

Clinical and Immunological Determinants of Glomerular Filtration Rate in Iraqi Patients with Systemic Lupus Erythematosus

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ABSTRACT

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Objective: To identify clinical, immunological, and cardiometabolic factors associated with estimated glomerular filtration rate (eGFR) in Iraqi patients with systemic lupus erythematosus (SLE) and to describe the distribution of chronic kidney disease (CKD) stages in this group.

Methods: This cross-sectional study included 44 patients with SLE attending Baghdad Teaching Hospital, Baghdad, Iraq, between September 2023 and March 2024. Age, sex, body mass index (BMI), blood pressure, antinuclear antibody (ANA) level, erythrocyte sedimentation rate (ESR), white blood cell (WBC) count, and serum creatinine (SCR) were recorded, and eGFR was calculated with the CKD-EPI 2021 equation. Group comparisons, correlation analysis, and multiple linear regression were performed.

Results: Most patients were female (88.6%), and the mean age was 42.05 ± 12.87 years. Five patients (11.4%) had CKD (eGFR <60 mL/min/1.73 m²) and eight (18.2%) had hypertension. Patients with CKD had higher SCR than those without CKD ($p < 0.001$). eGFR correlated negatively with age (Spearman $\rho = -0.547$, $p < 0.001$) and SCR ($\rho = -0.865$, $p < 0.001$). In multiple regression, age was independently associated with lower eGFR ($\beta = -1.475$, $p < 0.001$). ANA was also associated with eGFR ($\beta = 1.579$, $p = 0.002$), but this association depended on a single patient and was no longer significant when that patient was excluded. BMI was not associated with eGFR. The model explained 42.6% of the variance in eGFR (adjusted $R^2 = 0.331$). ESR was higher in female than in male patients ($p = 0.036$).

Conclusions: Older age was the factor most consistently associated with lower eGFR, whereas BMI, blood pressure, and inflammatory markers were not. Routine monitoring of SCR, eGFR, and blood pressure, with closer follow-up of older patients, may support early detection of renal impairment. Larger prospective studies are needed to confirm these findings.

Introduction

Systemic lupus erythematosus (SLE) is a chronic autoimmune disease that can affect almost any organ system, which makes its management challenging. Its pathogenesis involves an imbalance between innate and adaptive immunity, enhanced type I interferon (IFN) signaling, and deposition of immune complexes in the skin, joints, blood, brain, and, importantly, the kidney [1,2]. Disease outcomes and mortality differ considerably between populations, which makes population-specific data important.

Renal involvement is one of the most common and serious manifestations of SLE. It is estimated that between 40–60% of patients develop lupus nephritis, but this varies widely according to ethnicity, disease activity, and access to specialist care [3]. Immune complex deposition activates the complement system, which leads to inflammatory infiltration of the glomeruli, podocyte injury, and mesangial expansion and, in advanced disease, to glomerulosclerosis and interstitial fibrosis. Without timely treatment, a proportion of patients progress to chronic kidney disease (CKD) and end-stage renal disease (ESRD) requiring renal replacement therapy, with a considerable burden on patients and health systems [4].

Estimated glomerular filtration rate (eGFR), calculated from serum creatinine, age, and sex using the CKD-EPI [5] or MDRD [6] equation, remains the standard method for assessing renal function, and CKD is staged according to the KDIGO 2012 guideline [7]. eGFR is an important intermediate outcome in nephroprotection trials and a predictor of cardiovascular and all-cause mortality in patients with lupus [8].

Renal function in SLE is influenced not only by immune-mediated injury but also by cardiometabolic factors, including haemodynamic stress on the glomerular microvasculature, oxidative injury, and pro-inflammatory cytokine signalling. Hypertension is common in SLE and is associated with proteinuria and podocyte loss, even when immunological activity is low [9]. Markers of systemic inflammation (ESR) and autoimmunity (ANA) are routinely used to monitor the disease, but their relationship with renal function is not well defined [10].

