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Serum Albumin, eGFR, and Anemia in Patients with Renal Impairment: A Cross-Sectional Study

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ABSTRACT

Background: *Serum albumin is related with conditions such as malnutrition, inflammation, hematology, and renal impairment; however, the effect of serum albumin independently of eGFR in relation to prediction of anemia in cases with renal impairment is not well established.* ***Objective:*** *The goal is to assess the correlation of albumin in serum and eGFR with hematological status and prediction of anemia in patients with renal impairment.* ***Subjects and Methods:*** *The cross-sectional study consisted of 119 participants with renal dysfunction (age ≥18) and was carried out in March 2026. Tests performed included serum albumin, hemoglobin, packed cell volume (PCV), WBC count, fasting blood sugar (FBS), and creatinine. The eGFR was obtained using the CKD-EPI formula of 2021. The statistical tests included were Spearman correlation, multivariable regression, and ROC curve analysis (using SPSS v26 and confirmed in R) to analyze: (i) albumin alone, (ii) eGFR alone, and (iii) combination of albumin, eGFR, and FBS as a predictor of anemia.* ***Results:*** *Mean albumin was found to be 3.54 ± 0.74 g/dL, while the mean eGFR was 73.5 ± 40.4 mL/min/1.73m²; 37.0% of participants had impaired eGFR level (<60 mL/min/1.73 m²). Albumin was significantly correlated with hemoglobin (r = 0.354), packed cell volume (PCV) (r = 0.339), and eGFR (r = 0.411; p < 0.001 for all). In models adjusting for the effect of eGFR and gender, albumin independently correlated with hemoglobin (β = 0.707; p = 0.015) and PCV (β = 1.630; p = 0.047). As for anemia predictors, significant predictors were identified in eGFR (OR = 0.977; p < 0.001) but not in albumin level (OR = 0.71; p = 0.306). eGFR alone was more predictive than albumin with regard to anemia (AUC = 0.733 vs 0.633); The further combination of the two in a combined model provided only small incremental benefit (AUC = 0.738).* ***Conclusion:*** *The direct calculation of eGFR from serum creatinine level, age, and gender proves itself as the main indicator in connection with anemia and kidney dysfunction. Albumin shows its relationship independently with hemoglobin and PCV, but lacks predictive power alone regarding anemia once the calculation of eGFR is taken into consideration.*

Keywords: Serum Albumin; Anemia; eGFR; Renal Impairment; Hemoglobin.

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INTRODUCTION

The disease of Diabetes Mellitus is still a prevalent one, with diabetic nephropathy or diabetic kidney disease (DKD) being among its common microvascular complications, which can be said to be a major cause of End Stage Renal Disease all over the world. Anemia, in connection to diabetes, has been found in incidences between 14% and 45%. Prior cohort studies reveal that anemia leads to poor kidney functions, and is an independent risk marker for reduced glomerular filtration rate (GFR). Recent reviews about diabetic nephropathy have emphasized on inflammation as being a central player in the progression of the disease (1-3).

Albumin-related abnormalities are also increasingly recognized in kidney disease and

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diabetes. Hypoalbuminemia has been reported as a common complication in patients with chronic kidney disease and has been associated with inflammatory responses and adverse clinical events; in the same population, hemoglobin and red blood cell count were identified as independent risk factors for hypoalbuminemia in CKD stages 3 and 4. In patients with type 2 diabetes, studies have examined whether albumin structural alterations correlate with DKD severity and whether native and reduced albumin concentrations could complement DKD diagnosis (1,4,5).

