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Nonlinear Association and Variability of Hemoglobin as Predictors of Mortality in Home Health Care Patients: A Retrospective Cohort Study

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Abstract

Background

Patients receiving home health care services represent a vulnerable population with high morbidity and mortality risk. Although anemia has been associated with adverse outcomes, the prognostic role of longitudinal hemoglobin measurements and hemoglobin variability in home health care populations remains unclear. This study aimed to investigate the association between mean hemoglobin level, hemoglobin variability, and mortality in patients receiving home health care services.

Methods

This retrospective cohort study included patients newly enrolled in a home health care unit between January 2022 and December 2023. Patients with fewer than three hemoglobin measurements, those who died within the first three months, and those with missing records were excluded. Mean hemoglobin level and hemoglobin variability score were calculated using longitudinal measurements. One-year mortality was evaluated using Cox proportional hazards regression analysis. Nonlinear associations were assessed using piecewise modeling.

Results

A total of 410 patients were included in the final analysis, with 128 deaths during one-year follow-up. Mean hemoglobin level demonstrated a nonlinear association with mortality, with the lowest risk observed around 12.79 g/dL. Below this threshold, each one-unit decrease in mean hemoglobin level was associated with increased mortality (HR 1.72, 95% CI 1.48–1.99, $p < 0.001$). Above this threshold, each one-unit increase in mean hemoglobin level was also associated with increased mortality (HR 1.76, 95% CI 1.23–2.53, $p = 0.002$). Higher hemoglobin variability was independently associated with increased mortality (HR 1.71, 95% CI 1.32–2.22, $p < 0.001$).

Conclusions

Both low and high mean hemoglobin levels were associated with increased mortality, demonstrating a U-shaped relationship. Hemoglobin variability was also independently associated with mortality. These findings suggest that monitoring hemoglobin trends and variability may help identify high-risk patients receiving home health care services.

Background

Home health care services have become an increasingly important extension of primary care, particularly for frail, multimorbid, and functionally dependent individuals who experience difficulty

accessing conventional outpatient services. Homebound patients often have multiple chronic conditions, high symptom burden, and substantial functional impairment, requiring comprehensive and continuous care delivered outside traditional healthcare settings (1–3). These patients also demonstrate high healthcare utilization and mortality rates, highlighting the importance of identifying prognostic indicators in routine clinical practice (4, 5).

Anemia is highly prevalent in older and chronically ill patients receiving home-based care, with reported rates ranging from approximately 40% to over 60% among individuals receiving home health care services (6–8). Previous studies have demonstrated that anemia in older adults is associated with increased mortality, hospitalization, functional decline, and reduced quality of life (9, 10). In addition, hemoglobin levels may reflect overall physiological reserve, nutritional status, inflammatory burden, and chronic disease severity, all of which are particularly relevant in frail populations receiving home health care (11–14).

Beyond single measurements, recent research has emphasized the importance of variability in laboratory parameters as potential predictors of adverse outcomes. Hemoglobin variability has been associated with increased mortality in patients with chronic kidney disease and dialysis populations (15, 16). Similarly, hemoglobin fluctuations have been linked to poor outcomes in patients with cardiovascular disease and other chronic conditions (17). These findings suggest that hemoglobin variability may reflect clinical instability, inflammation, disease progression, or changes in treatment intensity. However, despite growing interest in hemoglobin variability, its prognostic value has not been adequately investigated in patients receiving home health care services.

Furthermore, the relationship between hemoglobin levels and mortality may not be strictly linear. Several studies have demonstrated a U-shaped association between hemoglobin concentration and mortality risk, with both low and high hemoglobin levels associated with increased mortality (9, 18, 19). Low hemoglobin levels may indicate anemia and reduced physiological reserve, whereas elevated hemoglobin levels may reflect dehydration, chronic hypoxia, or underlying comorbid conditions. This nonlinear relationship may be particularly relevant in frail populations receiving home health care services.

Despite the increasing number of patients receiving home health care services, data regarding the prognostic significance of hemoglobin levels and hemoglobin variability in this population remain limited. Identifying simple and routinely available predictors of mortality may help clinicians improve risk stratification and optimize follow-up strategies in home health care settings.

Therefore, this study aimed to investigate the association between mean hemoglobin levels, hemoglobin variability, and one-year mortality in patients receiving home health care services. Additionally, we evaluated whether the relationship between mean hemoglobin levels and mortality demonstrated a nonlinear (U-shaped) pattern and assessed the independent predictive value of hemoglobin variability.