Data on renal function in SLE from the Middle East are limited, and few studies have examined Iraqi patients. This population differs from Western cohorts in genetic background, frequency of consanguineous marriage, and access to specialist care, all of which may influence the pattern of renal disease. In addition, the combined effect of environmental, dietary, and health-care factors on lupus nephropathy has not been examined in this population using multivariable methods.

The aim of this study was to address this gap. The specific objectives were to: (i) describe the distribution of eGFR and CKD stages in a group of Iraqi patients with SLE; and (ii) identify clinical and immunological factors independently associated with eGFR using multiple linear regression.

Methods

Study Design and Setting

This was a cross-sectional observational study conducted at Baghdad Teaching Hospital, a tertiary referral centre for autoimmune and rheumatological diseases in Baghdad, Iraq, between September 2023 and March 2024. Reporting follows the STROBE guidelines. Formal approval from an institutional ethics committee was not obtained. The study was conducted in accordance with the Declaration of Helsinki, and written informed consent was obtained from all participants before data collection.

Study Population and Eligibility Criteria

Forty-four patients with SLE were recruited by convenience sampling. Inclusion criteria were age ≥ 18 years and a diagnosis of SLE fulfilling at least four of the 1997 revised American College of Rheumatology (ACR) classification criteria [11]. Exclusion criteria were incomplete clinical data, other renal diseases that may mimic lupus nephritis, such as lipoprotein glomerulopathy (LPG), acute kidney injury not related to lupus, and active urinary tract infection. Because the centre is a national referral centre, patients came from several governorates, including Baghdad (the largest group), Wasit, Najaf, Anbar, Diyala, Muthanna (Samawah), Babylon, Salahaddin (including Samarra), Basrah, and Diwaniyah.

Formal ethical approval for this study was obtained from the Research Ethics Committee of the College of Dentistry, Mustansiriyah University, and Baghdad, Iraq. The study was

conducted in accordance with the Declaration of Helsinki. All participants gave written and oral informed consent before data collection. They were informed of the aim and procedures of the study. Participation was voluntary, strict confidentiality and anonymity were ensured, and participants were informed that they could withdraw from the study at any time without consequences.

Data Collection and Measurements

All participants underwent clinical assessment at enrolment. Weight (kg) and standing height (cm) were obtained from medical records, and body mass index (BMI) was calculated as weight divided by height squared (kg/m^2) and categorised according to WHO cut-offs. Systolic (SBP) and diastolic (DBP) blood pressure were measured in mmHg using a calibrated sphygmomanometer in the sitting position after 5 minutes of rest. Mean arterial pressure (MAP) was calculated as $\text{DBP} + (\text{SBP} - \text{DBP})/3$ and pulse pressure (PP) as $\text{SBP} - \text{DBP}$. Laboratory tests included serum creatinine (SCR, mg/dL) by the Jaffe method, antinuclear antibody (ANA, IU/mL) by enzyme-linked immunosorbent assay (ELISA), erythrocyte sedimentation rate (ESR, mm/h), and white blood cell (WBC) count (cells/ μL). eGFR (mL/min/1.73 m^2) was calculated for all patients from SCR, age, and sex using the CKD-EPI 2021 equation [5]. Hypertension was defined as $\text{SBP} \geq 140$ mmHg or $\text{DBP} \geq 90$ mmHg according to the ESC/ESH definition [12], and clinically significant CKD was defined as $\text{eGFR} < 60$ mL/min/1.73 m^2 according to KDIGO 2012 [7].

Data Preprocessing and Quality Control

Data were checked for errors before analysis, and all corrections are documented in the data-cleaning log (Supplementary File). The electronic dataset was re-examined during revision. One recorded age of 242 years was corrected to 42 years as an assumed data-entry error. In one patient, the entries for smoking status, weight, height, and BMI were shifted between columns (a smoking code of 93 and a height of 19.3 cm), which had produced an implausible BMI of approximately 4295 kg/m^2 ; these four values were set to missing. One missing BMI value was calculated from the recorded weight and height. WBC values below 100 were assumed to have been recorded in $\times 10^3$ cells/ μL and were converted to cells/ μL . The variable originally reported as prothrombin time contained values consistent with platelet counts (including 279,000 and 319,000), and its identity could not be confirmed; it was therefore excluded from all analyses. Smoking and diabetes status were not analysed because the coding of these variables could not be confirmed. The renal function values used in the original analysis had been calculated with the Cockcroft–Gault formula and contained calculation errors in several patients, with one value missing. eGFR was therefore recalculated for all 44 patients from the recorded SCR, age, and sex using the CKD-EPI 2021 equation, and all analyses were repeated. No imputation was performed, and analyses were based on available data (complete-case analysis).

