean initial weight was 49.1 kg in PD patients and 54.5 kg in HD patients (22).

Malnutrition–inflammation complex syndrome is prominent in ESRD (23) and is associated with increased cardiovascular risk in HD (24). Elevated levels of indices of chronic inflammation are associated with loss of muscle mass in long-term HD patients (25). Whether those indices are also associated with low BMI values is not known.

**Obesity and survival in PD**

Unlike the situation in HD, in which studies consistently show a short-term survival advantage for obesity, the effect of obesity on PD patient survival varies in different studies. Small one-center studies have.

---

**TABLE I** Potential causes for the varying survival of obese patients on hemodialysis and of those in the general population

<table>
<thead>
<tr>
<th>Survival bias in chronic renal failure</th>
<th>Prevalent versus incident patients</th>
<th>Time discrepancies between risk factors with opposite effects on survival</th>
<th>Nutrition</th>
<th>Malnutrition–inflammation complex syndrome</th>
<th>Others (?)</th>
</tr>
</thead>
</table>

Tzamaloukas and Murata
shown no difference in survival between large and normal-sized patients (26–28), a survival advantage for obesity (29), and a survival disadvantage for obesity (30).

Recent reports from registries did not clarify the issue. In analyzing 9679 adult PD patients, a report from the Australian and New Zealand Dialysis and Transplant Registry found that obesity (BMI > 30 kg/m²) was associated with increased crude risk of death (31). The best survival was associated with a BMI of 20 kg/m². In contrast, in a report analyzing 41,197 Medicare patients on PD in the United States, only underweight PD patients (BMI < 18.5 kg/m²) had an increased adjusted risk of death (32). The adjusted risk of death in the overweight group (25 – 29.9 kg/m²) and the obese group (≥ 30 kg/m²) was not different from that in the reference (normal-weight) group (18.5 – 24.9 kg/m²). A third large study analyzed 12,074 HD patients and 1227 PD patients followed by an American dialysis chain. The preliminary reported (33) found a survival advantage for HD patients with a BMI > 30 kg/m² that was sustained even at a BMI > 40 kg/m², and a survival disadvantage for PD patients with a BMI > 30 kg/m². Finally, in a study of 1675 HD and 1662 PD patients that used a BMI cut-off of 30 kg/m² for obesity (34), 5-year survival in HD patients was significantly higher in the ones categorized as obese (39.8% vs. 32.3% in non-obese patients); but, in PD patients, the difference between the groups was not significant (38.7% in obese patients vs. 40.5% in non-obese patients). However, the study confirmed a survival advantage of obesity during the first year of PD.

Next, we will discuss some of the potential reasons for survival differences between obese patients on HD and on PD and between various PD studies.

**Table II** Potential causes of survival differences between obese patients on hemodialysis and those on peritoneal dialysis, and between different peritoneal dialysis studies

<table>
<thead>
<tr>
<th>Patient selection</th>
<th>Race/ethnicity</th>
<th>Chronic inflammatory state in obese patients on peritoneal dialysis</th>
<th>Nutrition</th>
<th>Adequacy of dialysis</th>
<th>Differences in body composition among overweight subjects</th>
<th>Differences in long-term effects of obesity on survival</th>
<th>Others (?)</th>
</tr>
</thead>
</table>

Why survival of obese patients varies between PD and HD and between various PD studies

Table II shows potential causes for the differences in survival between obese patients on PD and on HD and between various studies.

Selection of patients for PD may have a big effect on the outcome of the procedure. Selection criteria vary in different parts of the world. In the United States, PD is recommended to relatively few overweight ESRD patients (35). The effect of selection bias on the survival of overweight patients needs prospective study, but could potentially be large.

Race is another factor that affects the survival of dialysis patients. The better survival of African American patients on dialysis has been repeatedly confirmed. Asian American patients on HD also have a survival advantage; but, unlike the situation with African American patients, obesity does not convey a survival advantage in Asian American patients (36). In this regard, it is interesting that, with the same BMI, Asian Americans carry more body fat than do Caucasians (37) and that the long-term survival disadvantage of obesity in both HD and PD [discussed earlier (21,22)] was observed in Japanese and Chinese patients. Also, the adverse effect of obesity on PD patient survival in the Australian and New Zealand registry was not found in Maori/Pacific Islander PD patients (31).

One potential adverse effect of obesity on the survival of PD patients is its association with chronic inflammatory syndrome. One small cross-sectional study found elevated blood levels of tumor necrosis factor alpha, C-reactive protein, and leptin (which is considered atherogenic), but not of fibrinogen, in obese PD patients (38). That study needs confirmation by larger longitudinal studies. If obesity is indeed associated with chronic inflammation in large numbers of PD patients, then nutrition indices—particularly serum albumin and creatinine (39)—and body composition analyses (25) should both reflect the association.

