RESEARCH PAPER

TO COMPARE SERUM FRUCTOSAMINE AND HBA1C AS AN INDEX OF GLYCEMIC CONTROL IN DIABETIC HEMODIALYSIS PATIENT

Dr.Tushar R. Heda[1], Dr. Sushama K. Jotkar[2]

[1]Junior Resident, Department of General Medicine, D.Y. Patil Medical College, Hospital and Research Institute, Kolhapur 416006, MS, India. D.Y. Patil Education Society (Deemed to be University) Kolhapur
[2]Professor and HOD, Department of General Medicine,D.Y. Patil Medical College, Hospital and Research Institute, Kolhapur 416006, MS, India. D.Y. Patil Education Society (Deemed to be University) Kolhapur

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ABSTRACT

Background: Assessment of glycemic control in diabetic patients with chronic kidney disease (CKD), particularly those undergoing hemodialysis (HD), is challenging. Glycated hemoglobin (HbA1c), the conventional marker of long-term glycemic control, may be unreliable in HD patients because of anemia, shortened erythrocyte lifespan, erythropoietin therapy, and frequent transfusions. Serum fructosamine (FA), reflecting glycemic status over the preceding 2–3 weeks, may provide a more accurate assessment in this population.

Aim: To study the comparison between "serum FA and HbA1c as an index of glycemic control in diabetic HD patients.

Materials and Methods: A comparative cross-sectional study was conducted in the Department of General Medicine, Dr. D. Y. Patil Medical College and Hospital, Kolhapur, from January 2024 to December 2025. Adult diabetic CKD patients were categorized into Group A (non-hemodialysis CKD) and Group B (hemodialysis CKD). Clinical, biochemical, and renal function parameters were assessed. Serum fructosamine and HbA1c levels were measured and compared between groups. Correlation analysis between both glycemic markers and CKD stage was performed.

Results: The mean age of participants was 58.09 ± 8.98 years, with male predominance (67.2%). Group B exhibited significantly lower estimated glomerular filtration rate than Group A (10.39 ± 7.95 vs. 16.76 ± 5.24 mL/min/1.73 m²; $p<0.001$). HbA1c levels were significantly lower in HD patients (7.56 ± 0.77%) compared with non-HD patients (8.79 ± 0.72%; $p<0.001$). Conversely, serum fructosamine levels were significantly higher in Group B (380.62 ± 101.65 µmol/L) than Group A (281.80 ± 120.51 µmol/L; $p<0.001$). A significant positive correlation between HbA1c and fructosamine was observed in the HD group ($r=0.369$, $p=0.024$). Fructosamine levels increased significantly with advancing CKD stage, whereas HbA1c showed no consistent stage-wise variation.

Conclusion: Serum fructosamine appears to be a more sensitive and reliable marker of glycemic control than HbA1c in diabetic patients undergoing hemodialysis. Combined assessment of fructosamine and HbA1c may provide a more comprehensive evaluation of glycemic status in advanced CKD.

Keywords: Diabetes Mellitus; Chronic Kidney Disease; Hemodialysis; Fructosamine; HbA1c; Glycemic Control; Diabetic Nephropathy.

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INTRODUCTION

"Diabetes mellitus (DM)" is now the most important cause of nephropathy in diabetic subjects. Nephropathy impacts about 40% of those diagnosed with diabetes. Risk variables for the start of diabetic nephropathy (DN)include hypertension, lowerglycemic control, obesity, hypercholesterolemia, and metabolic disorders. Managing DN can be complicated as it requires ongoing monitoring and treatment to remain in the optimal range for blood sugar levels. [1]

As per the "International Diabetes Federation (IDF), in theninth edition of the IDF Global Diabetes Atlas", it was projected that 9 % of the world's population had DM (approximately 463 million people) within the adult population in 2019. Projections show that this figure will rise to "10.2% (578 million) and 10.9% (700 million) by 2030 and 2045", respectively, indicating that there is a growing global health issue and concern. DM prevalence is higher among people living in "urban areas (10.8%) than those living in rural areas (7.2%) and high-income countries (10.4%) relative to low-income countries (4.0%)". Additionally, almost half (50.1%) of all persons with DM are not aware they have DM. In 2019, approximately 7.5% (374 million people) globally were predicted to have abnormal glucose tolerance, with projections of "8.0% (454 million people) and 8.6% (548 million people) by 2030 and 2045, respectively". [2,3]

Chronically elevated blood sugar promotes increased levels of non-enzymatic glycation, producing stable Amadoricompound-type metabolites such as fructosamine (FA). These Amadori compounds undergo some further irreversible reaction(s), ultimately resulting in "advanced glycation end-products" (AGE's). Increased levels of both