The link between anemia, albumin-related indices, and kidney dysfunction in diabetes has also been examined in recent clinical studies. A large analysis using 327,999 data points from 48,056 individuals with dialysis-independent diabetic kidney disease showed that anemia prevalence increased as eGFR declined and that albuminuria severity modified the association between reduced eGFR and anemia (6). The red cell distribution width/serum albumin ratio, an integrative inflammatory marker, has been reported as an independent predictor of diabetic kidney disease, supporting continued interest in albumin-linked hematologic and inflammatory measures in renal risk assessment (7). Assessment of glycemic status is another important consideration in studies that involve albumin and renal function. Hemoglobin A1c (HbA1c) is widely used to estimate glycemia but is less reliable in patients with chronic kidney disease; glycated albumin has been independently associated with risks of end-stage kidney disease, cardiovascular disease, and mortality, and has been described as a biomarker of short-term glycemic control (8,9). The available literature has largely addressed inflammation, anemia, glycemic status, and renal dysfunction through albuminuria, glycated albumin, or composite albumin-based indices rather than through direct evaluation of serum albumin itself — alongside eGFR, calculated directly from creatinine — across hematologic and renal domains within one analytical framework. This study was designed to evaluate serum albumin and eGFR in relation to hematologic status and anemia risk in patients with renal impairment, and to compare their standalone and composite predictive value.

SUBJECTS AND METHODS

Study Design and Population

This cross-sectional study was conducted on adult patients with clinical evidence of renal impairment who provided blood samples during March 2026. Eligible participants were 18 years of age or older and had complete demographic data (age and sex) together with laboratory data for serum albumin, hemoglobin, PCV, WBC, fasting blood sugar, and creatinine. Individuals less than 18 years old, those with missing clinical or laboratory information, and any specimens which were hemolyzed or otherwise inappropriate for analysis were not included in the study. Laboratory results were verified with the source document; one pediatric chart (age 5 years) was removed from the dataset, along with three serum albumin results which were physiologically implausible (albumin greater than 5.5 g/dL). A total of 119 individuals comprised the analytic sample. Ethical approval and informed consent were obtained as specified on the title page.

Sample Collection and Laboratory Analysis

Venous blood samples were collected in accordance with aseptic principles and analyzed for biochemical and hematological characteristics. Biochemical tests were performed using the Siemens Dimension automatic chemistry analyzer (Siemens, Germany). Serum albumin was determined using a Nihon Kohden spectrophotometer (Nihon Kohden, Japan). Hemoglobin, PCV, and WBC were determined using an automated

hematology analyzer (Menderi, China), per the manufacturers' standard protocols.

Operational Definitions

Anemia was defined using standard gender-specific hemoglobin thresholds (hemoglobin <13 g/dL in males, <12 g/dL in females). Inflammation was defined as WBC >11×10⁹/L. Hyperglycemia was defined as FBS ≥126 mg/dL and hypoalbuminemia as albumin <3.5 g/dL. eGFR (mL/min/1.73m²) was calculated from creatinine, age, and sex using the 2021 CKD-EPI creatinine equation (race-free) (10), the standard recommended by the National Kidney Foundation and American Society of Nephrology; participants were classified into CKD stages G1-G5 accordingly, with reduced renal function defined as eGFR <60 mL/min/1.73m².

Statistical Analysis

Statistical analysis was performed using SPSS version 26 (11), with regression and ROC analyses cross-checked in R. Continuous variables were presented as mean ± standard deviation; normality was assessed, and non-parametric tests were used where indicated. Correlation with albumin was tested using Spearman's correlation. Gender comparisons used the Wilcoxon rank-sum (Mann-Whitney U) test, and age-group comparisons used the Kruskal-Wallis test. Multivariable linear regression evaluated the independent association between albumin and hemoglobin or PCV, and multivariable logistic regression evaluated albumin and anemia, adjusting for eGFR, sex, and FBS. For ROC analysis, the positive test direction for anemia was defined a priori as decreasing albumin and decreasing eGFR; a composite logistic model combining albumin, eGFR, and FBS was compared with each marker alone. A p-value <0.05 was considered statistically significant.