Nutrition is another potential cause of varying outcomes between obese PD and HD patients. However, in a sample of North American (Canadian and American) PD patients, we found that serum albumin and creatinine did not vary between PD patients of normal weight and those with obesity (40), and that protein nitrogen appearance was higher in the obese group (40,41). Underweight PD patients had poor
nutrition indices (41,42). Differences in nutrition between obese and lean patients appear to be similar in HD and PD.

One area in which some differences may exist between obese HD and PD patients is adequacy of dialysis as judged by urea kinetics. The percentage of patients reaching target clearances and the adverse effects of an increased dialysis dose are both potentially different between HD and PD. In a large study that demonstrated a beneficial effect of obesity on HD patient survival, the effect of urea clearance was stronger in each weight category than in the entire group (19). Although such a clear effect of dialysis dose on the survival of obese PD patients has not been reported, nutrition indices other than serum albumin are higher in obese PD patients with adequate urea clearance than in those with inadequate normalized urea clearance (43).

Increasing the dose of PD to achieve target clearances in large individuals has adverse effects. The large required daily drain volume dictates an increase in the number of daily exchanges and a shortening of the dwell time (44). The result is that the peritoneal membrane is exposed to high concentrations of glucose for long periods with resulting deterioration of the membrane (45) and increased absorption of glucose from the dialysate. The increased absorption leads to hyperglycemia, hyperinsulinemia, hyperlipidemia (45), and reduced protein intake (46).

The next potential explanation for the observed differences in the survival of obese patients between HD and PD and between PD studies relates to the shortcomings of BMI as an index of body fat content. A large cohort study of U.S. patients on HD that verified the beneficial effect of large BMI on survival estimated, by an indirect method, creatinine excretion as an indicator of creatinine production and consequently of fat-free body mass at the beginning of HD. The study found that, on average, the obese group excreted 100 mg more creatinine daily than did the normal-weight group, and that, compared to a reference group with normal BMI and creatinine excretion > 550 mg daily (the 25th percentile of creatinine excretion in the study), obese patients with a daily creatinine excretion > 550 mg had a significantly lower adjusted risk of death. Obese or normal-weight patients with daily creatinine excretion < 550 mg had a significantly higher risk of death (47). The study suggested that the survival advantage of obesity in HD is attributable to higher (on average) fat-free mass in the obese HD patients.

We reported measurements of creatinine excretion obtained at the first clearance study in PD patients (on average, approximately 9 months after initiation of PD). Obese PD patients have higher creatinine excretion rates than both normal-weight or underweight patients, and normal-weight patients have higher creatinine excretion rates than do underweight patients (40,42). Interestingly, in each weight category, the measured creatinine excretion in PD patients exceeded the estimated creatinine excretion in HD patients. Available evidence shows that creatinine excretion at the outset of PD affects patient survival (48).

Two studies suggested that PD might have adverse effects on body composition in certain genotypes of PD patients. Nordfors and colleagues reported that patients with the del/del genotype of the UCP2 mitochondrial uncoupling protein, which regulates energy expenditure, gained a substantial amount of fat during PD; those the ins/del genotype did not (49). Subsequently, Jolly and associates described 8 patients with >10 kg weight gain over 2 years on PD (50). Those patients, who typically had a high-average peritoneal transport type, lost fat-free mass during the weight gain (as estimated by bioimpedance). The authors suggested that increased peritoneal glucose uptake, coupled with genetically determined delays in energy metabolism, may cause sarcopenic obesity in PD patients. Varying percentages of such patients in PD populations would affect survival patterns and would also cause difficulties in interpreting BMI values. Patients on HD are not subject to the continuous glucose load.

Finally, the time course of adverse and beneficial influences of obesity may differ between PD and HD. However, long-term PD (and HD) survivors are not obese. In addition to Chinese patients with long survival (22), North American patients surviving on PD for more than 10 years have a low body weight (51).

Conclusions
Although this review mainly highlights the need for large prospective studies on obesity and dialysis, it appears that the beneficial effect of obesity on the survival of either HD or PD patients is short-lived (in the order of 1 – 3 years) and that lean dialysis
patients without comorbidities are usually the ones that live longer than 10 years. Differences in patient selection for each dialysis modality, in nutrition, in race, in adequacy of dialysis, in body composition, and in genotype may explain, at least in part, the reported short-term survival differences between obese patients on HD and on PD and between various PD studies.

Acknowledgment
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Hernias can lead to significant morbidity in patients on peritoneal dialysis (PD). We studied the natural history and outcome of incarcerated hernia (IH), with or without bowel strangulation (IHS), in PD patients.

We performed a retrospective chart review on all PD patients who developed an IH (n = 11) or an IHS (7/11) in the last 12 years. Of the 11 patients, 54% were female. The age range was 36 – 86 years (median: 61 years). Seven patients had a known history of a hernia that went on to become the index hernia that incarcerated with or without strangulation. The hernia types were umbilical (n = 8), inguinal (n = 2), and incisional in the area of the PD catheter (n = 1).