Statistical Analysis

The Shapiro–Wilk test was used to assess the normality of continuous variables. Normally distributed variables are presented as mean $\pm$ standard deviation (SD) and non-normally distributed variables as median (interquartile range, IQR). The Welch two-sample t-test was used for normally distributed variables and the Mann–Whitney U test for non-normally distributed variables. Bivariate relationships with eGFR were assessed using Pearson and Spearman correlation. Multiple linear regression was used to identify factors independently associated with eGFR, with R^2 and adjusted R^2 used to assess model fit; SCR was not entered as a predictor because it is used to calculate eGFR. The robustness of significant predictors was examined by repeating the model after excluding influential observations. Effect sizes were expressed as Cohen's d for parametric comparisons and rank-biserial correlation for non-parametric comparisons. A two-tailed significance level of $\alpha = 0.05$ was used. Analyses were performed in Python 3 using SciPy, statsmodels, and Matplotlib.

Results

Sample Characteristics

From the 44 patients, 39 (88.6%) were female and 5 (11.4%) were male, a ratio consistent with the known epidemiology of SLE. The mean age was 42.05 ± 12.87 years (range 18–73 years) (Table 1).

Most patients had a normal BMI (44.2%), followed by overweight (32.6%), obesity (16.3%), and underweight (7.0%). Hypertension was present in 8 patients (18.2%). The median eGFR was 110.0 (IQR 91.9–121.7) mL/min/1.73 m². Five patients (11.4%) had CKD (eGFR <60 mL/min/1.73 m²); of these, 3 (6.8%) were in stage G3a and 2 (4.5%) in stage G4 (Table 1).

Table 1. Characteristics of the study patients (n = 44)

Variable	N	Missing	Mean $\pm$ SD / Median (IQR)	Min–Max
Continuous variables				
Age (years)	44	0	42.05 ± 12.87	18–73
Body weight (kg)	43	1	62.98 ± 13.76	36–95
BMI (kg/m ²)	43	1	24.81 ± 5.14	14.8–37.1
ESR (mm/h)	44	0	23.0 (17.5–40.0)	0–80
ANA (IU/mL)	44	0	140.0 (138.0–142.2)	100–165
WBC (cells/ μ L)	44	0	8587.5 ± 2380.1	3700–14400
eGFR (mL/min/1.73 m ²)	44	0	110.0 (91.9–121.7)	15.9–139.3
SCR (mg/dL)	44	0	0.70 (0.60–0.80)	0.4–3.7
SBP (mmHg)	44	0	110.0 (100.0–120.0)	70–150
DBP (mmHg)	44	0	80.0 (78.8–80.0)	50–90
MAP (mmHg)	44	0	90.0 (86.7–93.3)	56.7–110.0
Categorical variables, n (%)				
Sex: female / male			39 (88.6) / 5 (11.4)	
Hypertension			8 (18.2)	
BMI: underweight / normal / overweight / obese (n = 43)			3 (7.0) / 19 (44.2) / 14 (32.6) / 7 (16.3)	
CKD stage: G1 / G2 / G3a / G3b / G4			35 (79.5) / 4 (9.1) / 3 (6.8) / 0 / 2 (4.5)	

Maternal indication of caesarian section

Table (2) describe maternal indication of CS, it revealed that significant differences between two maternity hospitals regarding previous cesarian section, antepartum hemorrhage, maternal request, bad obstetric history and diabetes meletus. The commonest maternal causes of CS in Al-Batool Teaching Maternity Hospital were previous CS 350 (55.3%), failure to progress 135 (21.3%), while in Al-Mosul General Hospital reported failure to progress 127 (21.65%) then cephalopelvic disproportion (15.3%) and previous CS (15.3). Hypertensive disorders in pregnancy 64 (10.1%) frequently seen in Al-Batool Teaching Maternity Hospital while antepartum hemorrhage 37 (6.3%) seen in Al-Mosul General Hospital. P-value not statistically different