RESULTS

Descriptive analysis of the 119 participants showed a mean age of 44.55±12.39 years. Mean hemoglobin, PCV, and WBC were 12.07±2.57 g/dL, 36.54±7.21%, and 8.98±3.00×10³/µL, respectively. Mean albumin was 3.54±0.74 g/dL, mean creatinine was 1.84±2.32 mg/dL, and mean FBS was 114.63±40.24 mg/dL. Mean eGFR was 73.5±40.4 mL/min/1.73m²; CKD stage distribution was G1: 51 (42.9%), G2: 24 (20.2%), G3a: 5 (4.2%), G3b: 15 (12.6%), G4: 12 (10.1%), G5: 12 (10.1%), with 44 (37.0%) having reduced eGFR. Anemia was the most common clinical abnormality (49.6%), followed by hypoalbuminemia (31.1%), hyperglycemia (21.8%), and inflammation (20.2%) (**Table 1, Figure 1**).

Table 1. General characteristics of the study sample (n=119).

Category	Variable	Value
Demographic	Age (years)	44.55 ± 12.39
Hematological	Hemoglobin (g/dL)	12.07 ± 2.57
Hematological	PCV (%)	36.54 ± 7.21
Hematological	WBC (×10³/µL)	8.98 ± 3.00
Biochemical	Albumin (g/dL)	3.54 ± 0.74
Biochemical	Creatinine (mg/dL)	1.84 ± 2.32
Renal	eGFR (mL/min/1.73m²)	73.5 ± 40.4
Renal	eGFR < 60, n (%)	44 (37.0%)
Metabolic	Fasting Blood Sugar (mg/dL)	114.63 ± 40.24
Clinical	Anemia, n (%)	59 (49.6%)
Clinical	Inflammation, n (%)	24 (20.2%)
Clinical	Hypoalbuminemia, n (%)	37 (31.1%)
Clinical	Hyperglycemia, n (%)	26 (21.8%)

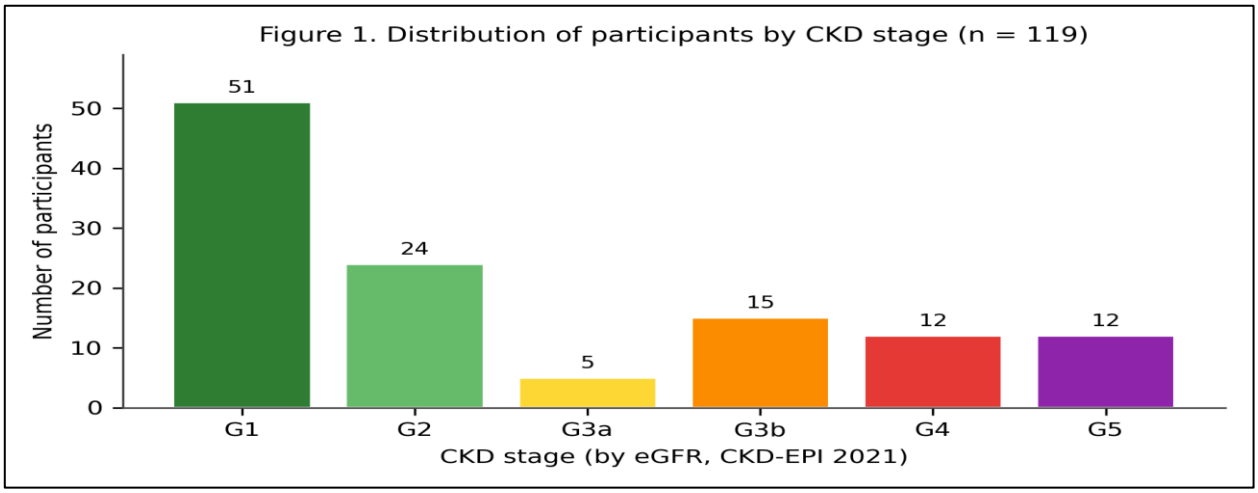

Figure 1. Distribution of participants by CKD stage, based on eGFR (2021 CKD-EPI equation).