Clinical presentations included painless abdominal mass (2 patients); tender and painful abdominal mass (4 patients); and abdominal pain, tenderness, and bowel obstruction (5 patients). Nine hernias were treated surgically—5 of them emergently for bowel ischemia. The other 4 patients who had incarcerated, non strangulated hernias were operated electively. One patient with IHS had the hernia manually reduced, and 1 patient with IHS had the hernia manually reduced and subsequently operated electively. Three patients with IHS and 2 with IH required temporary hemodialysis for between 4 days and 21 days.

In PD patients, IHs are most commonly umbilical and have a propensity to strangulate. Patients treated operatively have an excellent prognosis and are usually able to continue PD. Abdominal wall hernias should be referred early to minimize mechanical complications.

Key words
Incarcerated hernia, strangulated hernia

Introduction
Hernias are a common problem in peritoneal dialysis (PD) patients, having a prevalence of 10% – 15% in most series (1–3). Patients at risk to develop hernias include those who are older, female, and multiparous; those who have had a postoperative leak after PD catheter insertion (1) or a previous hernia repair (4); and those with polycystic kidney disease as the cause of their end-stage renal disease [ESRD (5)]. Hernias are clinically important because of the risk of incarceration, strangulation, and subsequent bowel obstruction, rupture, and peritonitis. Those complications may also result in the loss of PD as a dialysis modality because of damage to the peritoneal membrane.

In the present retrospective chart review, we studied the natural history and outcome of incarcerated hernia (IH), with or without bowel strangulation (IHS), in PD patients. With a better understanding of the risk factors leading to hernia formation and the types of hernias that are at increased risk for complications, an evidence-based algorithm for monitoring and early surgical referral may be possible.

Material and methods
We performed a retrospective chart review on all PD patients who developed an IH (n = 11) or an IHS (7/11) in the last 12 years. We defined an IH as a herniated segment of intestine that was not reducible when initially seen by a physician. We defined an IHS as a herniated segment of intestine with clinical evidence of bowel ischemia or evidence of bowel ischemia during operative repair of the hernia.

Once the patients were identified, we gathered their background history, presenting clinical features, and management and outcome information from clinic and hospital charts. Any missing information was gathered from the patients and their clinic nurses and physicians. All information was then entered into a spreadsheet for analysis.
Results
Of the 11 patients, 54% were female. The patients ranged in age from 36 years to 86 years (median: 61 years; Table I). Ten of patients had a history of a hernia in the past (non incarcerated hernias, including hernias at any anatomic location). Of the 10 patients with a history of hernia, 7 patients had a known history of hernia that went on to become the index hernia that incarcerated with or without strangulation. The hernias that were recognized before they incarcerated or strangulated were present for an average of 8 months (range: 1 – 24 months; Table I). The hernia locations were umbilical (n = 8), inguinal (n = 2), and incisional in the area of the PD catheter (n = 1). No patient had a history of a site leak post catheter insertion.

The underlying causes of ESRD were varied (Table I): focal segmental glomerulosclerosis (n = 1), “drug reaction” (n = 1), unknown (n = 1), chronic interstitial nephritis (n = 1), post-streptococcal glomerulonephritis (n = 1), hypertension (n = 2), diabetic nephropathy (n = 2), membranoproliferative glomerulonephritis (n = 1), and scleroderma (n = 1). None of the patients had a history of polycystic kidney disease as the cause of ESRD.

Patients presented in variety of ways. Two patients presented with a painless abdominal mass. Four patients complained of a tender and painful abdominal mass, and 5 patients, of abdominal pain, tenderness, and bowel obstruction (Table I). One of the patients who presented with incarceration and strangulation also had bloody effluent. Interestingly, that patient showed no evidence of bowel infarction at the time of operative reduction and repair of the hernia.

Of the 11 hernias, 10 were treated surgically—5 of them emergently because of clinical evidence of bowel ischemia such as tenderness or pain (Table I). Of 2 patients with IHS, 1 patient had the hernia manually reduced (patient 9), and 1 patient had the hernia manually reduced and was electively operated 1 month later (patient 10). Another 4 patients who had incarcerated, non strangulated hernias were operated electively. Three patients with IHS and 2 patients with IH required temporary hemodialysis for between 4 days and 21 days.

Discussion
Dialysis fluid in the peritoneal cavity leads to increased intra-abdominal pressure (IAP), which, in combination with maneuvers such as coughing, straining, and sitting in the upright position, can lead to tension on the abdominal wall (6). Intra-abdominal pressure increases linearly with intra-abdominal fluid volume and usually becomes symptomatic above 20 cm H₂O (1). Other researchers have tried to correlate peritoneal cavity fill volumes and the risk of hernia formation and have been unsuccessful (7,8).

<table>
<thead>
<tr>
<th>Patient</th>
<th>Age</th>
<th>Sex</th>
<th>Renal disease</th>
<th>PD type</th>
<th>Presentation</th>
<th>Hernia type</th>
<th>Known before incarceration?</th>
<th>Treatment</th>
<th>Converted to HD?</th>
</tr>
</thead>
</table>
Nevertheless, over time, free intraperitoneal fluid that causes increased IAP can lead to herniation through congenital and acquired defects in the abdominal wall (6). The complications are potentially disastrous, as discussed earlier. Other factors that have been correlated with the risk of hernia formation include uremia, protein losses into the peritoneal fluid, anemia, and obesity.

