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Prealbumin is Associated with Visceral Fat Mass in Hemodialysis Patients

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Abstract

Objective—Albumin and prealbumin are associated with nutritional status and inflammatory status. Each has a residual effect on mortality outcomes when included in regression models that include the other. Prealbumin is increased in the obese mouse model as a consequence of stabilization of prealbumin by Retinol Binding Protein 4 (RTB4), secreted by adipocytes. We carried out this study to establish the contribution of adiposity to prealbumin levels in prevalent dialysis patients and the relationship of prealbumin to RTB4.

Design—We determined whether prealbumin was associated with adiposity in hemodialysis (HD) patients, controlling for the effects of inflammation and nutrition.

Subjects and Methods—We evaluated body composition in 48 prevalent HD patients by magnetic resonance imaging (MRI), measuring total skeletal muscle mass (SM), visceral and subcutaneous adipose tissue (VAT and SAT), and serum albumin, prealbumin, RTB4, and interleukin-6 (IL-6). We used normalized protein catabolic rate (nPCR) to report nutrition and separately analyzed the determinants of albumin and then of prealbumin by multiple stepwise regression.

Results—Thirty two subjects were women, 16 were diabetic, median age and body mass index 54.5 and 27.3 kg/m², respectively; median TAT 24.3 kg and VAT and 3.25 kg, respectively. Prealbumin was positively associated with VAT, nPCR and RTB4, and negatively associated with IL-6; r^2 for the model 0.64. By contrast albumin was positively associated with nPCR and negatively with IL-6 but not with any measure of adiposity (r^2 for the model = 0.2).

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Conclusions—Prealbumin, like albumin, is associated with markers of nutrition (nPCR) and inflammation, but unlike albumin, prealbumin levels are positively associated with visceral adiposity.

Keywords

Prealbumin; Visceral Adipose Tissue; Retinol-Binding Protein 4; Interleukin-6; Inflammation; Hemodialysis

Introduction

Both albumin and prealbumin are associated with mortality among dialysis patients (1). Both proteins are negative acute phase proteins and exhibit decreased levels and synthetic rates in response to inflammation (2). Both the synthetic rate and blood levels of both proteins are also reduced during protein-energy wasting (3). Prealbumin was demonstrated to be a reliable marker of nutritional status in peritoneal dialysis patients, exhibiting significant relationships with energy and protein intakes as well as with fat stores and lean body mass (4). A recent meta-analysis showed that 9 out of 14 studies reported lower all-cause mortality with greater serum prealbumin levels in hemodialysis (HD) patients (4). Cardiovascular mortality is also inversely associated with prealbumin levels (5, 6). It was also demonstrated that lower prealbumin concentrations were associated with mortality and hospitalization rates due to infection, independently of serum albumin. Despite its association with lower cardiovascular mortality and lower risk of death (2), higher prealbumin levels are associated with increased rates of vascular access-related hospitalization (2). Rambod et al. showed that serum prealbumin correlated with surrogates of body composition, inflammation, and health-related quality of life in HD patients and that reduced baseline prealbumin levels, even in normoalbuminemic patients, were independently related with a trend toward increased death risk (7). Chertow et al. established that prealbumin had residual predictive effects on mortality outcomes among hemodialysis patients within strata of albumin (2) or after adjustment for albumin (8). Prealbumin is greater in peritoneal dialysis patients than in hemodialysis patients (9, 10) possibly as a consequence of differing responses of albumin and prealbumin to external losses.

Positive and negative acute phase proteins have specific functions that may relate to their association with outcomes beyond that of simply reflecting inflammation or nutritional status. Prealbumin functions as a transporter for thyroid hormone and binds retinol binding protein 4 (RTB4), serving as the basis for its alternate name, transthyretin (11). Thus prealbumin may reflect body fat stores in addition to reflecting acute protein and calorie intake in the short time interval around when the measurement of prealbumin was conducted.

The prealbumin molecule consists of 4 monomeric chains that are non-covalently linked, each of which is capable of covalently binding a molecule of RTB4. Stoichiometrically it is only possible for one prealbumin molecule to bind 2 RTB4 molecules, although the average binding in patients without renal failure is significantly less than 2 moles of RTB4 per mole

of prealbumin (11). Retinol stabilizes the quaternary structure of prealbumin through interactions with RBP4, secreted by adipocytes (11).