Methods

Study Design and Setting

This single-center retrospective cohort study was conducted at the Home Health Care Unit of Kanuni Training and Research Hospital, Trabzon, Türkiye. The unit provides home-based medical care to more than 1,000 registered patients. Three multidisciplinary teams, each consisting of a physician, nurse, healthcare assistant, and driver, conduct approximately 750 home visits to around 250 patients monthly. These visits include both evaluation of newly referred patients and follow-up of previously registered individuals.

Patients included in this study were those who were newly enrolled in the home health care service between January 1, 2022, and December 31, 2023. Data collection and analysis were performed between October and November 2025.

The study was approved by the Trabzon University Faculty of Medicine Non-Interventional Scientific Research Ethics Committee (approval number: 2025/25002, date: 06 October 2025). Due to the retrospective nature of the study, the requirement for informed consent was waived by the Trabzon University Faculty of Medicine Non-Interventional Scientific Research Ethics Committee. Throughout all stages of this research, the Helsinki Declaration and the principles of Good Clinical Practice were adhered to.

Participants

The study population consisted of patients who received home health care services for the first time between January 1, 2022, and December 31, 2023. No formal sample size calculation was performed, and all eligible patients meeting inclusion criteria were included.

Patients were included if they: received home health care services for the first time during the study period, were followed for at least one year or until death, had at least three hemoglobin measurements during the follow-up period. Patients were excluded if they: died due to acute bleeding, died within the first three months after enrollment, had missing medical records or unavailable comorbidity data. The exclusion of patients with fewer than three hemoglobin measurements and those who died within the first three months was necessary to allow assessment of longitudinal hemoglobin variability; however, this approach may have preferentially excluded patients with rapidly progressive disease or early mortality. Patient selection and exclusion process are presented in the study flow diagram (Fig. 1).

Data Collection and Variables

Patient data were obtained retrospectively from the hospital information management system. Patients were evaluated chronologically, and data from the date of enrollment into home health care services were collected.

The following variables were recorded: Age, sex, comorbidities, functional dependency status, nutritional status, use of enteral nutrition, anemia treatment during follow-up, red blood cell transfusion, hemoglobin measurements. Comorbid conditions included hypertension, diabetes mellitus, cerebrovascular disease, dementia, chronic kidney disease, malignancy, chronic obstructive pulmonary disease, heart failure, and other chronic diseases documented in patient records.

Hemoglobin Measurements

Hemoglobin values measured during follow-up were recorded along with their dates. If two or more hemoglobin measurements were obtained within the same month, their average value was calculated to avoid disproportionate weighting of closely spaced measurements. The following hemoglobin-related variables were defined: first measured hemoglobin value, mean hemoglobin level during follow-up, lowest hemoglobin level, highest hemoglobin level, hemoglobin variability score. The hemoglobin variability score was calculated as the mean absolute difference between consecutive hemoglobin measurements. Hemoglobin values were analyzed as continuous variables without predefined cut-off points to evaluate the effect of unit-level changes on mortality risk.

Outcomes

The primary outcome was all-cause mortality within one year after enrollment in home health care services. For time-to-event analysis: event time was defined as the month of death for deceased patients, patients who survived were censored at 12 months.

Statistical Analysis

Statistical analyses were performed using SPSS version 23.0 (IBM Corp., Armonk, NY, USA). Descriptive statistics were calculated for all variables. Continuous variables were expressed as mean ± standard deviation or median [interquartile range], depending on distribution. Categorical variables were presented as numbers and percentages.

Group comparisons were performed using: independent samples t-test, Mann–Whitney U test, Chi-square test. Univariable Cox proportional hazards regression analyses were performed to evaluate the association between independent variables and mortality. Multivariable Cox regression analyses were performed using the backward likelihood ratio method to identify independent predictors of mortality while minimizing overfitting and controlling for potential confounders. Variables with $p \leq 0.20$ in univariable analyses were entered into the multivariable model.

To assess potential nonlinear associations between hemoglobin levels and mortality, quadratic terms (hemoglobin²) were added to the models. When both linear and quadratic terms were statistically significant, the turning point of the curve was calculated using the formula: $-\beta_1 / (2 \times \beta_2)$. Piecewise Cox

regression models were subsequently constructed using the calculated turning point to evaluate the effect of hemoglobin levels below and above this threshold separately.