The median age of the study patients was 61 years. Many had a history of prior hernia repair. Such patients should receive careful surveillance and should be referred for repair in the event of hernia recurrence. Particular attention should be paid to umbilical hernias, because IH in a PD patient is most commonly umbilical and has a strong propensity to strangulate (9), as was demonstrated in our series. Those findings are in keeping with previous studies that have also demonstrated umbilical hernias to be the most common type of hernia seen in PD patients (9,10).

The higher percentage of umbilical hernias observed in the present study as compared with the percentage observed in a previous study in our PD population [72% vs. 53% (11)] may be attributable to the smaller size of the abdominal wall defect in umbilical as compared with incisional hernias, with incarceration and then strangulation of the viscus as a result. However, because of the small number of other types of hernias in our study, we could not confirm whether umbilical hernias have a higher rate of strangulation.

Early detection and surgical correction of hernias are important, because patients treated operatively had an excellent prognosis in our cohort. They were usually able to continue PD even if hemodialysis had to be used temporarily. That finding is also in keeping with results of another case series (9). Conventional hernioplasty followed by insertion of a polypropylene mesh reinforces the abdominal wall defect and does not appear to predispose to peritonitis via infection of the mesh (12). It may even promote a more rapid return to full-volume PD (13).

Conclusions
Abdominal wall hernias are common in PD patients and have high likelihood of incarceration and strangulation, particularly when they are umbilical. Because of the relative ease of, and excellent outcomes associated with, surgical correction, early detection should be facilitated by screening patients for the presence of hernias upon initiation of PD (14). To minimize mechanical complications and the risk of losing PD as a dialysis modality, patients should then be promptly referred for elective surgical correction.

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Noncompliance (NC) with the dialysis prescription has been described as a common problem in dialysis patients. In previous studies, NC in peritoneal dialysis (PD) patients has been assessed by obtaining patient or family histories, using questionnaires, and making home visits. With the use of the HomeChoice Pro Chip Card (PCC: Baxter Healthcare Corporation, Deerfield, IL, U.S.A.), the dialysis staff can monitor the total volume of dialysate used, the frequency of exchanges, and the duration of dialysis in patients maintained on automated peritoneal dialysis (APD).

Last year, we reported that the PCC was an effective tool for assessing compliance and noted that more than half of patients had a compliance rate (CR) < 95%. In the present study, we examined the impact of patient education on compliance with the prescribed dialysis regimen. We evaluated our APD patients for CR with their dialysis prescription. The PCC was used to record the duration of dialysis and the actual volume of fluid used.

From October 2002 to September 2003, all patients maintained at home for 3 consecutive months on APD in the New Haven continuous ambulatory peritoneal dialysis unit were educated concerning the importance of compliance with their dialysis regimen. They were also educated about the function of the PCC and were informed that the dialysis facility would be monitoring their compliance with the prescribed regimen. Compliance rates were calculated by dividing the delivered dialysis volume by the prescribed dialysis volume and multiplying by 100.

We obtained data on 42 APD patients. Of the 42 patients, 35 (83%) had a CR ≥ 95%, 3 (7%) had a CR between 90% and 94.9%, and 4 (10%) had a CR < 90%. Those CRs are much better than the ones we had previously reported, before the institution of the patient education program.

The PCC can be used to assess compliance in APD patients. Patient education results in an improvement in patient compliance. Further study is required to determine factors that affect CR in APD patients.

Key words
Compliance rate, education

Introduction
Recent data have suggested that patients maintained on hemodialysis who are noncompliant have a variety of worse outcomes (such as hyperkalemia and hyperphosphatemia, and increased mortality rates) than do compliant patients (1,2). Compliance in patients maintained on chronic peritoneal dialysis (CPD) is more difficult to assess because the therapy is home based. Previous studies have tried to address the issue. For example, noncompliance in CPD patients has been evaluated by administering patient questionnaires (3) and by performing home supply inventory analyses (4). At the American Society of Nephrology (ASN) meeting in 2002, our group presented data on the use of the Baxter HomeChoice Pro Card Chip (PCC) as a device to determine compliance in patients maintained on automated peritoneal dialysis (APD). An Italian study also reported the PCC to be a useful tool for assessing compliance (5).

The association between poor compliance in APD patients and various outcomes has not been addressed. Furthermore, the issue of whether compliance in APD patients can be improved with interventions has not been reported. The present study was designed to see if overall APD
compliance can be improved with a program of patient education and careful monitoring of patient compliance with the dialysis prescription using the Baxter HomeChoice PCC.

**Patients and methods**
The study was performed at New Haven CAPD, a free-standing CPD center in New Haven, Connecticut. The structure and operation of the CPD unit has been previously described (6).