Retinol-binding protein 4 (RBP4) is an approximately 21 kDa protein increased in insulin resistant adipose tissue specific Glut 4 null mice and reduced in insulin sensitive adipose specific Glut 4 transgenics (11). It has been noted to induce insulin resistance by impairing insulin signaling in lean body mass (12) and adipocytes (13) and leads to increased expression of phosphoenolpyruvate carboxykinase and glucose production in liver (12). Several studies in both rodent and human obesity have reported a strong correlation between serum levels of RBP4 and many aspects of the metabolic syndrome including inflammation, fatty liver disease and insulin resistance (12, 14, 15). Interestingly, recent studies have suggested that one possibility for this correlation may be renal insufficiency, which is common in type 2 diabetes (16). RBP4 levels may be increased in HD patients, due at least in part to impaired renal excretion and higher binding to elevated prealbumin (17–20). Therefore, we speculated that prealbumin might be associated with adiposity in HD patients, independently of the effects of inflammation or nutrition.

In order to understand the relationship between prealbumin levels and outcomes, it would be useful to understand the relationship between nutritional measures (protein catabolic rate, measures of body composition) and measures of inflammation and prealbumin concentration. To this end, we aimed in our study to evaluate the role of prealbumin with markers of nutrition and inflammation, including the relationship with RBP4 and adiposity as well as distribution of adipose tissue in a group of HD patients.

Materials and Methods

Institutional Review Board approval was obtained and all subjects signed informed consent prior to participation to the study. Forty-eight prevalent HD patients consisting of 32 women and 16 men over the ages of 18 years were included so as to encompass a wide range of body mass indices and ages. Thirty-seven patients were African American, 6 were non-black Hispanic, 3 were white, and 2 were Asian.

Sixteen patients were diabetic by history or review of the medical record. For analysis of the effect of race patients were coded as black or non black because of the small numbers in the other groups. All but one subject had been on maintenance HD for at least 3 months prior to study. Measurement of body composition was carried out approximately 3 hours prior to a midweek dialysis session.

Following an overnight fasting, body weight was measured to the nearest 0.1 kg (WeightTronix, New York), and height was measured to the nearest 0.5 cm by using a stadiometer (Holtain, Crosswell, United Kingdom). Whole-body magnetic resonance imaging (MRI) scans were prepared by using a 1.5 Tesla scanners (6X Horizon; General Electric, Milwaukee) to measure total skeletal muscle mass (SM), visceral and subcutaneous adipose tissue (VAT and SAT) (21).

Serum was obtained prior to the dialysis session following the MRI scan and stored at -80°C until time of analysis. All assays were performed on serum obtained while the patient was

in the fasting state. Interleukin (IL)-6 was measured by enzyme-linked immunosorbent assay (ELISA) (Hemagen Diagnostics, Columbia, MD, USA), prealbumin, albumin, total cholesterol and triglycerides by nephelometry (Beckman Array 360 (Beckman Instruments, Inc., Brea, CA, USA) (22). RTB4 was measured using an ELISA assay (Millipore, Billerica, Massachusetts). All measurements were made in duplicate using the average of these values for calculations.

We used normalized protein catabolic rate (nPCR) (g/kg/day) calculated from dialysis kinetic modeling during the month that body composition was measured as a valid surrogate for dietary protein intake (23) and separately analyzed the determinants of albumin and then of prealbumin by multiple stepwise regression.

Continuous variables were expressed as mean $\pm$ standard deviation (SD) and compared with Student's t-test, or analysis of variance (ANOVA) where appropriate. Correlation among variables was described with the Pearson product moment correlation coefficient. Categorical variables were described using proportions and were analyzed with the 2 test. A P value ≤ 0.05 was considered statistically significant. We included total adipose tissue (TAT), SAT, VAT and SM in the initial regression model as well as age, sex, diabetes status, race, RTB4, IL-6 concentration and nPCR. We used either albumin or prealbumin as the dependent variable in the models. Since IL-6 was not normally distributed we log transformed IL-6 in the model.