Table 2. Comparison of patients with and without CKD

Variable	Non-CKD (n = 39)	CKD (n = 5)	Test	p-value	Effect size
Age (years)	41.13 ± 12.13	49.20 ± 17.63	Welch t	0.371	d = -0.53
BMI (kg/m ²)	24.41 ± 4.87	27.83 ± 6.70	Welch t	0.324	d = -0.58
SCR (mg/dL)	0.70 (0.60–0.70)	1.50 (1.20–3.60)	Mann–Whitney U	<0.001***	r = 0.99
ESR (mm/h)	23.0 (17.0–39.0)	37.0 (23.0–40.0)	Mann–Whitney U	0.541	r = 0.17
ANA (IU/mL)	140.0 (138.0–141.5)	139.0 (135.4–149.0)	Mann–Whitney U	0.896	r = -0.04
WBC (cells/μL)	8483 ± 2502	9400 ± 696	Welch t	0.085	d = -0.50
SBP (mmHg)	110.0 (100.0–120.0)	110.0 (100.0–120.0)	Mann–Whitney U	0.734	r = -0.10
DBP (mmHg)	80.0 (80.0–80.0)	80.0 (60.0–80.0)	Mann–Whitney U	0.428	r = -0.20

Values are mean ± SD for normally distributed variables and median (IQR) for non-normally distributed variables. ***p < 0.001. d, Cohen's d; r, rank-biserial correlation; CKD, chronic kidney disease (eGFR <60 mL/min/1.73 m²); other abbreviations as in Table 1.