All patients who were maintained on APD therapy through New Haven CAPD for a minimum of 3 consecutive months were included in the study. The patients’ rates of compliance with their dialysis prescriptions were evaluated. The duration of dialysis and the actual volume of fluid used by all patients were recorded using the Baxter HomeChoice cycler with the PCC.

From October 2002 to September 2003, all APD patients were instructed to bring the PCC to each monthly clinic visit. The patients were informed of the function of the PCC. The nursing staff instructed all patients in the importance of complying with the dialysis prescription and informed all patients that the dialysis staff would be monitoring their compliance. Patients were told that the dialysis staff would be monitoring the volume of dialysate used, the frequency of exchanges, and the duration of each dialysis session. Patients were also encouraged to adhere to their dialysis prescriptions. Before starting the study, each patient met with the dialysis nurse to discuss in detail all of the issues regarding the dialysis prescription.

Compliance rates were determined by comparing the actual dialysate volume used to the volume prescribed. Rates were calculated by dividing the delivered dialysis volume by the prescribed dialysis volume and multiplying by 100. Compliance rates were arbitrarily divided into three categories: ≥95%, 90% – 94%, and <90%. We compared the compliance rates reported in our 2002 ASN presentation to this new study to determine if patient education had had an impact on compliance rates. For the ASN presentation, patient compliance had been tracked (as in the present study), but patients were not specifically informed of the importance of complying with their dialysis prescription, nor of the importance of compliance in terms of various outcomes.

**Results**
We identified 42 patients who completed 3 consecutive months on APD therapy at home for inclusion in the present study. The mean age of the patients was 58 ± 8 years; 24 were men; and 15 were African American, 3 were Hispanic, and 24 were Caucasian. The average time that the PCC was used to monitor the patients was 4.6 ± 2.3 months. The demographic data for the patients are similar to those for the patients in our previous compliance study (Table I).

Figure 1 shows the compliance rates for the two groups of patients. Of the patients who received education, 83% had compliance rates of 95% or higher. That compares to only 48% of the patients before initiation of the education program. In the present study, the percentage of patients with compliance rates < 90% decreased to 10% from 17%.

**Discussion**
Compliance with the dialysis prescription is essential for the well-being of a dialysis patient. Recent data in hemodialysis patients clearly demonstrate that non-compliance leads to worse outcome measures, such as mortality and morbidity. The importance of compliance with the dialysis prescription cannot be overstated, as it directly impacts the patient’s quality of life and survival.

**Table 1**

<table>
<thead>
<tr>
<th></th>
<th>2002 Study</th>
<th>2003 Study</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patients (n)</td>
<td>40</td>
<td>42</td>
</tr>
<tr>
<td>Sex (M/F)</td>
<td>23/17</td>
<td>24/18</td>
</tr>
<tr>
<td>Race (AA/O)</td>
<td>13/27</td>
<td>15/27</td>
</tr>
<tr>
<td>Mean age (years)</td>
<td>55.2±2.4</td>
<td>53.8±2.6</td>
</tr>
<tr>
<td>Mean time with PCC (months)</td>
<td>10.2±3.5</td>
<td>4.63±2.3</td>
</tr>
</tbody>
</table>

M = male; F = female; AA = African American; O = other; PCC = HomeChoice Pro Card Chip.

![Figure 1](image-url) Comparison of compliance rates before and after education.
as increased hyperkalemia and hyperphosphatemia and increased mortality (1,2).

Monitoring compliance is difficult with a home-based therapy such as CPD. Previous attempts at determining peritoneal dialysis compliance have included indirect observations. Using a questionnaire-based methodology, Blake et al. (3) noted higher non-compliance rates in U.S. continuous ambulatory peritoneal dialysis (CAPD) patients than in Canadian ones. Home dialysis inventory analyses have also been used to help determine compliance (4).

In this study, noncompliance was defined as performance of fewer than 90% of prescribed exchanges. Compliance was noted to be worse in the first 6 months of therapy (4). The reported prevalence of noncompliance with peritoneal dialysis in other studies has been suggested to range between 5% and 38% (7).

Recently, a direct method for measuring compliance was introduced with the development of the Baxter HomeChoice PCC. For APD patients, the PCC can record the number of exchanges, the dialysis volume, missed exchanges, and the ultrafiltration volume.

In 2002, we undertook an observational study of compliance in our APD patients. We noted that only 48% of patients had a compliance rate ≥ 95%, and 17% had a compliance rate < 90%. In Italy, Neri et al. (5) noted that noncompliance was lower than previously reported when they evaluated PCC data. No reports have yet tried to determine if intervention (such as a program of patient education) affects compliance rates in APD patients.

Conclusions
The present study indicates that compliance rates improve dramatically after patient education. Before education sessions were initiated, only 48% of all APD patients attained a compliance rate ≥ 95%; after education, 83% of patients achieved that goal (Figure 1).

Consideration should be given to correcting the measured peritoneal Kt/V and peritoneal creatinine clearance in APD patients for the observed compliance rate. Further study is required to better understand the problem of noncompliance in CPD patients and to help devise strategies to maximize patient compliance.