Results

Patients characteristics are indicated in Table 1. Prealbumin was positively associated with VAT (increase in prealbumin concentration of 1.8 mg/dL for each kg increase in VAT) ($P = 0.015$), nPCR (increase in prealbumin concentration of 20.8 mg/dL for each g/kg increase in nPCR) ($P < 0.001$) (Figure 1), RTB4 (increase in prealbumin concentration of 5.3 mg/dL for each $\mu\text{m/L}$ increase in RTB4 concentration) ($P = 0.06$), and negatively associated with IL-6 concentration ($P = 0.01$) (Figure 2), with a decrease in prealbumin concentration of 0.94 mg/dL for each increase in IL-6 concentration of 1 pg/mL; r^2 for the model was 0.64. Neither SAT nor TAT remained in the regression model after VAT was introduced into the model, however if VAT was omitted, prealbumin was significantly associated with TAT ($P = 0.03$).

The molar ratio of RTB4/prealbumin was 0.26 ± 0.11 . The molar ratio of RTB4/prealbumin was inversely associated with TAT ($P < 0.01$), male sex ($P < 0.05$) and positively associated with log IL-6 ($P < 0.002$); r^2 for the model was 0.56. By contrast albumin was positively associated with nPCR and negatively with IL-6 but not with any measure of adiposity (r^2 for the model = 0.2) (Figure 3).

Discussion

Our results showing a positive relationship between prealbumin levels and nPCR, as a surrogate for nutritional intake, and an independent and negative association between prealbumin and IL-6, are consistent with prealbumin independently reflecting nutrition and its function as a negative acute phase protein (3). Our observation that prealbumin is also

positively and independently associated with obesity, and specifically with visceral adiposity, despite the association between obesity and inflammation, may provide insight into both regulation of the serum concentration of this protein and add further interpretation into its relationship with outcomes.

Prealbumin levels are associated with outcomes, even after adjustment for albumin levels (1), are responsive to nutritional status and are reflective of inflammation as a consequence of reduced synthesis in the presence of inflammation (2, 24, 25). Our results showing a relationship between prealbumin levels and VAT point to a potential causative role of VAT in the link to clinical outcome. However, it should be reminded that the relationship between prealbumin and clinical outcomes may also reflect processes that establish their concentration in plasma as well as potential direct effects of these proteins. Clearly, we do not have the power within this cohort to resolve that question, however overweight and obese patients, i.e., patients with increased VAT, are more likely to initiate dialysis with an arteriovenous fistula or graft than patients who are underweight (26), but obesity is a risk factor for access failure and necessity for intervention (27), possibly contributing to the association between greater prealbumin concentration and the frequency of vascular access hospitalizations (2).

In contrast to prealbumin, serum albumin concentration was not associated with adiposity, but was associated with both nPCR and a marker of inflammation (IL-6) consistent with previous observations (9, 24).

In a previous study (2), we observed an independent association between low prealbumin levels and infectious hospitalizations, which may simply reflect the association between infection, the acute phase response and changes in prealbumin. However, decreased levels of active thyroid hormone is associated with outcomes of systemic infections (28). Therefore, the fact that prealbumin serves as a potent and effective carrier of thyroid hormone may also contribute to this association and explain why there remains a residual effect of prealbumin on predicting infectious outcomes even after adjusting for the effect of serum albumin concentration. Additionally, the positive effect of retinol (vitamin A) in protection from infection (29) may also contribute to the association between low prealbumin levels and increased infectious hospitalizations. Further understanding of the relationship of both positive and negative acute phase proteins and their specific associations with cause specific morbidity among dialysis patients may need to focus on differences in the functions of each of these proteins for specific targeted therapies other than improvement in nutritional status or nonspecific reduction in the inflammatory response to be developed.

The presence of chronic inflammation is strongly related with increased morbidity among patients with end-stage renal disease. Recently, Ishimura et al. showed in a group of prevalent HD patients a significant and independent association between truncal fat mass and CRP levels, after adjustment for gender, age and albumin levels (30). While we found a relationship between the long lived acute phase protein ceruloplasmin and VAT, we were unable to establish a relationship between IL-6 and VAT in this population (31). In the present study we demonstrate that in our HD population there is a strong positive association between prealbumin levels, VAT, nPCR and RTB4. While RTB4 was positively associated

with VAT, the ratio of RTB4 to prealbumin actually declined with increasing adiposity, suggesting that increased saturation of prealbumin with RTB4 was not directly associated with the mechanism responsible for increased prealbumin levels. Additionally, the molar ratio of the two proteins was well below the saturation levels of 2 RTB4 molecules per prealbumin quatramer. Nevertheless, the total content of circulating RTB4 was increased among patients having increased VAT in association with increased prealbumin concentration. In contrast to prealbumin, albumin concentration was not associated with adiposity in this analysis.