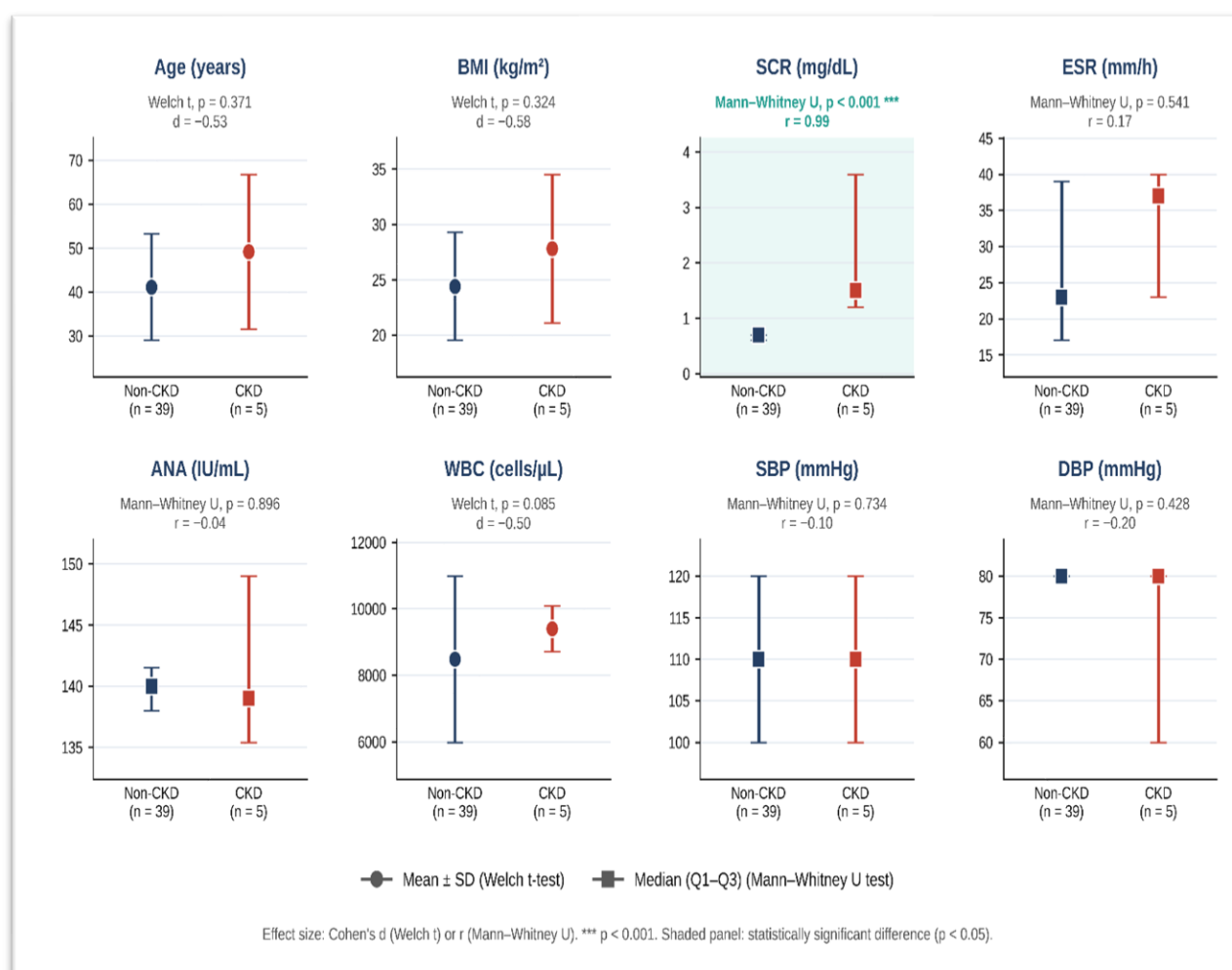


Figure 1: the Comparison of demographic, clinical, and laboratory variables between non-CKD and CKD groups.

Correlation Analysis

Correlations between eGFR and the candidate variables are shown in Table 3. Age showed a moderate negative correlation with eGFR (Pearson $r = -0.404$, $p = 0.007$; Spearman $\rho = -0.547$, $p < 0.001$), and SCR showed a strong inverse correlation ($r = -0.851$ and $\rho = -0.865$; both $p < 0.001$) (Figure 1). ANA was weakly correlated with eGFR in the Pearson analysis ($r = 0.321$, $p = 0.034$) but not in the Spearman analysis ($\rho = 0.012$, $p = 0.940$), indicating that the Pearson coefficient was driven by an outlying value. BMI, SBP, DBP, ESR, and WBC were not correlated with eGFR.

Table 3. Correlation of candidate variables with eGFR

Predictor	Pearson r	Pearson p	Spearman ρ	Spearman p	Significance
Age	-0.404	0.007	-0.547	<0.001	** / ***
BMI	-0.105	0.505	-0.081	0.607	ns / ns
SBP	0.071	0.648	-0.124	0.423	ns / ns
DBP	0.160	0.301	-0.150	0.332	ns / ns
SCR	-0.851	<0.001	-0.865	<0.001	*** / ***
ESR	-0.160	0.300	-0.196	0.203	ns / ns
ANA	0.321	0.034	0.012	0.940	* / ns
WBC	-0.099	0.524	-0.169	0.273	ns / ns

Significance is shown for the Pearson / Spearman coefficients. $n = 44$ (BMI, $n = 43$). ns, not significant; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$. Abbreviations as in Tables 1 and 2.

Multiple Linear Regression: Predictors of eGFR

The multiple linear regression model included age, BMI, SBP, ESR, ANA, and WBC ($n = 43$) and explained 42.6% of the variance in eGFR ($R^2 = 0.426$; adjusted $R^2 = 0.331$) (Table 4). Age was independently associated with lower eGFR ($\beta = -1.475$, $SE = 0.342$, $t = -4.312$, $p < 0.001$), corresponding to a decrease of 1.48 mL/min/1.73 m² in eGFR for each additional year of age after adjustment for the other variables (Figure 1). ANA was positively associated with eGFR ($\beta = 1.579$, $p = 0.002$); however, this association was driven by one patient with the lowest ANA value (100 IU/mL) and severely reduced eGFR, and it was no longer significant after this patient was excluded ($\beta = 0.488$, $p = 0.497$), whereas the association with age persisted ($\beta = -1.240$, $p = 0.001$). BMI, SBP, ESR, and WBC were not significantly associated with eGFR.