Gender comparisons showed significantly higher hemoglobin (13.21±2.59 vs 11.13±2.15 g/dL, p<0.001) and PCV (39.69±7.47 vs 33.92±5.85%, p<0.001) in males. No significant gender differences were found for albumin, WBC, FBS, or creatinine (all p>0.05). No significant differences across age groups were observed for any study variable (all p>0.05). Spearman correlation showed significant positive correlations between albumin and hemoglobin (r=0.354, p<0.001), PCV (r=0.339, p<0.001), and eGFR (r=0.411, p<0.001), and an inverse correlation with creatinine (r=-0.373, p<0.001). Albumin was not significantly correlated with WBC (r=-0.091, p=0.326) or FBS (r=-0.175, p=0.057) (**Table 2, Figure 2**).

In multivariable linear regression adjusting for eGFR, sex, and FBS, albumin remained an independent, significant correlate of hemoglobin (β=0.707, p=0.015) and PCV (β=1.630, p=0.047); eGFR was the strongest independent correlate of both outcomes (p<0.001). In logistic regression for anemia, eGFR was a strong independent predictor (OR=0.977, p<0.001) and female sex remained significant (OR=3.57, p=0.004), while albumin's independent contribution was not significant (OR=0.71, p=0.306) (**Table 3, Figure 3**).

ROC analysis was conducted with the positive test direction defined as decreasing albumin and decreasing eGFR. Standalone eGFR showed good discriminative ability for anemia (AUC=0.733), outperforming standalone albumin (AUC=0.633, optimal cut-off 3.70 g/dL, sensitivity 0.58, specificity 0.70). A composite model (albumin+eGFR+FBS) achieved an AUC of 0.738, only marginally higher than eGFR alone, indicating that eGFR accounts for most of the composite model's discriminative power. Discriminative performance for inflammation remained poor for albumin (AUC=0.451) (**Table 4, Figure 4**).

Table 2. Spearman correlation between serum albumin and study variables.

Variable	Spearman r	p-value
Hemoglobin	0.354	<0.001
PCV	0.339	<0.001
WBC	−0.091	0.326
FBS	−0.175	0.057
Creatinine	−0.373	<0.001
eGFR	0.411	<0.001

