Research Article

Low Serum Albumin Is Associated with Poor Prognosis in Patients Receiving Peritoneal Dialysis Treatment

Yanan Shi, Jiajie Cai, Chunxia Shi, Conghui Liu, Jingjing Zhou, and Zhongxin Li

Department of Nephrology, Beijing Lu-He Hospital, Capital Medical University, Beijing 101100, China

Correspondence should be addressed to Zhongxin Li; lhyy6806@ccmu.edu.cn

Received 21 December 2021; Accepted 18 March 2022; Published 18 April 2022

Academic Editor: Enas Abdulhay

Copyright © 2022 Yanan Shi et al. This is an open access article distributed under the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Background. The number of patients receiving dialysis treatment is sustainably increasing, especially peritoneal dialysis. Objectives. It is necessary to find out potential factors that may indicate the prognosis of patients receiving peritoneal dialysis treatment. Methods. This study retrospectively involved 325 patients who received peritoneal dialysis treatment. Results. Low serum albumin (HR = 2.254; 95% CI: 1.534–3.311; \( P < 0.001 \)) and high FBG (Fasting blood glucose) (HR = 1.474; 95% CI: 1.025–2.120; \( P = 0.037 \)) were risk factors for death in patients receiving peritoneal dialysis treatment. Serum albumin (AUC = 0.683; \( P < 0.001 \)) and creatinine (AUC = 0.625; \( P < 0.001 \)) exhibited value of prognosis prediction. Both high FBG \( (P = 0.005) \) and low albumin \( (P < 0.001) \) were associated with poor prognosis, and low albumin predicted poorer survival. Conclusions. Low serum albumin and high fasting blood glucose were risk factors and associated with poor prognosis. Low albumin has a potential in predicting the prognosis of patients receiving peritoneal dialysis treatment.

1. Introduction

Dialysis is a renal replacement therapy (RRT), mainly including hemodialysis and peritoneal dialysis [1, 2]. The principle of peritoneal dialysis is the solutes and fluid exchange between the peritoneal capillary blood and the dialysis solution, in which the flow rate can be adjusted to achieve a maximum removal [2]. It is estimated that more than 272,000 patients are receiving peritoneal dialysis globally, accounting for approximately 11% dialysis patients worldwide (in 2017) [3]. The number of patients receiving dialysis treatment is sustainably increasing, especially peritoneal dialysis [4]. Among different countries, the selection of dialysis modality is dramatically different [3]. Different dialysis modalities bring important consequences for quality of life, patients’ survival, financial implications, and logistics for the medical system [1, 5]. In Asia, the application of peritoneal dialysis ranges from 3% to 73%, and China has a fairly high peritoneal dialysis rate [3, 4, 6]. Notably, there is a steep rise in peritoneal dialysis utilization in China in the past decade [7].

Albumin is a single protein species and the most abundant plasma protein representing approximately 3/5 in quantity [8]. Albumin produced in the liver is an anionic, flexible, heart-shaped molecule with a molecular weight of \( \sim 65 \text{kDa} \) [9]. Normally, the serum albumin is about 45 g/L in human. Albumin plays an important role in maintaining an oncotic pressure difference between plasma and the interstitial space by regulating fluid exchange [10]. Besides, albumin carries a number of substances including bilirubin, fatty acids, ions, hormones, and drugs [8, 10]. Notably, low albumin in serum is in association with increased mortality [10].

It is necessary to find out potential factors that may indicate the prognosis of patients receiving peritoneal dialysis treatment. Herein, factors associated with the prognosis of patients receiving peritoneal dialysis treatment, such as serum albumin, creatinine, and fasting blood glucose, were evaluated. We also compared their abilities of prognosis prediction.
prediction by ROC (receiver operating characteristic) analysis and survival analysis.

2. Materials and Methods

2.1. Patients. This study retrospectively involved 325 patients who received peritoneal dialysis treatment. Each patient had a complete record of dialysis during the period. All lab parameters were measured at admission as a baseline. The follow-up duration was 7 years.

Patients who were older than 18 years old and received peritoneal dialysis treatment for more than 3 months were included.