Author for Correspondence: Dr.Tushar R. Heda

Amadori compounds and AGE's within the tissues of diabetic persons with associated complications such as nephropathy, retinopathy, and atherosclerosis are allied with more free radical action; this free radical activity damages biomolecules. [4]

HbA1c is utilized as a broad sign of continuing blood glucose regulation. It reports average blood sugar levels, which in turn is a tool to evaluate the risk of DM-related difficulties. Also, in addition to traditional risk variables like dyslipidemia, we see that high HbA1c levels are now recognized as a separate indicator of heart disease in diabetics.Studies have shown that for every 1% rise in HbA1c, the risk of cardiovascular disease (CVD)increases by approximately 18% in diabetic patients. [5,6] HbA1c testing offers data on a person's average blood glucose levels over the preceding 2 to 3 months, which aligns with the typical lifespan of red blood cells (RBC). [7] It is now broadly endorsed as a useful technique for both identification and ongoing treatment of DM. [8]

In diabetic "hemodialysis (HD)" subjects, HbA1c levels may be unreliable because of a shortened lifetime of RBC and anemia. Serum FA reflects shorter-term glycemic control and is unaffected by these factors. Comparing both markers helps determine the more accurate indicator for monitoring blood glucose in a specific population. Hence, this research aimed to compare serum FA and HbA1c as measures of glycemic regulator in subjects receiving HD for DM.

METHODOLOGY

The comparative cross-sectional study was conducted at Department of General Medicine, Dr. D. Y. Patil Medical College& Hospital, Kolhapur, After getting approval from the institutional ethics committee (IEC) The study conducted for a duration of 18 months.The study subjects were selected fulfilling exclusion and inclusion criteria

Inclusion criteria Patients aged over 20 years with DM and chronic kidney disease (CKD), **Exclusion Criteria:**Patients who had undergone prior renal transplantation, Subjects newly diagnosed with DM after the initiation of dialysis, Patients with sickle cell anemia or thalassemia.

Patients with T1DM, Patients with gestational DM, "Patients with inflammatory or infectious diseases, Patients with autoimmune or rheumatic diseases, Patients diagnosed with cancer or hematological disorders.

METHODS

Patients were divided in two groups

Group 1: T2DM with CKD but without dialysis;

Group 2: T2DM with CKD on hemoadialysis.

To estimate serum HbA1c level between Group 1: T2DM with CKD but without dialysis; Group 2: T2DM with CKD on hemoadialysis.

To estimate serum FA level between; Group 1: T2DM with CKD but without dialysis; Group 2: T2DM with CKD on hemoadialysis.

To compare"HbA1C and serum FAas an index of glycemic control in both groups".

RESULTS

Age and BMI

"The mean age of the study participants was 58.09 ± 8.98 years. The mean BMI was 25.18 ± 2.28 kg/m²

Gender Among the total 54 study participants, 43 (67.20%) were males, and 21 (32.80%) were females **Comparison of Clinical and Laboratory Parameters between Groups**

The "mean Hb level was 10.16 ± 2.11 g/dl in Group A and 10.44 ± 1.69 g/dl in Group B, with no statistically significant difference observed (p = 0.561). Similarly, Sr. Ab levels were comparable between the two groups, being 3.40 ± 0.48 g/dl in Group A and 3.54 ± 0.29 g/dl in Group B (p = 0.207).

A statistically significant difference was observed in eGFR, which was higher in Group A (16.76 ± 5.24 ml/min/1.73 m²) compared to Group B (10.39 ± 7.95 ml/min/1.73 m²), with p < 0.001. However, no significant differences were noted in systolic blood pressure (SBP), which was 138.52 ± 7.37 mmHg in Group A and 140.89 ± 8.29 mmHg in Group B (p = 0.272), or diastolic blood pressure (DBP), which was 88.00 ± 3.84 mmHg in Group A and 88.96 ± 4.59 mmHg in Group B (p = 0.407)" (Table 4 and Figure 4).

Table 4. Comparison of Clinical and Laboratory Parameters between Groups

Variables	Group	Mean	SD	p-value
Hb(g/dl)	A	10.16	2.11	0.561
	B	10.44	1.69	
Albumin serum	A	3.40	0.48	0.207
	B	3.54	0.29	
eGFR (ml/min/1.73m2)	A	16.76	5.24	<0.001*
	B	10.39	7.95	
SBP	A	138.52	7.37	0.272
	B	140.89	8.29	

DBP	A	88.00	3.84	0.407
	B	88.96	4.59	

Distribution of stages of CKD

In Group A, a greater proportion of subjects were in Stage 4 CKD, accounting for 16 (59.30%) cases, while 11 (40.70%) patients were in Stage 5. In contrast, Group B had a greater proportion of patients in Stage 5 CKD, with 27 (73.00%) cases, compared to 10 (27.00%) patients in Stage 4.