References

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Peritoneal dialysis (PD) has seldom been reported in patients developing end-stage renal disease (ESRD) after liver transplantation (LTx). Here we present our recent experience with PD in 5 such patients.

Of the 5 patients, 3 were men and 2 were women. Average age at initiation of PD was 64.6 years (range: 54 – 72 years). Chronic renal failure (CRF) was diagnosed an average of 3.8 years (range: 1 – 7 years) post transplant and resulted in ESRD an average of 9.2 years (range: 6 – 15 years) after LTx. Calcineurin inhibitor toxicity was the presumed causative factor in all 5 patients, with biopsy confirmation in 2. All of the patients had hypertension at the time of diagnosis of CRF; 2 had coronary artery disease, and 1 developed diabetes mellitus. No patient had ascites before PD initiation. Peritoneal dialysis catheter implantation was uneventful in all patients.

Average duration of follow-up was 13.6 months (range: 6 – 29 months). Three episodes of peritonitis occurred in 2 patients (coagulase-negative staphylococcus, Staphylococcus aureus, and Acinetobacter). All episodes of peritonitis responded to standard treatment. Clearance was found to be adequate in all but 1 patient. One patient died 19 months after initiation of PD. At the time of writing, the remaining 4 patients are alive on PD after an average of 12.2 months (range: 6 – 29 months).

We conclude that PD is a viable and safe option for managing ESRD that develops after LTx.

Key words
Liver transplantation

Introduction
Developments in the field of transplantation have benefitted a large population of patients with failure of various solid organs. Improvements in technical and clinical understanding, together with the development of new immunosuppressive agents, have increased the success rate and availability of transplantation. As a result, the incidence of complications arising from the original medical condition and the immunosuppressive regimen has increased.

Chronic renal failure (CRF) is one well-recognized complication of non renal solid-organ transplantation, occurring at varying rates depending on the transplanted organ. Liver transplantation (LTx) in particular is associated with a high incidence of renal failure (1). Strategies for renal replacement therapy have ignored the possible benefits of peritoneal dialysis (PD) in this particular subpopulation of end-stage renal disease (ESRD) patients.

We have used PD to treat 5 patients who developed ESRD after LTx. Here, we describe our experience.

Patients and methods
Table I shows the demographic data for the 5 patients, with an emphasis on the cause and duration of renal disease in relation to the LTx. Age at initiation of PD ranged between 54 years and 72 years. Chronic renal failure was diagnosed an average of 3.8 years (range: 1 – 7 years) following transplantation, and the condition progressed to ESRD requiring regular dialysis after an average of 9.2 years (range: 6 – 15 years).

Results
All 5 patients were supported on a calcineurin inhibitor (CNI)–based immunosuppressive regimen, and CNI toxicity was assumed to be responsible for renal failure in all of the patients. Two patients underwent renal biopsy, which showed features of chronic CNI toxicity. One patient with nephrotic-range proteinuria showed the presence of focal and segmental glomerulosclerosis related to cyclosporine. Hypertension was present in all patients at the time of diagnosis of CRF. In addition, 2 patients had vascular disease, and 1 patient had diabetes.

All but 1 patient had some degree of residual renal function. None of the patients had evidence of ascites.
before the insertion of the PD catheter. Catheter insertion was uncomplicated in all patients, although 1 patient experienced a small self-resolving abdominal wall hematoma. No intra-abdominal adhesions were observed.

No mechanical complications were observed during an average follow-up of 13.6 months (range: 6–29 months) after initiation of PD. Three episodes of peritonitis occurred in 2 patients (Table II). One of these patients developed peritonitis with coagulase-negative staphylococcus at 1 month after catheter insertion; the other developed 2 episodes of peritonitis with Staphylococcus aureus and Acinetobacter at 10 and 14 months respectively after initiation of PD. All episodes of peritonitis responded well to standard treatment and did not recur. All patients tolerated PD well, and no complications of membrane or technique failure were observed.

Of the 5 patients, 4 had higher transport characteristics (2 high-average, 2 high; Table III). The dialysis dose was adequate, meeting Canadian Society of Nephrology guidelines in all but 1 patient. That patient (weekly Kt/V: 1.91) showed high permeability (D/P creatinine: 0.94) with a residual renal Kt/V of 0.3 and a weekly renal creatinine clearance (CCr) of 19.1 L. However, the weekly total CCr was found to be adequate (75.6 L), and the patient had no symptoms related to inadequate dialysis.

Of the 5 patients, 4 were started on PD with significant residual renal function. One patient who was followed for 2 years showed maintenance of residual renal function during that period.

**Discussion**

Liver transplantation is associated with high incidence of renal failure (1). Calcineurin inhibitor toxicity contributes heavily to the development of such renal failure (2–6). The pathologic correlates commonly found at renal biopsy (such as arteriolar hyalinosis, nodular hyaline deposits, and mucoid intimal edema) were seldom described in transplant patients of the pre-cyclosporine era (5). Most available data relate to the use of cyclosporine A (7).