Hazard ratios (HRs) with 95% confidence intervals (CIs) were reported. A two-sided p-value < 0.05 was considered statistically significant.

Use of Artificial Intelligence

Artificial intelligence–based tools were used for language editing and stylistic refinement of the manuscript. The AI tool (ChatGPT, OpenAI) was used to improve clarity, grammar, and academic tone of the text written by the authors. No AI tools were used in study design, data collection, statistical analysis, data interpretation, or figure generation. All analyses and interpretations were conducted by the authors, who take full responsibility for the content of the manuscript.

Results

Patient Selection

Between January 1, 2022 and December 31, 2023, a total of 1,118 patients were visited by the home health care unit. Of these, 368 patients had previously received home health care services and were excluded. The remaining 750 patients who were newly enrolled during the study period were evaluated for eligibility.

Among these patients, 231 died within one year and 519 survived. Sixty-three patients who died within the first three months of follow-up were excluded. Additionally, 37 patients in the deceased group and 215 patients in the survivor group were excluded due to the absence of at least three hemoglobin measurements during follow-up. Furthermore, three patients in the deceased group and 22 patients in the survivor group were excluded due to missing clinical data.

After applying exclusion criteria, a total of 410 patients were included in the final analysis, including 128 patients in the deceased group and 282 patients in the survivor group. The study flow diagram is presented in Fig. 1.

A total of 1,118 patients were visited by the home health care unit during the study period. After excluding 368 previously visited patients, 750 newly assessed patients were evaluated. Among these, 231 patients died during follow-up and 519 were alive at one year. Patients who died within the first three months, those with fewer than three hemoglobin measurements, and those with missing medical records were excluded. The final study population consisted of 410 patients, including 128 deceased and 282 surviving patients.

Clinical Characteristics of the Study Population

The median age of the study population was 81 years [interquartile range: 15], and 268 patients (65.4%) were female. More than half of the patients (52.9%) were fully dependent, and 34.1% were receiving enteral nutrition. PEG feeding or nasogastric tube use was present in 12.2% of patients.

Hypertension was the most common comorbidity, present in 67.6% of patients, followed by diabetes mellitus (32.9%), dementia (32.2%), and cerebrovascular disease (24.6%). Malignancy was present in 12.0% of patients.

During follow-up, the median number of hemoglobin measurements was 4 [2]. The mean first hemoglobin level was 11.53 ± 1.85 g/dL, and the mean hemoglobin level during follow-up was 11.35 ± 1.72 g/dL. The mean lowest hemoglobin value was 10.24 ± 1.95 g/dL, and the mean highest hemoglobin value was 12.42 ± 1.77 g/dL. The median hemoglobin variability score was 1.9 [1.7].

Oral iron therapy was used in 16.6% of patients, while red blood cell transfusion was administered to 21.7% of patients. Detailed clinical characteristics of the study population are presented in Table 1.

Table 1
Characteristics of the study population and hemoglobin-related follow-up measures

Age	**Overall (n = 410)**
	81 [15]
Male sex	142 (34.6)
Fully dependent	217 (52.9)
Nutritional Status	
Percutaneous endoscopic gastrostomy feeding	24 (5.9)
Nasogastric tube	26 (6.3)
Enteral nutrition solution use	140 (34.1)
Comorbidities	
Hypertension	277 (67.6)
Diabetes mellitus	135 (32.9)
Thyroid disease	37 (9.0)
Hyperlipidemia	37 (9.0)
Dementia	132 (32.2)
Cerebrovascular disease	101 (24.6)
Epilepsy	16 (3.9)
Asthma / Chronic obstructive pulmonary disease	74 (18.0)
Pulmonary embolism	15 (3.7)
Chronic kidney disease	42 (10.2)
Coronary artery disease	62 (15.1)
Heart failure	61 (14.9)
Atrial fibrillation	59 (14.4)
Malignancy	49 (12.0)
Psychiatric disease	19 (4.6)
Hemoglobin-related characteristics	
Total hemoglobin measurements	4 [2]
First hemoglobin	11.53 ± 1.85
Lowest hemoglobin	10.24 ± 1.95

Age	Overall (n = 410)
	81 [15]
Highest hemoglobin	12.42 ± 1.77
Mean hemoglobin	11.35 ± 1.72
Hemoglobin variability score	1.9 [1.7]
Anemia-related treatment	
Oral iron therapy	68 (16.6)
Red blood cell transfusion	89 (21.7)
Values are presented as mean ± standard deviation, median [interquartile range], or number (percentage) as appropriate.	