The variance in the distribution of CKD stages between the two groups was noted to be statistically substantial (p = 0.012), indicating a higher severity of disease in Group B compared to Group A (Table 5 and Figure 5).

Table 5. Distribution of stages of CKD

Stages of CKD	Groups n, (%)		P-value
	A	B	
Stage 4	16 (59.30)	10 (27.00)	0.012
Stage 5	11 (40.70)	27 (73.00)	
Total	27 (100.00)	37 (100.00)	

Comparison of HbA1c and Serum FA Levels between Groups

The "mean HbA1c level was significantly higher in Group A (8.79 ± 0.72%) compared to Group B (7.56 ± 0.77%), with a statistically significant difference (p < 0.001).Similarly, serum FA levels showed a significant difference between the two groups". Group A had a mean FA level of 281.80 ± 120.51 µmol/L, whereas Group B demonstrated higher levels at 380.62 ± 101.65 µmol/L (p < 0.001)(Table 6 and Figures6 and 7).

Table 6. Comparison of HbA1c and Serum FA Levels between Groups

Parameters	Group	Mean	SD	p-value
HbA1C (%)	A	8.79	0.72	<0.001*
	B	7.56	0.77	
Serum FA (µmol/L)	A	281.80	120.51	<0.001*
	B	380.62	101.65	

Correlation between HbA1c and Serum FA Levels

In Group A, "a weak negative correlation was observed between HbA1c and serum FA (r = -0.089), which was not statistically significant (p = 0.658), indicating no meaningful association between the two parameters in this group.In contrast, Group B demonstrated a weak to moderate positive correlation between HbA1c and serum FA levels (r = 0.369), which was statistically significant (p = 0.024)" (Table 7 and Figure 8).

Table 7. Correlation between HbA1c and Serum FA Levels

Group	Correlations Between		Pearson Correlation	p-value
A	HbA1C (%)	Serum FA (µmol/L)	-0.089	0.658
B	HbA1C (%)	Serum FA (µmol/L)	0.369	0.024

Comparison of serum FA according to CKD stages

In Group A, the mean serum FA level was greater in Stage 4 CKD (300.09 ± 121.14 µmol/L) compared to Stage 5 CKD (255.18 ± 120.13 µmol/L); however, this variance was not statistically substantial (p = 0.352).

"In Group B, a statistically significant difference was observed between CKD stages". Patients with Stage 5 CKD had markedly higher serum FA levels (432.77 ± 61.08 µmol/L) compared to those with Stage 4 CKD (239.80 ± 19.60 µmol/L), with p < 0.001 (Table 8 and Figure 9).

Table 8. Comparison of serum FA according to CKD stages

Groups	Serum FA (µmol/L)		P-value
	Stage 4 CKD	Stage 5 CKD	
A	300.09±121.14	255.18±120.13	0.352
B	239.80±19.60	432.77±61.08	<0.001

Comparison of HbA1c according to CKD stages

The comparison of HbA1c levels across CKD stages is shown in the table. In Group A, the "mean HbA1c" was greater in Stage 5 CKD (9.14 ± 0.35%) compared to Stage 4 CKD (8.55 ± 0.38%); however, this variance was not statistically substantial (p = 0.074).

In Group B, HbA1c levels were slightly higher in Stage 4 CKD (7.70 ± 0.54%) compared to Stage 5 CKD (7.51 ± 0.85%), but the change was not statistically substantial (p = 0.435) (Table 9 and Figure 10).

Table 9. Comparison of HbA1c according to CKD stages

Groups	HbA1c(%)		P-value
	Stage 4 CKD	Stage 5 CKD	
A	8.55±0.38	9.14±0.35	0.074
B	7.70±0.54	7.51±0.85	0.435