In a population of LTx patients, Tauxe et al. (7) compared the use of cyclosporine and tacrolimus, and found significantly less impairment in effective renal

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**Table I**

<table>
<thead>
<tr>
<th>Patient</th>
<th>Sex</th>
<th>Age (years)</th>
<th>Cause</th>
<th>CNI</th>
<th>Age (years)</th>
<th>Cause</th>
<th>Biopsy</th>
<th>Comorbidities</th>
<th>CRF (years)</th>
<th>ESRD (years)</th>
</tr>
</thead>
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<tr>
<td>1</td>
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<td>62</td>
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<td>Cyclosporine</td>
<td>69</td>
<td>?CNI</td>
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<td>HCV</td>
<td>Cyclosporine</td>
<td>54</td>
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<td>Yes</td>
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<td>6</td>
</tr>
<tr>
<td>3</td>
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<td>50</td>
<td>HBV</td>
<td>Tacrolimus</td>
<td>57</td>
<td>FSGS, CNI</td>
<td>Yes</td>
<td>HT</td>
<td>1</td>
<td>7</td>
</tr>
<tr>
<td>4</td>
<td>Female</td>
<td>57</td>
<td>Biliary</td>
<td>Cyclosporine</td>
<td>72</td>
<td>?CNI</td>
<td>No</td>
<td>HT, VD</td>
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<td>15</td>
</tr>
<tr>
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<td>64</td>
<td>Alcoholic</td>
<td>Cyclosporine</td>
<td>71</td>
<td>?CNI</td>
<td>No</td>
<td>HT, VD</td>
<td>5</td>
<td>7</td>
</tr>
</tbody>
</table>

*Duration considers time taken to develop the diagnosis after liver transplant.*

CNI = calcineurin inhibitor; CRF = chronic renal failure; ESRD = end-stage renal disease; HT = hypertension; DM = diabetes mellitus; HCV = hepatitis C virus; HBV = hepatitis B virus; FSGS = focal and segmental glomerulosclerosis; VD = vascular disease.

**Table II**

<table>
<thead>
<tr>
<th>Patient</th>
<th>Episodes (n)</th>
<th>Time since initiation of PD (months)</th>
<th>Organism</th>
<th>Duration of follow-up (months)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>1</td>
<td>CNS</td>
<td>6 *</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>10</td>
<td>Staphylococcus aureus</td>
<td>19</td>
</tr>
<tr>
<td></td>
<td></td>
<td>14</td>
<td>Acinetobacter</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>0</td>
<td></td>
<td></td>
<td>29 *</td>
</tr>
<tr>
<td>4</td>
<td>0</td>
<td></td>
<td></td>
<td>7 *</td>
</tr>
<tr>
<td>5</td>
<td>0</td>
<td></td>
<td></td>
<td>7 *</td>
</tr>
</tbody>
</table>

*Continued survival with regular follow-up.*

PD = peritoneal dialysis; CN = coagulase-negative staphylococcus.
plasma flow, glomerular filtration rate, and filtration fraction in patients treated with the latter agent. However, it is now believed that CNI toxicity is class-specific and that tacrolimus is associated with a similar incidence of renal dysfunction (1,8,9). In addition, withdrawal of CNI after the development of renal failure seldom results in long-term improvement in renal function. The decline continues inexorably even after CNI is minimized or substituted by an alternative agent (6).

Hypertension, diabetes, and hyperlipidemia also contribute to the development and progression of renal failure. Immunoglobulin A (IgA) nephropathy, hepatorenal syndrome, perioperative renal dysfunction, and pre-existing renal failure are some of the organ-specific factors that contribute significantly to the later development of CRF in this subgroup of patients (5,6).

The reported incidence of renal failure varies between 8% and 78% 5 years after transplantation (5,6,10). Lack of uniformity in the definition of CRF contributes significantly to that wide variation in incidence. A milder degree of renal failure has been reported more frequently.

Fisher et al. (6) found reduced renal function—as manifested by a serum creatinine > 125 µmol/L—in nearly 80% of patients with 5 years' follow-up. Tauxe et al. (7) reported only 23% of patients with normal creatinine by 3 years post transplantation. However, even with the conservative estimates, the incidence of severe renal failure approximates 3.8% – 13% 5 years after transplantation, with at least half of the subgroup reaching ESRD (5,6,10,11). The higher incidence is seen mainly in patients with diagnosed hepatorenal syndrome before transplantation (6,12).

In a recent large cohort analysis of data from the Scientific Registry of Transplant Recipients, Ojo and associates (1) found the incidence of severe renal failure (defined as a CCr < 29 mL/min corrected for body surface area) to be 8%, 13.9%, and 18.1% at 1, 3, and 5 years post transplant respectively. The occurrence of ESRD in the LTx population has been estimated to be 1% – 1.5% per year (1,5,6, 10–12).

