The normalized protein catabolic rate (nPCR) reflects daily dietary protein intake in stable dialysis patients. In peritoneal dialysis (PD) patients, reports about the importance of nPCR as marker of nutrition and outcome have been inconsistent. The objective of the present study was to investigate the relationships of nPCR with body composition parameters, micronutrient electrolytes, and long-term survival in PD patients.

From November 2000 to May 2008, 57 PD patients were enrolled in the study. On enrollment, demographic, clinical, and biochemical data were recorded. Patients were followed through September 2011.

Mean age of the patients was 56 years, and 61% were of African descent. Mean and maximum follow-up were 2.83 years and 11 years respectively. Mean daily nPCR was 0.944 g/kg. The nPCR correlated directly with albumin ($r = 0.34$, $p = 0.012$), magnesium ($r = 0.48$, $p < 0.0001$), phosphorus ($r = 0.42$, $p = 0.02$), and the phase angle body composition parameter ($r = 0.26$, $p = 0.049$). Compared with patients whose enrollment daily nPCR was less than 0.8 g/kg, those with an enrollment daily nPCR of 0.8 g/kg or more experienced significantly better 11-year cumulative survival ($p = 0.04$). In multivariate Cox regression analysis with adjustment for confounding variables, nPCR was an independent predictor of all-cause mortality ($p = 0.018$).

In conclusion, lower nPCR is associated with poorer nutrition status and increased risk of all-cause mortality in PD patients followed for up to 11 years.

Key words
Nutrition, nPCR, fluid status, mortality

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albumin, magnesium, and phosphate were recorded. An impedance plethysmograph (800 mA and 50 kHz) was used to take BIA measurements. Values of electrical impedance, resistance, and reactance were used in a computerized calculation of body composition parameters for each patient, including extracellular mass and body cell mass (BIA-101 and Cyprus version 1.0: Akern/RJL Systems, Clinton Township, MI, U.S.A.). Patients were followed through September 2011. The study was approved by the Institutional Review Board of Long Island College Hospital, Brooklyn, New York, and informed consent was obtained from each patient.

**Statistical analysis**
Continuous variables are expressed as mean ± standard deviation. Correlations are reported as either a Pearson correlation coefficient or a Spearman rank correlation coefficient. Observed survival was computed by the Kaplan–Meier method (16). The log-rank test was used to assess differences between survival curves. Independent predictors of survival were determined by Cox regression analysis. Calculations were performed using the SPSS software application for Windows (version 12.0.1: SPSS, Chicago, IL, U.S.A.).

**Results**
In this group of patients, mean age was 56 years; 56% were women; most (61%) were of African descent; and 26% had diabetes. Enrollment mean body mass index, phase angle, and ratio of extracellular mass to body cell mass were 25.4 ± 5.46 lbs/in.², 6.06 ± 1.63 degrees, and 1.21 ± 0.197 respectively. Enrollment mean albumin, magnesium, and phosphate were 3.71 ± 0.59 g/dL, 1.597 ± 0.28 mEq/L, and 5.06 ± 1.73 mg/dL respectively. Mean and median daily nPCR were 0.944 g/kg and 0.910 g/kg respectively. Daily nPCR was below 0.8 g/kg in 35% of the patients.

Table I shows the correlations of nPCR with body composition parameters and biochemical markers. The nPCR correlated significantly and positively with phase angle \((r = 0.26, p = 0.049)\), albumin \((r = 0.34, p = 0.012)\), magnesium \((r = 0.48, p < 0.0001)\), and phosphate \((r = 0.42, p = 0.02)\).

Mean and maximum follow-up were 2.83 years and 11 years respectively. At 11 years of observation, cumulative observed survival was significantly better for patients with an enrollment daily nPCR of 0.8 g/kg or more than for those with an enrollment daily nPCR of less than 0.8 g/kg \((p = 0.04, \text{Figure} \ 1)\).