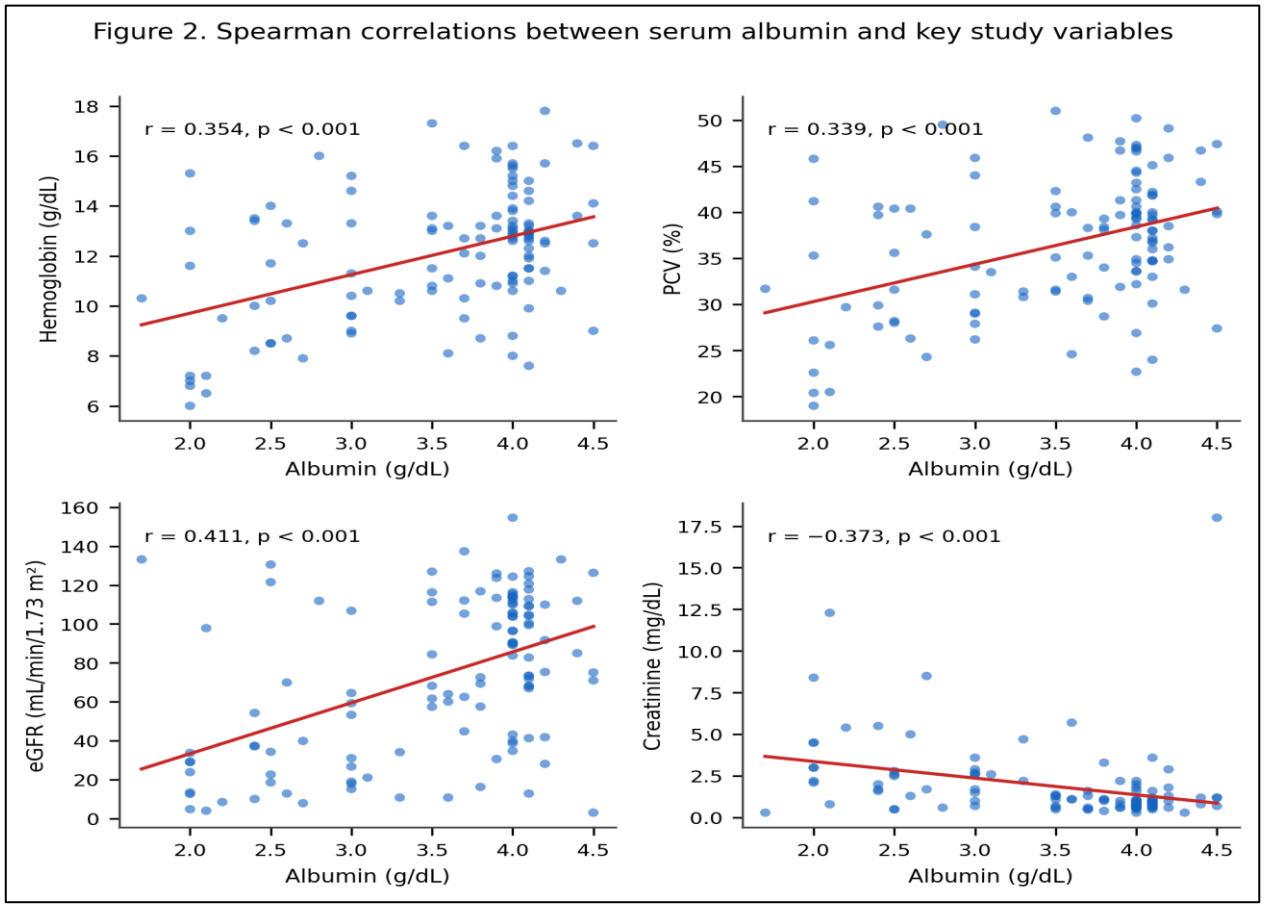

Figure 2. Correlations between serum albumin and hemoglobin, PCV, eGFR, and creatinine, with linear trend lines.

Table 3. Multivariable regression for hemoglobin, PCV (linear, β) and anemia (logistic, OR).

Outcome	Predictor	Estimate	95% CI	p-value
Hemoglobin (β)	Albumin	0.707	0.143 to 1.270	0.015
	eGFR	0.023	0.013 to 0.033	<0.001
	Sex (female)	−1.859	−2.568 to −1.150	<0.001
	FBS	−0.008	−0.017 to 0.001	0.092
PCV (β)	Albumin	1.630	0.026 to 3.233	0.047
	eGFR	0.067	0.039 to 0.095	<0.001
	Sex (female)	−5.177	−7.195 to −3.160	<0.001
	FBS	−0.022	−0.049 to 0.005	0.102
Anemia (OR)	Albumin	0.71	0.37 to 1.37	0.306
	eGFR	0.977	0.965 to 0.989	<0.001
	Sex (female)	3.57	1.51 to 8.46	0.004
	FBS	0.994	0.983 to 1.006	0.344