Renal failure has been associated with increased mortality as compared with mortality in a general population. Mortality is also known to rise proportionately with the degree of renal failure. Patients who develop CRF after a non renal transplant show higher mortality than do patients who do not develop renal failure. Ojo and associates (1) found a significant rise in the relative risk of death (RR: 4.55) among patients with CRF as compared with patients with no renal failure. The difference persisted even after correction for patients with ESRD: the mortality remained twice that of the non renal failure population (1).

Information on the survival rate for ESRD after LTx is lacking. Gonwa et al. (12) found that patients who developed ESRD had a much lower survival than those who did not develop renal failure. Six years after initiation of hemodialysis, survival in their group of 45 patients (27%) was similar to that of the general ESRD population (27.8%) as recorded in the U.S. Renal Data System during the same period. In a retrospective analysis by Fisher et al. (6) of single-center LTx patients, the median time to death was found to be 1.2 years and 1.6 years after the diagnosis of severe CRF and ESRD respectively.

Management of LTx patients by PD has not been reported in literature. Fisher et al. (6) in their retrospective analysis mentioned the use of continuous

<table>
<thead>
<tr>
<th>Patient</th>
<th>D/P Cr</th>
<th>Membrane type</th>
<th>Weekly Creatinine Clearance (L)</th>
<th>Weekly Kt/V</th>
<th>Renal</th>
<th>Peritoneal</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
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<td>Weekly Creatinine Clearance</td>
<td></td>
<td>Renal</td>
<td>Peritoneal</td>
<td>Total</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Strong, Moderate, or Weak</td>
<td></td>
<td>Strong, Moderate, or Weak</td>
<td>Strong, Moderate, or Weak</td>
<td>Strong, Moderate, or Weak</td>
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<tr>
<td>1</td>
<td>0.58</td>
<td>LA</td>
<td>77.5</td>
<td>40.7</td>
<td>118.2</td>
<td>2.14</td>
<td>1.63</td>
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<tr>
<td>2</td>
<td>0.8</td>
<td>HA</td>
<td>0</td>
<td>62</td>
<td>62</td>
<td>0</td>
<td>2.1</td>
</tr>
<tr>
<td>3</td>
<td>0.78</td>
<td>HA</td>
<td>45.9</td>
<td>45.7</td>
<td>91.6</td>
<td>0.81</td>
<td>1.47</td>
</tr>
<tr>
<td>0.78</td>
<td></td>
<td></td>
<td></td>
<td>51.5</td>
<td>96.3</td>
<td>0.63</td>
<td>1.5</td>
</tr>
<tr>
<td>4</td>
<td>0.84</td>
<td>H</td>
<td>43.2</td>
<td>79.6</td>
<td>122.8</td>
<td>0.9</td>
<td>2.98</td>
</tr>
<tr>
<td>5</td>
<td>0.94</td>
<td>H</td>
<td>19.1</td>
<td>56.4</td>
<td>75.5</td>
<td>0.3</td>
<td>1.61</td>
</tr>
</tbody>
</table>

* Follow-up peritoneal membrane study.

D/P Cr = dialysate-to-plasma ratio of creatinine at 4 hours of a peritoneal equilibration test; CCr = creatinine clearance; LA = low average; HA = high average; H = high.
ambulatory peritoneal dialysis (CAPD), but did not provide further details.

Treatment by PD in the general ESRD population has been found to be associated with better survival (13) and better preservation of residual renal function during the initial period after dialysis initiation. The contribution of residual renal function to that improvement has been well described in a reanalysis by Bargman et al. of the CANUSA study (14). Given those advantages of PD in the general ESRD population, we feel that the benefit of PD in the LTx group of solid-organ transplant patients with declining renal function has not been well explored. The use of PD after heart transplantation has been reported, but we did not find any data that deal with PD in the management of ESRD developing after LTx—with the exception of a single report that mentions just 2 patients (6).

We tried to establish the feasibility of PD in patients with ESRD developing after LTx. Of the 5 patients studied, 4 had high to high-average membrane permeability characteristics (Table III). Similar observations have been made in the past in other studies of patients with chronic liver disease being treated with CAPD (15,16). Higher protein losses that declined over time were initially noted in those patients. Those findings and long-term changes of peritoneal membrane characteristics need to be confirmed in a larger population of patients. Bajo and associates (16) noted a higher incidence of peritonitis in patients with chronic liver disease on PD. However, given our data, we are not able to comment on that finding.

Conclusions
The increasing success of LTx is likely to add a new population of patients to the existing CRF cohort. Despite the availability of numerous newer immunosuppressive drugs, CNIs are likely to remain the mainstay of immunosuppressive regimens for some time. The long-term effects of newer anti-proliferative agents such as sirolimus and mycophenolate mofetil in improving long-term renal function still need to be established. Although discontinuation of CNIs temporarily improves renal function or slows the rate of CRF progression, long-term deterioration of renal function is hardly affected once CNIs are started. In view of the possible beneficial effects of PD during the earlier years after initiation of dialysis, it seems reasonable to conclude, based on our data, that PD is a viable and perhaps the preferred option for managing ESRD occurring after LTx.

References
14 Bargman JM, Thorpe KE, Churchill DN, and the


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