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Distinct Hemoglobin Trajectories and Their Prognostic Implications in Chronic Kidney Disease: Findings from the KNOW-CKD Cohort

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Objectives : Anemia is a common comorbidity in patients with chronic kidney disease (CKD) and has been associated with adverse kidney and cardiovascular outcomes. However, longitudinal patterns of hemoglobin (Hb) change and their prognostic implications remain unclear. We aimed to identify distinct Hb trajectories and evaluate their associations with clinical outcomes in CKD.
Methods : We analyzed 1,940 adults with CKD from a prospective cohort, applying group-based trajectory modeling (GBTM) to repeated Hb measurements. The primary endpoint was a composite kidney outcome (≥50% decline in eGFR, doubling of serum creatinine, initiation of dialysis, or kidney transplantation). Secondary endpoints were cardiovascular events and all-cause mortality.
Results : GBTM identified four distinct Hb trajectories: high, moderately high, intermediate, and low. Compared with the intermediate trajectory, the high group showed substantially lower risk of the composite kidney outcome (hazard ratio [HR] 0.210, 95% confidence interval [CI] 0.125–0.353), the moderately high group showed comparable risk (HR 0.766, 95% CI 0.555–1.058), and the low group had higher risk (HR 1.595, 95% CI 1.186–2.145). No significant associations were observed with cardiovascular events or all-cause mortality after full adjustment.
Conclusions : Distinct Hb trajectories were strongly associated with kidney outcomes in CKD. Sustained higher Hb trajectories conferred favorable renal prognosis, whereas persistently low trajectories predicted adverse outcomes. Beyond static Hb values, trajectory-based assessment may provide a novel framework for individualized risk stratification and anemia management in CKD.

Figure 1.jpg

Figure 1. Longitudinal hemoglobin trajectories

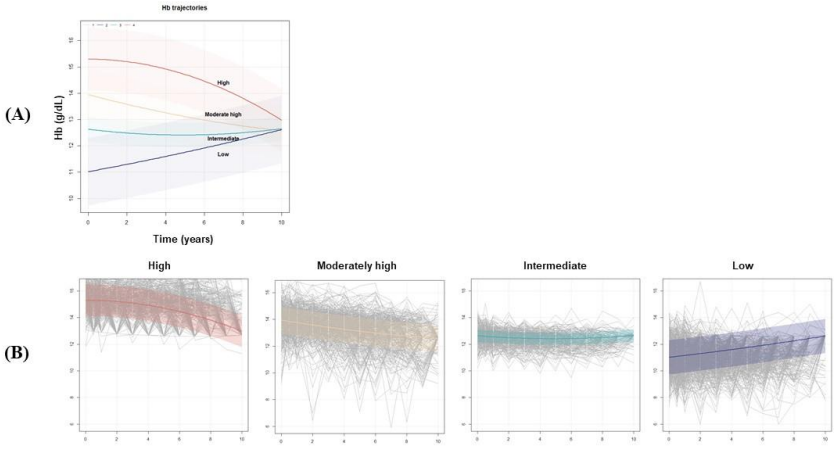

Figure 1.jpg

Table 2A. Risk of composite kidney outcome according to Hb trajectories

	Model 1		Model 2		Model 3		Model 4	
	HR (95% CI)	*P* value	HR (95% CI)	*P* value	HR (95% CI)	*P* value	HR (95% CI)	*P* value
High	0.215 (0.152–0.305)	<0.001	0.204 (0.142–0.295)	<0.001	0.207 (0.144–0.299)	<0.001	0.210 (0.125–0.353)	<0.001
Moderately high	0.775 (0.621–0.966)	0.024	0.704 (0.559–0.886)	0.003	0.710 (0.563–0.894)	0.004	0.766 (0.555–1.058)	0.106
Intermediate	Reference		Reference		Reference		Reference	
Low	2.872 (2.367–3.484)	<0.001	1.753 (1.436–2.140)	<0.001	1.889 (1.538–2.321)	<0.001	1.595 (1.186–2.145)	0.002

Model 1 is not adjusted for.
Model 2 is adjusted for age, sex, BMI, smoking history, eGFR, and comorbidities (hypertension, diabetes mellitus and cardiovascular disease).
Model 3 was adjusted for the variables in Model 2, and medications (renin-angiotensin-aldosterone system blocker, beta blocker, statin, diuretics, iron agent and ESA)
Model 4 was adjusted for the variables in Model 3, urine protein-creatinine ratio, albumin and cholesterol.

Table 2B. Group-specific risk of composite kidney outcome according to Hb trajectories

	Model 1		Model 2		Model 3		Model 4	
	HR (95% CI)	*P* value	HR (95% CI)	*P* value	HR (95% CI)	*P* value	HR (95% CI)	*P* value
High	0.150 (0.110–0.204)	<0.001	0.230 (0.166–0.318)	<0.001	0.231 (0.167–0.319)	<0.001	0.238 (0.151–0.375)	<0.001
Moderately high	0.594 (0.506–0.697)	<0.001	0.817 (0.691–0.967)	0.019	0.819 (0.692–0.971)	0.021	0.944 (0.748–1.191)	0.627
Intermediate	0.854 (0.710–1.028)	0.095	0.958 (0.758–1.211)	0.721	0.943 (0.778–1.141)	0.545	1.008 (0.767–1.323)	0.957
Low	4.479 (3.902–5.143)	<0.001	2.439 (2.061–2.887)	<0.001	2.632 (2.210–3.134)	<0.001	2.071 (1.613–2.659)	<0.001

Model 1 is not adjusted for.
Model 2 is adjusted for age, sex, BMI, smoking history, eGFR, and comorbidities (hypertension, diabetes mellitus and cardiovascular disease).
Model 3 was adjusted for the variables in Model 2, and medications (renin-angiotensin-aldosterone system blocker, beta blocker, statin, diuretics, iron agent and ESA)
Model 4 was adjusted for the variables in Model 3, urine protein-creatinine ratio, albumin and cholesterol.

Figure 2. Cumulative incidence of kidney outcome according to Hb trajectories