Univariable Cox Regression Analysis

Univariable Cox regression analyses showed that older age (HR 1.02, 95% CI 1.01–1.04, p = 0.003), male sex (HR 1.44, 95% CI 1.01–2.04, p = 0.043), full dependency (HR 2.54, 95% CI 1.73–3.73, p < 0.001), and enteral nutrition use (HR 1.93, 95% CI 1.36–2.73, p < 0.001) were associated with increased mortality.

Among comorbidities, hypertension (HR 0.56, 95% CI 0.39–0.79, p = 0.001) and hyperlipidemia (HR 0.36, 95% CI 0.15–0.89, p = 0.027) were associated with lower mortality risk, whereas malignancy was associated with increased mortality (HR 1.98, 95% CI 1.28–3.06, p = 0.002).

Regarding hemoglobin-related variables, lower first hemoglobin level, lower minimum hemoglobin level, lower maximum hemoglobin level, and lower mean hemoglobin level were all associated with increased mortality risk. Additionally, higher hemoglobin variability score (HR 1.23, 95% CI 1.12–1.37, p < 0.001) and red blood cell transfusion (HR 3.87, 95% CI 2.73–5.48, p < 0.001) were significantly associated with increased mortality. The results of univariable Cox regression analyses are presented in Table 2.

Table 2
Univariable Cox regression analyses for one-year mortality

Variable	HR	95% CI	p-value
Age	1.02	1.01–1.04	0.003
Male sex	1.44	1.01–2.04	0.043
Fully dependent	2.54	1.73–3.73	< 0.001
Nutritional Status			
Percutaneous endoscopic gastrostomy feeding	1.46	0.77–2.79	0.248
Nasogastric tube	1.46	0.79–2.70	0.233
Enteral nutrition solution use	1.93	1.36–2.73	< 0.001
Comorbidities			
Hypertension	0.56	0.39–0.79	0.001
Diabetes mellitus	0.82	0.56–1.20	0.316
Thyroid disease	0.55	0.26–1.17	0.121
Hyperlipidemia	0.36	0.15–0.89	0.027
Dementia	0.99	0.68–1.44	0.960
Cerebrovascular disease	0.67	0.43–1.05	0.078
Epilepsy	0.34	0.08–1.37	0.128
Asthma / Chronic obstructive pulmonary disease	1.32	0.87–2.00	0.200
Pulmonary embolism	1.70	0.79–3.63	0.175
Chronic kidney disease	0.62	0.31–1.21	0.160
Coronary artery disease	1.18	0.75–1.87	0.473
Heart failure	1.32	0.84–2.07	0.230
Atrial fibrillation	0.96	0.58–1.58	0.878
Malignancy	1.98	1.28–3.06	0.002
Psychiatric disease	0.46	0.15–1.45	0.185
Hemoglobin-related characteristics			
First hemoglobin	0.90	0.82–0.99	0.025
Lowest hemoglobin	0.70	0.63–0.77	< 0.001
Highest hemoglobin	0.77	0.69–0.86	< 0.001

Variable	HR	95% CI	p-value
Mean hemoglobin	0.66	0.59–0.75	< 0.001
Hemoglobin variability score	1.23	1.12–1.37	< 0.001
Anemia-related treatment			
Oral iron therapy	0.83	0.51–1.37	0.475
Red blood cell transfusion	3.87	2.73–5.48	< 0.001

Hemoglobin variability score was calculated as the mean absolute difference between consecutive hemoglobin measurements.

HR: Hazard ratio, CI: Confidence interval

Multivariable Cox Regression Analysis

In multivariable Cox regression analyses, first hemoglobin level was not independently associated with mortality after adjustment for potential confounders (Supplementary Table 1). When mean hemoglobin level and its quadratic term were included in the model, both variables remained significantly associated with mortality, indicating a nonlinear association between mean hemoglobin level and mortality (Supplementary Table 2). After further adjustment for hemoglobin variability, both the nonlinear association and hemoglobin variability remained independently associated with mortality (Supplementary Table 3).

The calculated turning point for mean hemoglobin level was 12.79 g/dL. Below this threshold, each one-unit decrease in mean hemoglobin level was associated with increased mortality (HR 1.72, 95% CI 1.48–1.99, $p < 0.001$). Similarly, above this threshold, each one-unit increase in mean hemoglobin level was associated with increased mortality risk (HR 1.76, 95% CI 1.23–2.53, $p = 0.002$). Additionally, higher hemoglobin variability score remained independently associated with increased mortality (HR 1.71, 95% CI 1.32–2.22, $p < 0.001$). The final multivariable model is presented in Table 3, while the detailed modeling steps are provided in Supplementary Table 4.