The exclusion criteria were as follows: incubation in other hospitals, hemodialysis to peritoneal dialysis, kidney transplant to peritoneal dialysis, annual follow-up <2, and missing baseline data.

2.2. Clinical Data Collection. After admission, the age of patients was recorded, and systolic pressure, diastolic pressure, and pulse were measured. Moreover, the patients received laboratory examination including total protein (g/L), albumin (g/L), Ca²⁺ (mmol/L), phosphate (mmol/L), K⁺ (mmol/L), Na⁺ (mmol/L), Cl⁻ (mmol/L), fasting blood glucose (FBG; mmol/L), blood urea nitrogen (BUN; mmol/L), creatinine (μmol/L), hemoglobin (g/L), and parathyroid hormone (PTH; pg/mL) test. Normal, low, and high individual parameters were defined according to the clinical standard of the clinical lab of our hospital.

2.3. Statistical Analysis. Software SPSS 22.0 (IBM, USA) was used. Data were exhibited as mean ± SD. Quantitative data are expressed as mean ± standard deviation or median (interquartile range). Qualitative data are expressed as a rate or composition ratio. Differences between groups were analyzed by the T-test or analysis of variance. Survival risk analysis was performed using a cox risk regression model. The ROC (receiver operating characteristic) curve was used to predict the risk of death for patients receiving peritoneal dialysis treatment, and the AUC (area under curve) was calculated. P < 0.05 was considered statistically significant.

3. Results

3.1. Characteristics of Patients Receiving Peritoneal Dialysis Treatment. The summary of all the characteristics of patients receiving peritoneal dialysis treatment is shown in Table 1. The average age was 62.51 years old. Among the 325 patients, 147 were male and 178 were female. The average survival time was 892.36 days.

3.2. Differences between Survived Patients and Dead Patients. The subsequent comparisons between the survival and the death were further performed (Table 2). No significant differences were found in gender (P = 0.651), systolic pressure (P = 0.198), pulse (P = 0.745), total protein (P = 0.092), Ca²⁺ (P = 0.533), phosphate (P = 0.467), K⁺ (P = 0.322), Na⁺ (P = 0.260), Cl⁻ (P = 0.390), FBG (P = 0.333), BUN (P = 0.251), and PTH (P = 0.882). Survival time (P = 0.049) and diastolic pressure (P = 0.047) showed a little statistical difference. The hemoglobin (P = 0.038) was statistically different.

The age was significantly different (P < 0.001) as the dead patients (66.96 ± 13.89 years old) were much older than the survived patients (28.75 ± 13.13 years old).

The albumin was significantly different (P < 0.001) as the albumin in dead patients (32.98 ± 4.94 mmol/L) was much lower than that in survived patients (36.59 ± 4.85 mmol/L).

The creatinine was significantly different (P < 0.001) as the creatinine in dead patients (564.64 ± 268.80 μmol/L) was much lower than that in survived patients (684.77 ± 271.00 μmol/L).

3.3. Risk Factors for Death in Patients Receiving Peritoneal Dialysis Treatment. Based on the results of the comparison between survived patients and dead patients, we further analyzed the risk factors for death in patients receiving peritoneal dialysis treatment. As shown in Table 3, albumin, FBG, and creatinine were found to be significantly different. However, the HR of creatinine was 0.999, with 95% CI of 0.998–1.000. Therefore, low albumin (HR = 2.254; 95% CI: 1.534–3.311; P < 0.001) and high FBG (HR = 1.474; 95% CI: 1.025–2.120; P = 0.037) were considered to be risk factors.

3.4. Prognosis Prediction in Patients Receiving Peritoneal Dialysis Treatment. To evaluate the prognosis prediction value of the observed risk factors, ROC curves were drawn (Figure 1). FBG did not show the prediction value (P = 0.593). Albumin (P < 0.001) and creatinine (P < 0.001) exhibited a value of prognosis prediction (Table 4). Of note, the albumin (with AUC of 0.683) showed a higher prognosis prediction value than creatinine (with AUC of 0.625).