Table 4. Multiple linear regression of factors associated with eGFR ($n = 43$, $R^2 = 0.426$, adjusted $R^2 = 0.331$)

Predictor	β coefficient	SE	t	p-value	Significance
Intercept	-92.035	69.627	-1.322	0.195	ns
Age (years)	-1.475	0.342	-4.312	<0.001	***
BMI (kg/m ²)	-0.516	0.765	-0.674	0.505	ns
SBP (mmHg)	0.355	0.237	1.501	0.142	ns
ESR (mm/h)	0.232	0.233	0.997	0.325	ns
ANA (IU/mL)	1.579	0.472	3.341	0.002	**
WBC (cells/ μ L)	0.0002	0.0015	0.142	0.888	ns

Dependent variable: eGFR (mL/min/1.73 m²). SCR was not entered because it is used to calculate eGFR. After exclusion of one patient with an outlying ANA value, age remained significant ($\beta = -1.240$, $p = 0.001$), whereas ANA did not ($\beta = 0.488$, $p = 0.497$). β , unstandardised regression coefficient; SE, standard error; ns, not significant; ** $p < 0.01$; *** $p < 0.001$; other abbreviations as in Table 1.

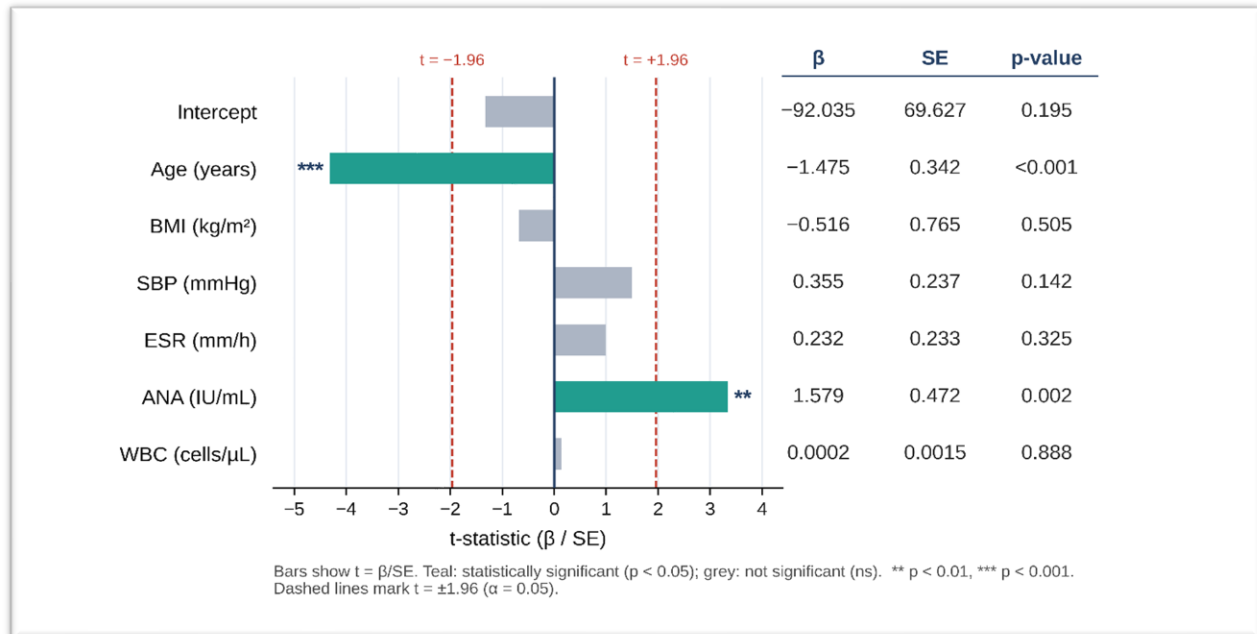


Figure2: the multiple linear regression analysis of predictors of the outcome variable. Bars characterize the t-statistic (β/SE) for each predictor; teal bars indicate statistically significant predictors ($p < 0.05$) and grey bars indicate non-significant predictors.