Table 3
Final multivariable Cox regression model for one-year mortality

Variable	B	SE	Wald	p	HR	95% CI
Mean hemoglobin, per 1 g/dL lower value below 12.79 g/dL	0.540	0.075	51.290	< 0.001	1.72	1.48–1.99
Mean hemoglobin, per 1 g/dL higher value above 12.79 g/dL	0.567	0.185	9.361	0.002	1.76	1.23–2.53
Hemoglobin variability score	0.537	0.133	16.372	< 0.001	1.71	1.32–2.22

Adjusted for age, full dependency, hypertension, thyroid disease, asthma/chronic obstructive pulmonary disease, chronic kidney disease, and malignancy.

Multivariable Cox proportional hazards regression analysis was performed using the backward likelihood ratio method. The turning point for mean hemoglobin was calculated from the quadratic model and estimated as 12.79 g/dL.

Nonlinear Association Between Hemoglobin and Mortality

The nonlinear relationship between mean hemoglobin level and mortality demonstrated a U-shaped pattern. Mortality risk was lowest around the mid-range hemoglobin values and increased at both lower and higher hemoglobin levels. This association is illustrated in Fig. 2A.

Hemoglobin Variability and Mortality

Higher hemoglobin variability was associated with increased mortality risk independent of mean hemoglobin level and other confounding variables. The relationship between hemoglobin variability score and mortality is shown in Fig. 2B.

(A) Non-linear association between mean hemoglobin level and mortality risk. The hazard ratio reached its lowest value around 12.79 g/dL, demonstrating a U-shaped relationship between mean hemoglobin level and mortality. (B) Association between hemoglobin variability score and mortality risk. Increasing hemoglobin variability was associated with progressively higher mortality risk. HR: Hazard ratio. Hemoglobin variability score was defined as the mean absolute difference between consecutive hemoglobin measurements. Predicted hazard ratios were calculated using regression coefficients from the final multivariable Cox model while holding other covariates at their mean values

Discussion

In this study of patients receiving home health care services, we found that mean hemoglobin levels demonstrated a nonlinear association with mortality, with the lowest risk observed around 12.79 g/dL. Both lower and higher mean hemoglobin levels were independently associated with increased mortality risk. In addition, hemoglobin variability during follow-up was independently associated with mortality, regardless of mean hemoglobin level and other clinical factors. These findings suggest that not only

anemia but also elevated hemoglobin levels and fluctuations in hemoglobin may serve as important prognostic indicators in home health care populations.

Previous studies have consistently demonstrated an association between anemia and mortality in older populations. In a large cohort study including 8,935 community-dwelling older adults in Thailand, anemia was associated with increased mortality (20). Similarly, Simsek Yurt and Yavuz reported that anemia was independently associated with hospitalization and mortality in 341 patients receiving home health care services in Türkiye (21). These findings support the prognostic importance of hemoglobin levels in vulnerable populations.

Additional studies in older adults have also reported similar findings. In cohort studies including centenarians, hospitalized older adults, and community-dwelling elderly individuals, anemia was consistently associated with increased mortality risk (10, 22, 23). Furthermore, Riva et al. demonstrated that even mild anemia was independently associated with hospitalization and mortality in a cohort of approximately 10,000 individuals aged 65–84 years (24). These findings suggest that even modest decreases in hemoglobin levels may have clinically meaningful prognostic implications.

Consistent with previous literature, we observed that lower hemoglobin levels were associated with increased mortality. Several physiological mechanisms may explain this association. Reduced hemoglobin levels impair oxygen delivery to tissues, leading to tissue hypoxia, particularly in organs with high metabolic demand such as the heart, brain, and kidneys (25). In older adults with reduced physiological reserve, compensatory mechanisms such as increased cardiac output may be insufficient, increasing the risk of heart failure, ischemia, and arrhythmias.

Anemia may also contribute to mortality through inflammatory and oxidative mechanisms. Chronic hypoxia may increase oxidative stress and endothelial dysfunction, accelerating atherosclerosis (26). Additionally, inflammatory cytokines such as IL-6 and TNF-α may suppress erythropoiesis and increase systemic inflammatory burden (27). These mechanisms may contribute to functional decline and increased mortality in home health care populations.