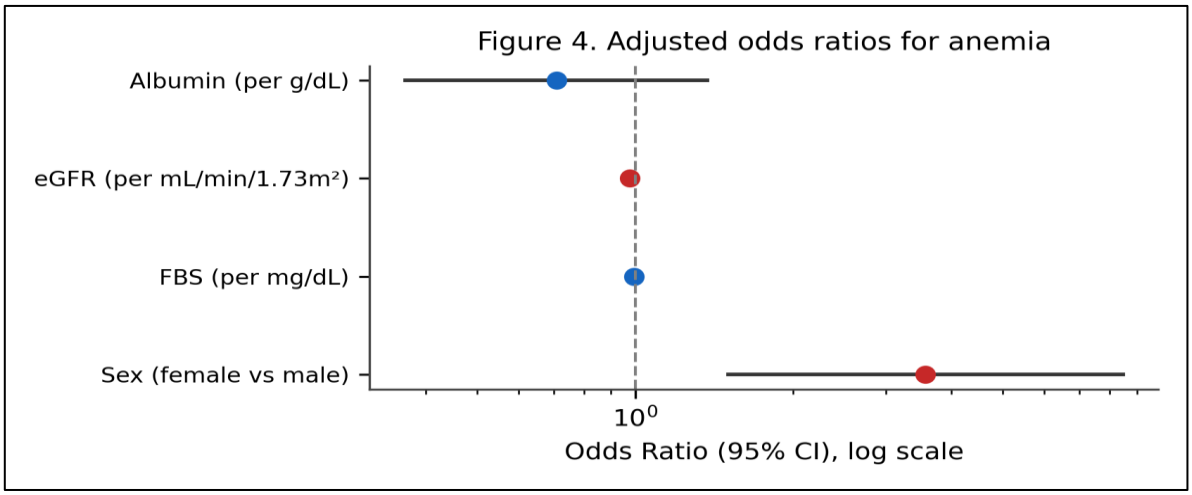

Figure 3. Adjusted odds ratios (95% CI) for anemia. Red markers denote statistically significant predictors (CI excludes 1).

Table 4. ROC analysis: standalone and composite models.

Model	Outcome	AUC	95% CI	Notes
Albumin alone	Anemia	0.633	0.532–0.729	Cut-off 3.70 g/dL
eGFR alone	Anemia	0.733	0.641–0.819	—
Composite (Alb+eGFR+FBS)	Anemia	0.738	0.647–0.823	—
Albumin alone	Inflammation	0.451	—	Poor discrimination

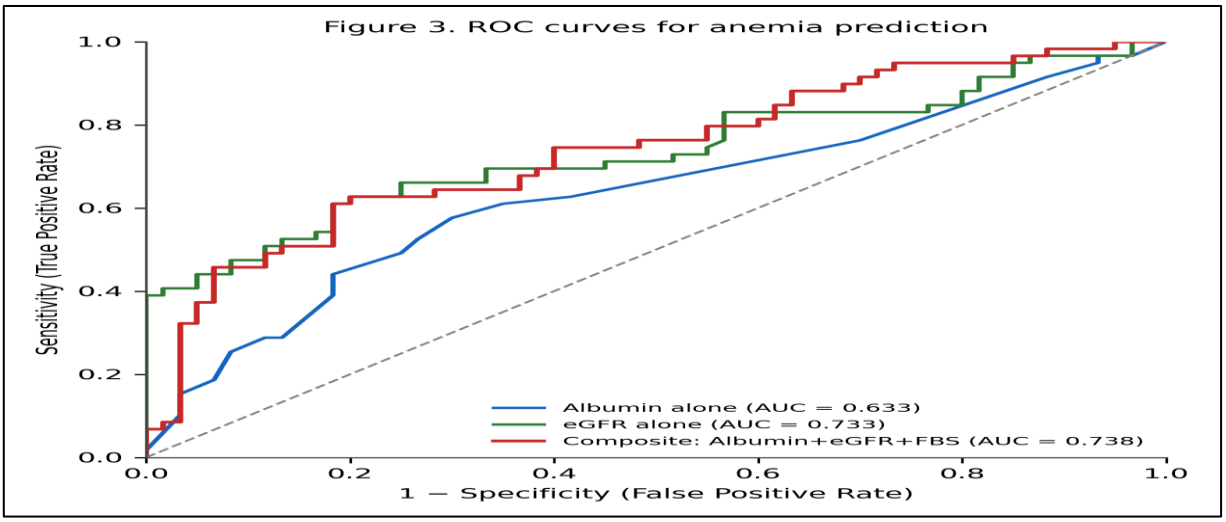

Figure 4. ROC curves comparing albumin alone, eGFR alone, and the composite model for anemia prediction.