3.5. Low Albumin and High FBG Were Associated with Poor Prognosis. Finally, the survival of patients receiving peritoneal dialysis treatment was analyzed (Figure 2). Both high FBG (P = 0.005) and low albumin (P < 0.001) were associated with poor prognosis, and low albumin predicted a poorer survival.

4. Discussion

In this study, we found age, albumin, and creatinine were significantly different between dead and survived patients receiving peritoneal dialysis treatment. Albumin and creatinine showed the value of prognosis prediction. Furthermore, low albumin and high fasting blood glucose were risk factors and associated with poor prognosis. Thus, it is suggested that low albumin has a potential in predicting the prognosis of patients receiving peritoneal dialysis treatment.

To some extent, the level of albumin represents nutrition status and infection [11, 12]. Renal handling of albumin can influence renal function by the effects of albumin. Albumin filtration in glomeruli and tubular reabsorption are two major processes in the renal handling of albumin. The dysfunction of them leads to an increased excretion of
Table 1: Characteristics of patients receiving peritoneal dialysis treatment.

| Characters               | Mean (median) | SD (quartile spacing) | n   |
|--------------------------|---------------|-----------------------|-----|
| Age                      | 62.51         | 14.07                 | 301 |
| Male                     | —             | —                     | 147 |
| Female                   | —             | —                     | 178 |
| Survival time (d)        | 962.36        | 716.22                | 325 |
| Systolic pressure (mmHg) | 146.72        | 48.71                 | 325 |
| Diastolic pressure (mmHg)| 82.32         | 12.96                 | 325 |
| Pulse (beat per minute)  | 77.83         | 11.60                 | 313 |
| Total protein (g/L)      | 65.54         | 25.18                 | 323 |
| Albumin (g/L)            | 34.89         | 5.20                  | 323 |
| Ca²⁺ (mmol/L)            | 2.21          | 0.52                  | 323 |
| Phosphate (mmol/L)       | 1.38          | 0.89                  | 324 |
| K⁺ (mmol/L)              | 4.19          | 9.90                  | 322 |
| Fasting blood glucose (mmol/L) | 7.63    | 3.92                  | 323 |
| Blood urea nitrogen (mmol/L) | 19.68  | 32.59                 | 323 |
| Creatinine (µmol/L)      | 628.24        | 276.15                | 323 |
| Hemoglobin (g/L)         | 114.04        | (101–129)             | 325 |
| Parathyroid hormone (pg/mL) | 146.90      | (55.46–270.90)        | 325 |

Note. FBG: fasting blood glucose; BUN: blood urea nitrogen; PTH: parathyroid hormone.

Table 2: Comparisons between survival and death.

|                          | Survival (n = 173) | Death (n = 152) | t (x²) | P value |
|--------------------------|--------------------|-----------------|--------|---------|
| Age                      | 28.75 ± 13.13      | 66.96 ± 13.89   | 5.267  | <0.001  |
| Male                     | 78                 | 67              | 0.859  | 0.651   |
| Female                   | 93                 | 85              |        |         |
| Survival time (d)        | 965.59 ± 794.95    | 809.02 ± 606.39 | 1.975  | 0.046   |
| Systolic pressure (mmHg) | 146.72 ± 63.41     | 139.74 ± 22.05  | 1.289  | 0.198   |
| Diastolic pressure (mmHg)| 82.32 ± 16.01      | 79.08 ± 12.96   | 1.990  | 0.047   |
| Pulse (beat per minute)  | 77.63 ± 11.21      | 78.05 ± 12.05   | 0.325  | 0.745   |
| Total protein (g/L)      | 67.77 ± 33.77      | 63.04 ± 7.49    | 1.688  | 0.092   |
| Albumin (g/L)            | 36.59 ± 4.85       | 32.98 ± 4.94    | 6.621  | <0.001  |
| Ca²⁺ (mmol/L)            | 2.22 ± 0.29        | 2.20 ± 0.26     | 0.624  | 0.533   |
| Phosphate (mmol/L)       | 1.40 ± 0.51        | 1.36 ± 0.53     | 0.729  | 0.467   |
| K⁺ (mmol/L)              | 4.29 ± 0.84        | 4.09 ± 0.95     | 2.035  | 0.322   |
| Na⁺ (mmol/L)             | 139.87 ± 2.95      | 139.60 ± 2.91   | 1.128  | 0.260   |
| Cl⁻ (mmol/L)             | 99.84 ± 9.24       | 98.89 ± 10.60   | 0.861  | 0.390   |
| FBG (mmol/L)             | 7.43 ± 3.87        | 7.86 ± 3.97     | 0.970  | 0.333   |
| BUN (mmol/L)             | 21.65 ± 44.15      | 17.47 ± 7.75    | 1.151  | 0.251   |
| Creatinine (µmol/L)      | 684.77 ± 271.00    | 564.64 ± 268.80 | 3.992  | <0.001  |
| Hemoglobin (g/L)         | 117.54 ± 23.72     | 112.19 ± 22.25  | 2.085  | 0.038   |
| PTH (pg/mL)              | 212.30 ± 203.37    | 208.34 ± 275.71 | 0.148  | 0.882   |