Importantly, our study demonstrated a U-shaped relationship between hemoglobin levels and mortality. Similar nonlinear associations have been reported in previous studies. Zakai et al. and Culleton et al. demonstrated that both low and high hemoglobin levels were associated with increased mortality in older adults (9, 18). Consistent with these findings, we identified a turning point at 12.79 g/dL, with increased mortality observed at both lower and higher hemoglobin levels.

Several mechanisms may explain the association between elevated hemoglobin levels and mortality. Increased hemoglobin levels may lead to increased blood viscosity, impaired microcirculation, and increased thrombotic risk (28). Additionally, hemoconcentration due to dehydration may transiently increase hemoglobin levels and reflect acute clinical deterioration (29). Elevated hemoglobin levels may also indicate underlying conditions such as chronic hypoxia, malignancy, or inappropriate erythropoietin use (30).

Another important finding of our study was the independent association between hemoglobin variability and mortality. Previous studies have demonstrated similar findings. In a large Korean cohort including 182,757 individuals, higher hemoglobin variability was associated with increased mortality (31). A meta-analysis of hemodialysis patients also demonstrated that hemoglobin variability was associated with increased mortality risk (32).

Hemoglobin variability may reflect clinical instability, fluctuating inflammatory status, or disease progression. Inflammatory activity, anemia duration, and comorbid conditions have been identified as major determinants of hemoglobin variability, and greater fluctuations have been associated with adverse clinical outcomes (33, 34). Repeated fluctuations in oxygen delivery may increase myocardial workload, contribute to ventricular remodeling, and elevate cardiovascular risk. Indeed, previous studies have demonstrated associations between hemoglobin variability and left ventricular hypertrophy, impaired cardiac function, and increased cardiovascular mortality (35, 36). Furthermore, hemoglobin variability may also reflect autonomic dysfunction and impaired physiological reserve, as hemoglobin levels have been linked to reduced heart rate variability and diminished physiological resilience in chronically ill populations (37).

Strengths and Limitations

This study has several strengths. First, to our knowledge, this is one of the few studies evaluating the prognostic significance of longitudinal hemoglobin measurements in patients receiving home health care services. Unlike previous studies that relied primarily on baseline hemoglobin values, we evaluated multiple hemoglobin-related parameters, including mean hemoglobin, minimum and maximum values, and hemoglobin variability. This approach allowed a more comprehensive assessment of hemoglobin dynamics over time.

Second, repeated hemoglobin measurements were summarized using monthly averages to minimize the influence of short-term fluctuations and measurement noise. This methodological approach enabled a more reliable representation of longitudinal hemoglobin trends and strengthened the validity of the observed associations.

Third, our study included a relatively homogeneous and clinically relevant population of patients receiving home health care services, representing a vulnerable group with high morbidity and mortality risk.

Finally, the use of nonlinear modeling and hemoglobin variability analysis provided additional insights beyond conventional anemia classification, revealing a U-shaped relationship between hemoglobin levels and mortality and identifying hemoglobin stability as an independent prognostic factor.

This study also has several limitations. First, the retrospective design limits causal inference, and unmeasured confounding factors may have influenced the results. Prospective studies with standardized measurement intervals would help validate these findings.

Second, the study was conducted in a single center, which may limit generalizability to other populations with different demographic characteristics, care models, or healthcare systems.

Importantly, our inclusion criteria required at least three hemoglobin measurements and excluded patients who died within the first three months of follow-up. While this approach was necessary to reliably assess longitudinal hemoglobin variability, it may have introduced selection bias by preferentially excluding patients with the most severe clinical conditions or rapidly progressive disease. As a result, the study population may represent relatively more stable patients who survived long enough to undergo repeated laboratory assessments. Therefore, the observed associations between hemoglobin parameters and mortality should be interpreted in the context of this potential survivor bias and may not be fully generalizable to patients with very early mortality or extreme clinical instability.

Finally, clinical conditions at the time of hemoglobin measurements could not be fully assessed due to the retrospective nature of the study. Acute illnesses, dehydration, infections, or treatment changes may have influenced hemoglobin levels and contributed to variability.

Conclusions

In patients receiving home health care services, both low and high mean hemoglobin levels were independently associated with increased mortality, demonstrating a U-shaped relationship. The lowest mortality risk was observed around a mean hemoglobin level of 12.79 g/dL. Additionally, hemoglobin variability during follow-up was independently associated with increased mortality, regardless of mean hemoglobin level and other clinical factors.