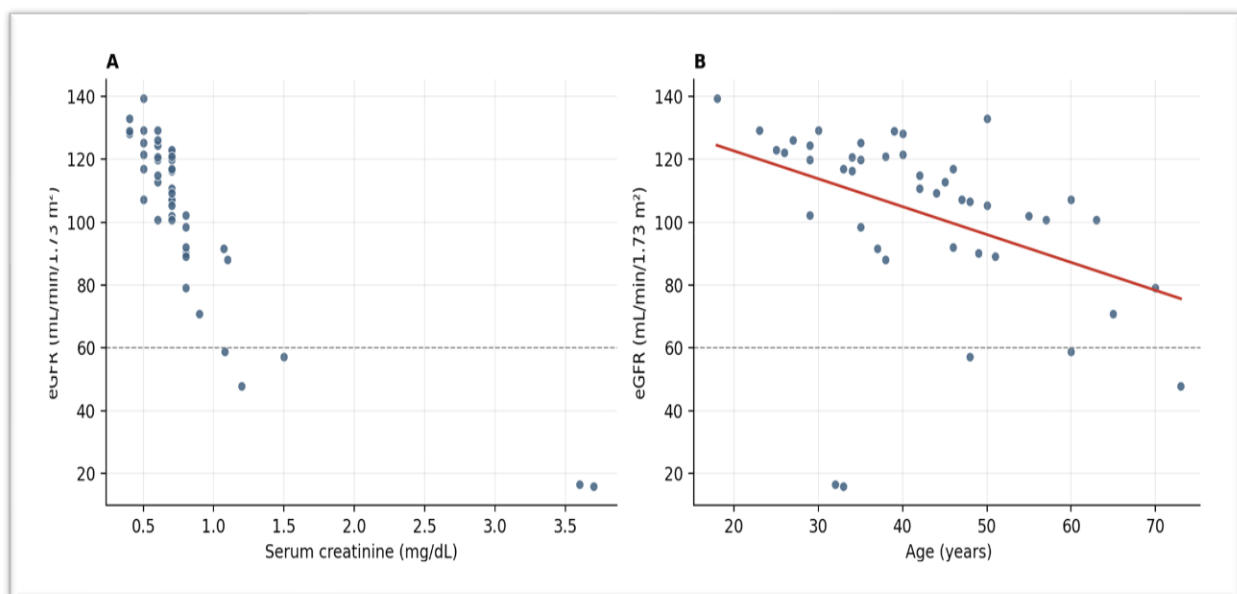


Figure 3: Relationship of eGFR with serum creatinine (A) and age (B).

eGFR, estimated glomerular filtration rate calculated with the CKD-EPI 2021 equation. The dashed line marks eGFR = 60 mL/min/1.73 m²; the solid line in panel B is the fitted linear regression line.

Discussion

To the best of our knowledge, this is one of the first studies to apply multivariable analysis to the determinants of renal function in Iraqi patients with SLE. The main findings are discussed below in the context of the international literature.

The predominance of females (88.6%) and the mean age of the patients (42.05 years) are consistent with the global epidemiology of SLE, which mainly affects women of reproductive and post-reproductive age, with female-to-male ratios of about 9:1 [13].

The prevalence of CKD in this study (11.4%) was lower than that reported in North American and European lupus nephritis cohorts (30–50%) [3,14]. The differences could be explained by the cross-sectional design, which captures prevalence at a single time point rather than the cumulative incidence of CKD, the relatively young mean age of the sample, and possible under-detection of milder stages of CKD in resource-limited settings [3,14]. Similarly, the prevalence of hypertension (18.2%) was lower than the 40–60% reported in established lupus registries, which may again reflect the younger age of the sample and the cross-sectional design; the cumulative incidence of both hypertension and CKD would be expected to rise with longer follow-up.