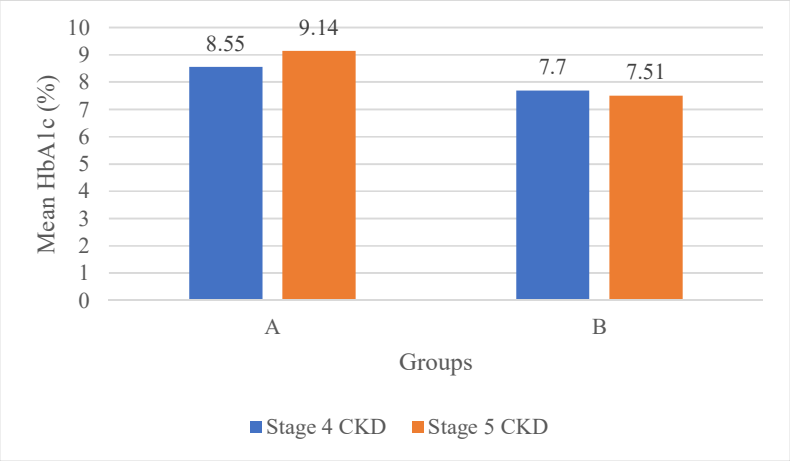

Figure 10. Comparison of HbA1c according to CKD stages

DISCUSSION

The assessment of glycemic control in patients with diabetes mellitus (DM) and chronic kidney disease (CKD), particularly those undergoing haemodialysis (HD), remains challenging. Although HbA1c is the standard marker of long-term glycemic control, its reliability in advanced CKD is affected by anemia, shortened erythrocyte lifespan, erythropoietin therapy, iron supplementation, and blood transfusions, which may falsely lower HbA1c values. Serum fructosamine (FA), reflecting glycemic control over the preceding 2–3 weeks through glycation of serum proteins, has emerged as a useful alternative marker. Therefore, the present study compared HbA1c and serum FA as indicators of glycemic control in diabetic CKD patients with and without HD.

The mean age of participants was 58.09 ± 8.98 years and the mean BMI was 25.18 ± 2.28 kg/m², indicating a predominantly middle-aged to elderly and overweight population. Advancing age and excess body weight are recognized risk factors for diabetic nephropathy and CKD progression. Males constituted 67.20% of the study population, suggesting a male predominance among diabetic CKD patients, possibly reflecting greater susceptibility to diabetic complications and dialysis dependency. [11,12]

Baseline haemoglobin, serum albumin, systolic blood pressure, and diastolic blood pressure were comparable between the two groups (p>0.05), minimizing their confounding effects on glycemic markers. However, eGFR was significantly lower in the HD group (10.39 ± 7.95 ml/min/1.73 m²) than in the non-HD group (16.76 ± 5.24 ml/min/1.73 m²; p<0.001), confirming more advanced renal dysfunction among dialysis patients. Similarly, Stage 5 CKD was significantly more common in the HD group (73%) than in the non-HD group (40.7%) (p=0.012), reflecting the expected progression of CKD. [10,13]

A major finding was the significant difference in glycemic markers between groups. HbA1c was significantly higher in the non-HD group (8.79 ± 0.72%) than in the HD group (7.56 ± 0.77%; p<0.001). This apparent improvement in glycemic control among dialysis patients is likely misleading, as HD-related factors such as shortened red cell survival, erythropoietin therapy, recurrent blood loss, and transfusions can produce falsely low HbA1c values. In contrast, serum FA was significantly higher in the HD group (380.62 ± 101.65 µmol/L) than in the non-HD group (281.80 ± 120.51 µmol/L; p<0.001), suggesting that FA may better reflect actual glycemic exposure in advanced CKD because it is independent of erythrocyte turnover.

Correlation analysis revealed poor agreement between HbA1c and FA in non-dialysis CKD patients (r = −0.089, p = 0.658). In HD patients, a weak but significant positive correlation was observed (r = 0.369, p = 0.024), indicating

modest concordance between the two markers. Nevertheless, factors such as nutritional status, protein metabolism, inflammation, and dialysis adequacy may continue to influence FA measurements. Serum FA also increased significantly with worsening renal function, with Stage 5 CKD patients showing markedly higher FA levels than Stage 4 patients (432.77 ± 61.08 vs. 239.80 ± 19.60 µmol/L; $p<0.001$), whereas HbA1c did not show consistent stage-wise variation. [9,15]

The findings of the present study are consistent with previous reports by Patel H and Anuradha N, Tuttle KR et al., Goyal J et al., Nathan DM et al., and other investigators who have highlighted the limitations of HbA1c in advanced CKD and HD populations and suggested a potential role for alternative glycemic markers such as fructosamine. These studies demonstrated that HbA1c may underestimate glycemic burden because of CKD-related alterations in erythrocyte turnover, whereas FA provides a more reliable assessment of short-term glycemic status in patients with renal dysfunction. [9,10,14,15]

Overall, the present study suggests that HbA1c may underestimate true glycemic status in diabetic patients undergoing HD, whereas serum FA appears more sensitive to changes in glycemic control and more closely associated with CKD severity. These findings support the use of FA as an adjunctive marker for glycemic monitoring in advanced CKD. Consistent with current recommendations, HbA1c should be interpreted cautiously in dialysis patients, and incorporation of serum FA into routine assessment may improve monitoring and clinical management of diabetic CKD patients receiving HD.

CONCLUSION

The present study indicate that serum FA is a valuable adjunctive marker for assessing glycemic control in diabetic patients with CKD, particularly those receiving HD. While HbA1c continues to provide useful information regarding long-term glycemic trends, its interpretation should be approached with caution in advanced CKD. The combined use of HbA1c and serum FA may offer a more comprehensive and accurate evaluation of glycemic status by providing information on both long-term and short-term glucose control. Such an integrated approach may facilitate better clinical decision-making, optimize therapeutic interventions, and improve overall diabetes management in patients with chronic kidney disease.

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