Note. FBG: fasting blood glucose; BUN: blood urea nitrogen; PTH: parathyroid hormone.

Table 3: Risk factors for death in patients receiving peritoneal dialysis treatment.

|                          | P value | HR  | Lower | Upper |
|--------------------------|---------|-----|-------|-------|
| PTH                      | 0.410   | 1.00| —     | —     |
| <75                      | 0.110   | 1.481| 0.915 | 2.398 |
| 150–300                  | 0.618   | 1.136| 0.676 | 1.877 |
| >300                     | 0.335   | 1.282| 0.774 | 2.262 |
| Albumin                  | 0.853   | 1.00| —     | —     |
| Normal                   | 0.971   | 1.010| 0.586 | 1.740 |
| Low                      | 0.574   | 1.201| 0.634 | 2.275 |
| Cl⁻                      | 0.971   | 1.010| 0.586 | 1.740 |
| Low                      | 0.574   | 1.201| 0.634 | 2.275 |
Recently, Yamada et al. found lower serum albumin level is associated with an increased risk for loss of residual kidney function in patients receiving peritoneal dialysis treatment [13]. The loss of residual kidney function can make the general condition of patients worse and finally lead to the death. Our study goes further in exploring the prognosis prediction value of albumin by involving and considering the survival. Chiu et al. also reported lower serum albumin was associated with poorer survival [14]. Hao et al. used time-averaged albumin level and serum albumin reach rate as predictor variables and found higher serum albumin was associated with a lower all-cause mortality rate in patients undergoing long-term peritoneal dialysis treatment [15]. It is indicated that low serum albumin was a risk factor of both early and late death in incident peritoneal dialysis patients [16]. Interestingly, Singh et al. concluded that peritoneal dialysis is associated with

| Predictors       | Cut-off value | ROC curves | p value |
|------------------|---------------|------------|---------|
| Albumin          | 35.75         | 0.683      | 0.626–0.739 | <0.001 |
| Creatinine       | 711.50        | 0.625      | 0.565–0.684 | <0.001 |
| Fasting blood glucose | 4.44          | 0.483      | 0.422–0.545 | 0.593  |

| Table 4: ROC curve in patients receiving peritoneal dialysis treatment.

Note. FBG: fasting blood glucose; PTH: parathyroid hormone.

Figure 1: ROC curve of albumin (a), creatinine (b), and FBG (c) for death risks in patients receiving peritoneal dialysis treatment.
lower mortality than hemodialysis in patients with low serum albumin [17]. As for the study of serum creatinine, Inaquma et al. reported the ratio of blood urea nitrogen to serum creatinine is associated with mortality by conducting a multicenter prospective cohort study [18].

By comparison of the age between dead and survived patients receiving peritoneal dialysis treatment, we found the age may influence the clinical outcomes and mortality. Consistent with the study conducted by Sakaci et al., mortality was higher in elderly patients and low albumin levels affected mortality [19]. The treatment of peritoneal dialysis should be cautious and based on accurate assessment, because of a higher incidence of intestinal complications, previous history abdominal surgeries, multiple comorbidities, and other possible contraindications [20, 21]. Our result also revealed that high fasting blood glucose may be associated with poor prognosis. Chen et al. reported the association of impaired fasting glucose and mortality in nondiabetic patients on maintenance peritoneal dialysis [22]. The role of high blood glucose in cardiovascular complications and even mortality of peritoneal dialysis treatment needs to be studied.