DISCUSSION

In this cross-sectional study of patients with renal impairment, anemia was the most common clinical finding, with 37.0% of participants having reduced eGFR, consistent with global data indicating that anemia is among the most prevalent complications of chronic kidney disease, with an estimated 96% rise in global CKD-related anemia cases between 1990 and 2021 (12). Albumin was positively correlated with hemoglobin, PCV, and eGFR; these associations with hemoglobin and PCV persisted after multivariable

adjustment. However, once eGFR (calculated directly from creatinine, age, and sex) and sex were accounted for, albumin's independent contribution to anemia risk was no longer significant, and eGFR emerged as the dominant independent predictor. The independent use of the standalone eGFR was a better predictor compared to albumin (AUC 0.733 vs 0.633), while the improvement achieved by incorporating albumin and FBS in the composite model was minimal (AUC 0.738).

Positive association noted between albumin and hemoglobin/PCV is in agreement with scientific literature that has found a link between anemia and renal disease, systemic metabolism (13,14). Anemia in patients of chronic kidney disease mainly stems from decreased erythropoietin production, besides which there are other inflammatory and metabolic factors as causative agents in its formation (15,16). Albumin remaining independently associated with hemoglobin and PCV even after adjusting for eGFR supports the coexistence of hematologic and systemic metabolic impairment, though the magnitude of albumin's contribution was smaller than when raw creatinine was used, reflecting that eGFR is a more complete, standardized measure of renal function than creatinine alone (17-19). The strong independent association between eGFR and anemia is consistent with the pathophysiology of renal anemia, in which declining nephron mass reduces erythropoietin synthesis in a manner more directly captured by a standardized filtration estimate than by creatinine alone, which is also influenced by muscle mass, age, and sex. Female sex was also independently associated with higher anemia risk, consistent with evidence that women with CKD have lower hemoglobin levels across disease stages and bear a disproportionate burden of CKD-related anemia globally (12,20).

No significant relationship was found between albumin and inflammation (WBC), consistent with reports that albumin alone is insufficient to capture inflammatory status, and that composite indices such as the neutrophil-to-albumin ratio or C-reactive protein-to-albumin ratio may better capture combined inflammatory-nutritional signals in renal impairment (21,22). Similarly, the lack of correlation between albumin and FBS is consistent with literature indicating that glycated albumin, rather than total albumin, is the more informative albumin-based glycemic marker in renal populations (8,9).

A key methodological point is that the specified direction of the outcome variable materially affects ROC-based interpretation: an incorrectly specified positive-test direction would produce a misleadingly low AUC, whereas the correctly specified direction showed fair, statistically significant discrimination. This, together with the attenuation of albumin's independent effect after adjusting for eGFR and sex, illustrates that correlation, univariate discrimination, and multivariable independence each capture a different aspect of a biomarker's value and should be interpreted together (23). The comparison between eGFR alone, albumin alone, and the model shows that there is more emphasis on eGFR than pure creatinine in assessing the risk of anemia, where albumin contributes in a secondary but relatively smaller fashion.

Limitations

The current study uses a cross-sectional approach, thereby precluding cause-and-effect relationships. Sample recruitment was confined to one site within one month, which may limit applicability. Neither measurements of glycated albumin nor HbA1c were carried out. Estimate glomerular filtration rate was calculated on the basis of one creatinine level. When data was being scrutinized, three unreasonable values of albumin were replaced

and one patient was removed, although such changes did not change the overall picture, yet emphasizing the importance of a thorough review of data quality. The small sample size decreased the accuracy of calculations in some subgroups (CKD stage G3a, n=5).

CONCLUSION

Albumin in serum is found to have a relationship with Hb and PCV which is independent even with the inclusion of estimated glomerular filtration rate (eGFR) and gender. Nevertheless, eGFR is considered the major independent factor related to anemia in people who are suffering from renal disease, while albumin loses its independent significance once it becomes a component of eGFR. The addition of albumin and fasting blood sugar (FBS) in addition to eGFR gives a minor gain in the overall value of such a model. The findings clearly indicate that it is better to use eGFR instead of creatinine levels as the main renal function factor while evaluating serum albumin in anemia risk.

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