The positive correlation that we found between prealbumin levels and RTB4 can be explained by the fact that plasma transport of retinol is carried out only by RBP which itself is carried on prealbumin. Retinol stabilizes the quaternary structure of prealbumin, through its interactions with RBP (11). This physiological stabilization of prealbumin appears not perturbed in our HD group.

We acknowledge that the majority of the patients enrolled in the present study were African Americans, which may reduce the generalizability of our results. In fact, racial disparities have been demonstrated in dietary habits, body fat mass and death rate (32). However, recent study seems to suggest that no relationship exists between prealbumin and race, and that prealbumin levels do not change significantly with time (9).

In conclusion, prealbumin concentrations appear to be strongly related to adiposity and inflammatory status in HD patients. Larger studies are mandatory to confirm and clarify the possible metabolic and nutritional implications of prealbumin metabolism in end stage renal disease.

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Practical application

This study shows that serum prealbumin concentration is associated with markers of nutrition (nPCR) and inflammation, but unlike albumin, prealbumin is positively associated with visceral adiposity. If confirmed in larger clinical trials, prealbumin levels would be helpful to nephrologists and nutritionists to predict metabolic and nutritional modifications in HD patients.

Relationship between Prealbumin and nPCR and VAT

Figure 1.
Relationship observed in the 48 hemodialysis patients between prealbumin levels, normalized protein catabolic rate (nPCR), and visceral adipose tissue (VAT).

Relationship between Prealbumin and IL-6 and VAT

Figure 2.
Relationship observed in the 48 hemodialysis patients between prealbumin levels, interleukin-6 (IL-6), and visceral adipose tissue (VAT).

Relationship Between Albumin and IL-6 and nPCR

A

Relationship Between Prealbumin and IL-6 and nPCR

B

Figure 3.

Relationship observed in the 48 hemodialysis patients between albumin levels, interleukin-6 (IL-6), and normalized protein catabolic rate (nPCR) (A); Relationship observed in the 48 hemodialysis patients between prealbumin levels, interleukin-6 (IL-6), and normalized protein catabolic rate (nPCR) (B).

Table 1

Demographic, clinical, nutritional and inflammatory parameters of the 48 hemodialysis (HD) patients studied.

Characteristic	Mean $\pm$ SD	Median	Range
Age (years)	55 $\pm$ 10.9	54.5	33 – 80
Weight (kg)	79.2 $\pm$ 17.8	78.1	43.2 – 120
BMI (kg/m ²)	28.2 $\pm$ 5.9	27.3	19.4 – 46.6
SAT (kg)	21.7 $\pm$ 9.8	20.3	5.75 – 50.79
TAT (kg)	24.9 $\pm$ 11.3	24.3	6.2 – 57.62
VAT (Kg)	3.35 $\pm$ 2.18	3.25	0.13 – 8.88
SM (kg)	23.4 $\pm$ 6.47	23.3	12.15 – 36.88
Prealbumin (mg/dL)	39.2 $\pm$ 11.1	37.6	11.8 – 72.4
nPCR (g/kg/day)	1.1 $\pm$ 0.29	1.09	0.43 – 1.84
RTB4 (ng/mL)	17.8 $\pm$ 5.25	17.48	9.62 – 35.66
Molar ratio RTB4/prealbumin	0.27 $\pm$ 0.12	0.24	0.11 – 0.69
IL-6 (pg/mL)	6.98 $\pm$ 4.34	5.52	1 – 22.1
Albumin (g/dL)	4.07 $\pm$ 0.44	4.1	2.5 – 4.7

Abbreviations BMI, body mass index; SAT, subcutaneous adipose tissue; TAT, total adipose tissue; VAT, visceral adipose tissue; SM, skeletal muscle mass; nPCR, normalized protein catabolic rate; RTB4, retinol binding protein 4; IL-6, interleukin-6.