A number of researchers focus on the study of risk factors for mortality in patients receiving peritoneal dialysis treatment. Female gender, lower Kt/V (weekly urea clearance), and WCCr (weekly creatinine clearance) were found to be risk factors [23]. Lower hemoglobin levels and the presence of diabetes were shown to be risk factors as well [16].

In this study, common laboratory test indicators were analyzed to predict the prognosis of patients with peritoneal dialysis, which is helpful to advance treatment intervention for patients with possible poor prognosis and improve the prognosis of these patients. For patients with hypoalbuminemia and/or high FBG, which may lead to poor prognosis, dietary modification, intravenous albumin supplementation, and more stringent measures of blood glucose control may be considered. However, further prospective studies are needed to confirm the clinical efficacy of these measures.

This is a retrospective study, which is the major limitation. In the future study, we plan to involve the complications and causes of death. It is known that peritonitis has a notable association with peritoneal dialysis treatment since technique failure of peritoneal dialysis treatment could lead to peritonitis [24, 25]. The cardiovascular complication is another severe risk for peritoneal dialysis treatment [26]. The association of albumin and complication of peritoneal dialysis treatment is not clear and remains to be further studied.

4.1. Implications. Low albumin and high fasting blood glucose were risk factors and associated with poor prognosis. Low albumin has a potential in predicting the prognosis of patients receiving peritoneal dialysis treatment.

Data Availability

The data used to support the findings of this study are included within the article.

Ethical Approval

The clinical study was approved by the Ethics Committee of Beijing Lu-He Hospital and was conducted in accordance with the provisions of the Declaration of Helsinki.

Consent

Written informed consent was obtained from all participants before enrolment.

Conflicts of Interest

The authors declare that there are no conflicts of interest.
References

[1] N. Lameire and W. Van Biesen, "Epidemiology of peritoneal dialysis: a story of believers and nonbelievers," *Nature Reviews Nephrology*, vol. 6, no. 2, pp. 75–82, 2010.

[2] R. Gokal and N. Mallick, "Peritoneal dialysis," *The Lancet*, vol. 353, no. 9155, pp. 823–828, 1999.

[3] P. K.-T. Li, K. M. Chow, M. W. M. Van de Luijtgaarden et al., "Changes in the worldwide epidemiology of peritoneal dialysis," *Nature Reviews Nephrology*, vol. 13, no. 2, pp. 90–103, 2017.

[4] T. Liyanage, T. Ninomiya, V. Jha et al., "Worldwide access to treatment for end-stage kidney disease: a systematic review," *The Lancet*, vol. 385, no. 9981, pp. 1975–1982, 2015.

[5] S. J. Davies, "Peritoneal dialysis-current status and future challenges," *Nature Reviews Nephrology*, vol. 9, no. 7, pp. 399–408, 2013.

[6] C. B. Leung, W. L. Cheung, and P. K. T. Li, "Renal registry in Hong Kong-the first 20 years," *Kidney International Supplements*, vol. 5, pp. 33–38, 2011.

[7] X. Yu and X. Yang, "Peritoneal dialysis in China: meeting the challenge of chronic kidney failure," *American Journal of Kidney Diseases*, vol. 65, no. 1, pp. 147–151, 2015.

[8] M. Gekle, "Renal tubule albumin transport," *Annual Review of Physiology*, vol. 67, no. 1, pp. 573–594, 2005.

[9] D. C. Carter, X.-M. He, S. H. Munson et al., "Three-dimensional structure of human serum albumin," *Science*, vol. 244, no. 4909, pp. 1195–1198, 1989.

[10] H. Birn and E. I. Christensen, "Renal albumin absorption in physiology and pathology," *Kidney International*, vol. 69, no. 3, pp. 440–449, 2006.