Age was the strongest independent predictor of lower eGFR ($\beta = -1.475$, $p < 0.001$), which is biologically plausible. In addition to immune-mediated glomerular injury, ageing is associated with glomerulosclerosis, arteriolar hyalinosis, tubular atrophy, and cortical fibrosis [15], which reduce renal reserve and the ability of the kidney to compensate for nephron loss. Older patients with SLE may therefore benefit from closer renal monitoring. However, part of this association is expected by design, because age is included in the eGFR equation. Patients with CKD were older on average, but this difference was not statistically significant, probably because only five patients had CKD.

BMI was not associated with eGFR. Because the CKD-EPI 2021 equation does not include body weight, this result is not influenced by body size, unlike estimates based on creatinine clearance formulas such as Cockcroft–Gault, which can create a spurious positive association between body weight and renal function. The strong inverse relationship between SCR and eGFR ($\rho = -0.865$) reflects the known curvilinear relationship between creatinine and GFR [5].

ANA was not independently associated with eGFR after exclusion of one outlying patient, and the unadjusted Pearson correlation was driven by the same observation. The ANA titre does not reflect the specificity, avidity, or complement-fixing capacity of antibodies, which determine the pathogenicity of immune complexes in the kidney. In addition, ANA values in this cohort were narrowly distributed, with most values between 138 and 142 IU/mL, which limits their discriminatory value. Specific nephritogenic antibodies, such as anti-dsDNA, anti-C1q, and anti-Sm, are likely to be more informative than a single overall ANA measurement [16,17].

In resource-limited settings such as Iraq, the variables most strongly associated with renal function in this study, age and SCR, are inexpensive and easy to measure. A surveillance approach based on serial SCR and eGFR measurement and regular blood pressure monitoring is feasible in most rheumatology and primary care settings without special equipment. Patients with early renal impairment may benefit from renin–angiotensin system blockade with angiotensin-converting enzyme inhibitors or angiotensin receptor blockers to slow progression [18,19].

Strengths and Limitations

The strengths of this study include the recalculation of eGFR for all patients with a standard, race-free equation and the use of multivariable analysis in a population that is under-represented in the SLE literature. Several limitations should be noted. First, the cross-sectional design does not allow causal inference or assessment of changes in eGFR over time, and CKD was defined from a single eGFR measurement rather than persistence for more than three months as required by KDIGO [7]. Second, the small sample size, particularly the small numbers of male patients ($n = 5$) and patients with CKD ($n = 5$), reduces statistical power and increases the risk of type I and type II errors; for this reason, multivariable analysis of CKD status was not attempted. Third, age is a component of the eGFR equation, so part of its association with eGFR is expected by design. Fourth, the single-centre design and convenience sampling limit the generalisability of the results to all Iraqi patients with SLE. Finally, data on urinalysis, proteinuria, renal biopsy, and specific autoantibodies (anti-dsDNA, anti-C1q, and anti-Sm) were not available, and smoking and diabetes status could not be analysed.

Conclusions

In this cross-sectional study of Iraqi patients with SLE, older age was the factor most consistently associated with lower eGFR, whereas BMI, blood pressure, and inflammatory markers were not independently associated with renal function. Reduced renal function and hypertension were present in a considerable proportion of patients. These findings support regular renal monitoring, including SCR, eGFR, and blood pressure, as part of routine SLE care in Iraq, with closer follow-up of older patients and those with elevated SCR. Because of the small sample and cross-sectional design, the results should be regarded as hypothesis-generating. Prospective studies with larger samples, longer follow-up, and data on urinalysis, specific autoantibodies, and treatment are needed to confirm them.

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Data Sharing: The de-identified dataset and analysis code are available from the corresponding author on reasonable request.

Authorship Contributions (CRediT): Provided on the separate title page to preserve blinding of the manuscript.

Declaration of Artificial Intelligence (AI) Use: During the preparation of the revised manuscript, the authors used Claude (Anthropic) to assist with language editing, checking the consistency of reported results, and repeating the statistical analysis of the dataset. The authors reviewed and edited all output and take full responsibility for the content of the manuscript.

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