In multivariate Cox regression analysis after adjustment for confounding variables such as body mass index, sex, race, diabetes, hypertension, dialysis vintage at enrollment, creatinine, blood urea nitrogen, hemoglobin, and white blood cell count, nPCR was an independent predictor of all-cause mortality \((p = 0.018)\). For each 0.01 g/kg rise in daily nPCR, the relative risk of mortality declined by 5.2%.

**Discussion**
In the present study, we demonstrated that a higher daily nPCR at enrollment is independently associated

<table>
<thead>
<tr>
<th>Variable</th>
<th>Correlation coefficient</th>
<th>p Value</th>
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</thead>
<tbody>
<tr>
<td>Body mass index (^a)</td>
<td>0.24</td>
<td>0.08</td>
</tr>
<tr>
<td>Phase angle (degrees)</td>
<td>0.26</td>
<td>0.049</td>
</tr>
<tr>
<td>ECM/BCM ratio</td>
<td>–0.24</td>
<td>0.076</td>
</tr>
<tr>
<td>Serum albumin (g/dL)</td>
<td>0.34</td>
<td>0.012</td>
</tr>
<tr>
<td>Serum magnesium (mEq/L)</td>
<td>0.48</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Serum phosphate (mg/dL)</td>
<td>0.42</td>
<td>0.02</td>
</tr>
</tbody>
</table>

\(^a\) Pounds per inch squared. ECM = extracellular mass; BCM = body cell mass.

**Figure 1** Observed survival (Kaplan–Meier method) by normalized protein catabolic rate at enrollment in peritoneal dialysis patients.
with increased long-term survival (up to 11 years) in our PD patients. Those findings accord with the few previously published reports concerning the association of daily nPCR with mortality in PD patients (11–13,17). In those studies, daily nPCR was used as a categorical variable to examine its predictive power for all-cause mortality in univariate or multivariate models; our study used daily nPCR at enrollment as a continuous variable in multivariate analysis. Duration of follow-up was longer in our study than in previous studies. Our finding that cumulative survival was significantly better for patients with a daily nPCR of 0.8 g/kg or more than for those with a daily nPCR below 0.8 g/kg confirms the results of the previous studies (13,17). In contrast, Blake et al. (15) did not detect any association between a urea kinetic model including nPCR and clinical outcome in continuous ambulatory PD patients.

Another important observation in our study was the significant positive correlation of nPCR with serum albumin, BIA-derived phase angle, and the serum electrolytes magnesium and phosphate. The association of daily nPCR with albumin in the present study and with prealbumin in our earlier study (10) indicates that daily nPCR could reflect visceral protein stores in our PD patients. A higher phase angle (a body composition parameter) is associated with better nutrition status and survival in PD patients (5).

We recently reported the importance of serum magnesium as a marker for nutrition status and survival in PD patients (7,18). Our finding concerning the strong direct correlation between nPCR and serum magnesium confirms the results of a previously published paper (19). In PD patients, dietary protein intake can influence the level of serum magnesium.

The significant positive correlation between daily nPCR and phosphate in the present study might be attributable to the close relationship between dietary protein intake and phosphorus intake. In hemodialysis patients, elevated serum phosphate is associated with both higher dietary protein intake and higher serum parathyroid hormone (20). Surprisingly, a study by Pag et al. (19) could not find any significant correlation between daily nPCR and phosphate. It is of interest to note that the correlation of daily nPCR with a highly sensitive nutritional marker, ratio of extracellular mass to body cell mass, did not quite reach significance (p = 0.076). Some authors have suggested that daily nPCR might not be a strong marker of nutrition in PD patients (14,15).

Conclusions
A lower daily nPCR at enrollment was significantly and independently associated with an increased risk of mortality in PD patients followed for up to 11 years. Association of daily nPCR with albumin, BIA phase angle, and the serum electrolytes magnesium and phosphate implies the importance of daily nPCR as a marker of nutrition and the potential involvement of nPCR or dietary protein intake in the regulation of serum magnesium and phosphate in PD patients.

Disclosures
None of the authors has any financial interests to declare.

References


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