[11] H. Tsujikawa, S. Tانaka, Y. Matsukuma et al., "Development of a risk prediction model for infection-related mortality in patients undergoing peritoneal dialysis," *PLoS One*, vol. 14, no. 3, Article ID e0213922, 2019.

[12] K. Hassan, "Does whey protein supplementation improve the nutritional status in hypoalbuminemic peritoneal dialysis patients?" *Therapeutic Apheresis and Dialysis*, vol. 21, no. 5, pp. 485–492, 2017.

[13] S. Yamada, Y. Kawai, S. Tsuneyoshi et al., "Lower serum albumin level is associated with an increased risk of loss of residual kidney function in patients receiving peritoneal dialysis," *Therapeutic Apheresis and Dialysis*, vol. 24, no. 1, pp. 72–80, 2020.

[14] P.-F. Chiu, C.-C. Tsai, C.-L. Wu et al., "Trajectories of serum albumin predict survival of peritoneal dialysis patients," *Medicine*, vol. 95, no. 12, Article ID e3202, 2016.

[15] N. Hao, B.-C. Cheng, H.-T. Yang et al., "Time-varying serum albumin levels and all-cause mortality in prevalent peritoneal dialysis patients: a 5-year observational study," *BMC Nephrology*, vol. 20, no. 1, p. 254, 2019.

[16] X. Liu, R. Huang, H. Wu et al., "Patient characteristics and risk factors of early and late death in incident peritoneal dialysis patients," *Scientific Reports*, vol. 6, no. 1, p. 32359, 2016.

[17] T. Singh, B. C. Astor, and S. Waheed, "End-Stage renal disease patients with low serum albumin: is peritoneal dialysis an option?" *Peritoneal Dialysis International: Journal of the International Society for Peritoneal Dialysis*, vol. 39, no. 6, pp. 562–567, 2019.

[18] D. Inaguma, S. Koide, S. Koide et al., "Ratio of blood urea nitrogen to serum creatinine at initiation of dialysis is associated with mortality: a multicenter prospective cohort study," *Clinical and Experimental Nephrology*, vol. 22, no. 2, pp. 353–364, 2018.

[19] T. Sakaci, E. Ahbap, Y. Koc et al., "Clinical outcomes and mortality in elderly peritoneal dialysis patients," *Clinics*, vol. 70, pp. 363–368, 2015.

[20] K. J. Jager, J. C. Korevaar, F. W. Dekker, R. T. Krediet, and E. W. Boeschoten, "The effect of contraindications and patient preference on dialysis modality selection in ESRD patients in The Netherlands," *American Journal of Kidney Diseases*, vol. 43, no. 5, pp. 891–899, 2004.

[21] N. B. Dimkovic, S. Prakash, J. Roscoe et al., "Chronic peritoneal dialysis in octogenarians," *Nephrology Dialysis Transplantation*, vol. 16, no. 10, pp. 2034–2040, 2001.

[22] K.-H. Chen, J.-L. Lin, C.-C. Hung et al., "Impaired fasting glucose association with mortality in nondiabetic patients on maintenance peritoneal dialysis," *The American Journal of the Medical Sciences*, vol. 341, no. 4, pp. 312–317, 2011.

[23] H.-L. Chen, D.-C. Tarng, and L.-H. Huang, "Risk factors associated with outcomes of peritoneal dialysis in Taiwan," *Medicine*, vol. 98, no. 6, 2019.

[24] L. Troidle, N. Gorban-Brennan, A. Kliger, and F. O. Finkelson, "Renal research institute symposium: continuous peritoneal dialysis-associated peritonitis: a review and current concepts," *Seminars in Dialysis*, vol. 16, no. 6, pp. 428–437, 2003.

[25] P. K.-T. Li, C. C. Szeto, B. Piraino et al., "Peritoneal dialysis-related infections recommendations: 2010 update," *Peritoneal Dialysis International: Journal of the International Society for Peritoneal Dialysis*, vol. 30, no. 4, pp. 393–423, 2010.

[26] W. Lu, W.-F. Pang, L. Jin et al., "Peritoneal protein clearance predicts mortality in peritoneal dialysis patients," *Clinical and Experimental Nephrology*, vol. 23, no. 4, pp. 551–560, 2019.