These findings suggest that hemoglobin stability, in addition to absolute hemoglobin levels, may serve as an important prognostic indicator in home health care populations. Regular monitoring of hemoglobin trends and early identification of significant fluctuations may help clinicians identify high-risk patients and optimize follow-up strategies.

Future prospective studies are needed to confirm these findings and to determine whether targeted interventions aimed at maintaining optimal hemoglobin levels and reducing variability may improve clinical outcomes in patients receiving home health care services.

Declarations

Conflict of Interest:

The authors declare no conflict of interest.

Ethics approval and consent to participate

The study was approved by the Trabzon University Faculty of Medicine Non-Interventional Scientific Research Ethics Committee (approval number: 2025/25002, date: 06 October 2025). Due to the retrospective nature of the study, the requirement for informed consent was waived by the Trabzon University Faculty of Medicine Non-Interventional Scientific Research Ethics Committee. Throughout all stages of this research, the Helsinki Declaration and the principles of Good Clinical Practice were adhered to.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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Author Contribution

M.G. conceptualized the study, collected the data, and drafted the initial manuscript. C.Y. contributed to the study design, performed the statistical analyses, interpreted the data, and critically revised the manuscript. M.V. contributed to the study design, supervised the research process, and critically revised the manuscript. All authors read and approved the final manuscript.

Acknowledgement

Not applicable

Data Availability

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

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Figures

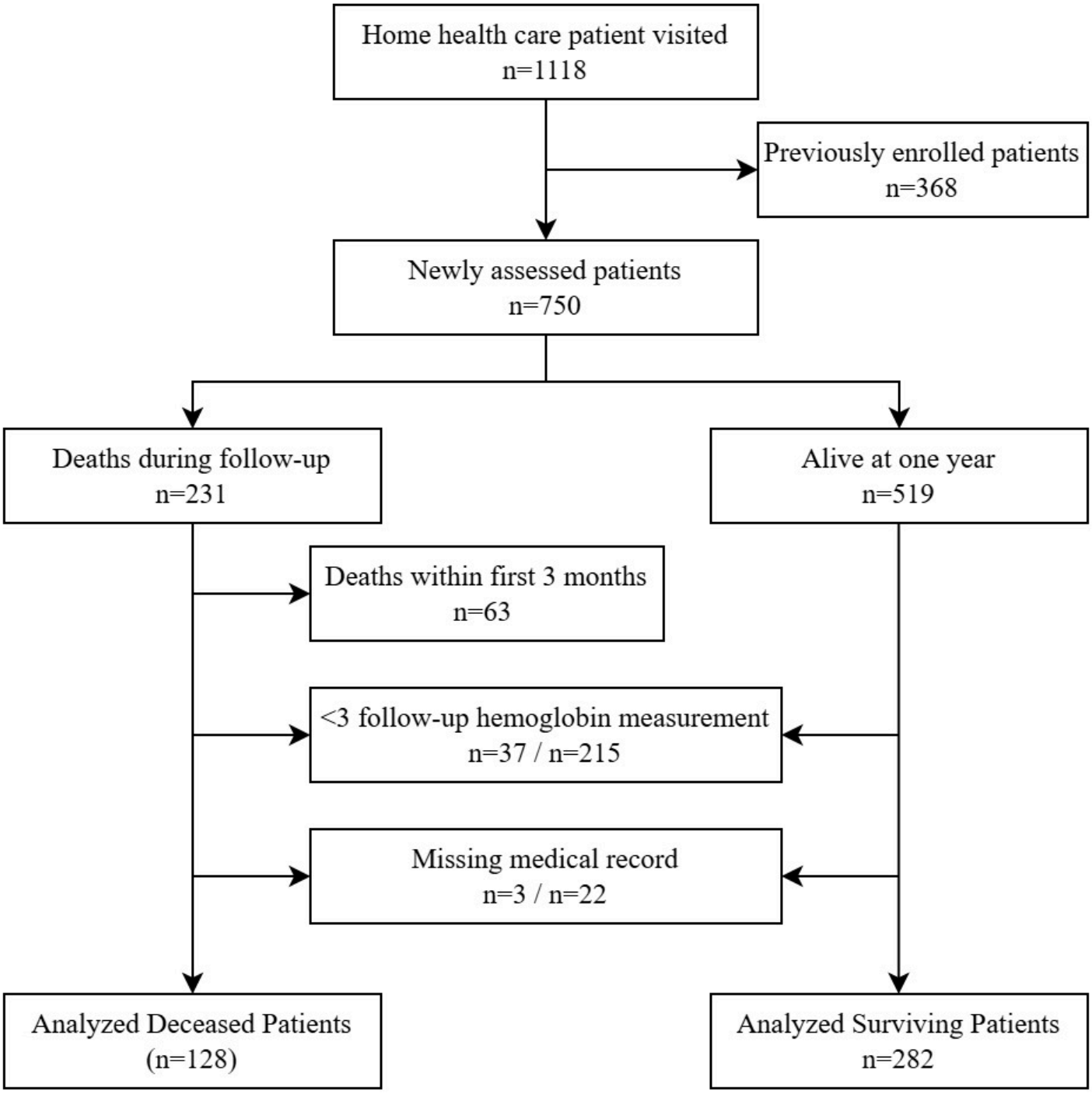


Figure 1

Flow diagram of patient selection and study population.

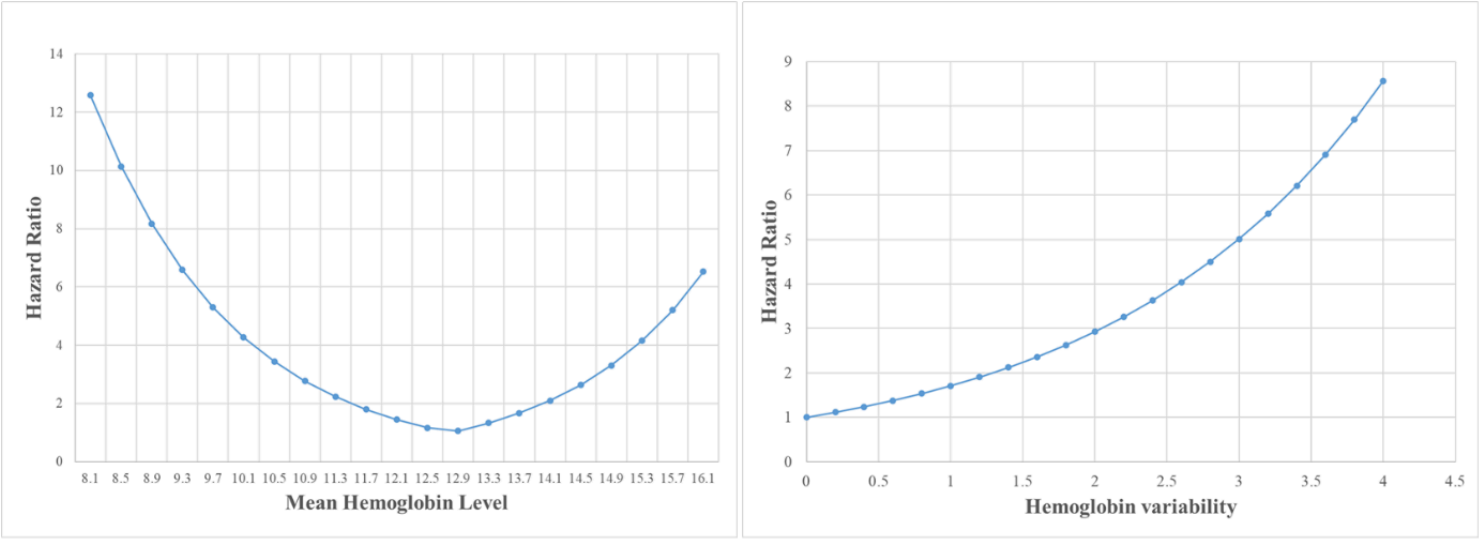


Figure 2

Association of mean hemoglobin level and hemoglobin variability with mortality.

(A) Non-linear association between mean hemoglobin level and mortality risk. The hazard ratio reached its lowest value around 12.79 g/dL, demonstrating a U-shaped relationship between mean hemoglobin level and mortality. (B) Association between hemoglobin variability score and mortality risk. Increasing hemoglobin variability was associated with progressively higher mortality risk. HR: Hazard ratio. Hemoglobin variability score was defined as the mean absolute difference between consecutive hemoglobin measurements. Predicted hazard ratios were calculated using regression coefficients from the final multivariable Cox model while holding other covariates at their mean values

Supplementary Files

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- SupplementaryTables.docx