Research Square

Preprints are preliminary reports that have not undergone peer review.
They should not be considered conclusive, used to inform clinical practice,
or referenced by the media as validated information.

Early Admission HALP Score and Mortality Risk in ICU Patients with Acute Aortic Dissection: A Retrospective Cohort Study Based on the MIMIC-IV Database

Le Li
Dongzhimen Hospital Affiliated to Beijing University of Chinese Medicine
yaqing Li
Liyong Ma
maliyong@163.com

Dongzhimen Hospital Affiliated to Beijing University of Chinese Medicine

Research Article

Keywords: acute aortic dissection, HALP score, MIMIC-IV, prognosis, in-hospital mortality, retrospective cohort study

Posted Date: September 4th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-10466932/v1

License: This work is licensed under a Creative Commons Attribution 4.0 International License.
Read Full License

Additional Declarations: No competing interests reported.

Early Admission HALP Score and Mortality Risk in ICU Patients with Acute Aortic Dissection: A Retrospective Cohort Study Based on the MIMIC-IV Database

Le Li1,yaqing Li2,Liyong Ma1*

1 Department of Cardiovascular Medicine , Dongzhimen Hospital , Beijing University of Chinese Medicine , Beijing,China.2 Zhangye People's Hospital Affiliated to Hexi University.*Corresponding author.

These authors contributed equally to this work .

Abstract

Objective: To evaluate the association between the early admission hemoglobin, albumin, lymphocyte and platelet (HALP) score and in-hospital, 30-day, and 90-day mortality among patients with acute aortic dissection (AAD) admitted to the intensive care unit (ICU).

Methods: This retrospective cohort study was conducted using the MIMIC-IV database and included adult patients with a diagnosis of AAD during their first ICU admission. HALP was calculated from the first available laboratory results within 24 hours after ICU admission. The primary outcome was in-hospital all-cause mortality, and the secondary outcomes were 30-day and 90-day all-cause mortality. Multivariable logistic regression was used to assess the associations between HALP quartiles and mortality outcomes. Restricted cubic splines, Kaplan-Meier curves, receiver operating characteristic (ROC) curves, subgroup analyses, and propensity score matching were used as supplementary analyses.

Results: A total of 271 patients were included, of whom 38 (14.0%) died during hospitalization. Compared with HALP Q1, HALP Q4 was associated with a higher risk of in-hospital mortality (OR=5.404, 95% CI: 1.860-15.705, P=0.002) and 30-day mortality (OR=6.413, 95% CI: 1.999-20.579, P=0.002) in the fully adjusted model. In the analysis of 90-day mortality, both HALP Q3 (OR=3.326, 95% CI: 1.416-7.814, P=0.006) and Q4 (OR=3.115, 95% CI: 1.307-7.424, P=0.010) were associated with a higher mortality risk. ROC analysis showed limited to moderate discrimination for mortality outcomes, with AUC values ranging from 0.61 to 0.68.

Conclusion: In the MIMIC-IV database, higher early admission HALP levels were associated with increased in-hospital and short- to mid-term mortality among ICU-treated patients with AAD.

Keywords: acute aortic dissection; HALP score; MIMIC-IV; prognosis; in-hospital mortality; retrospective cohort study

Introduction

Acute aortic dissection (AAD) is a cardiovascular emergency associated with a high risk of death and is often accompanied by hemodynamic instability, organ hypoperfusion, and multiorgan dysfunction. Despite continuing advances in imaging diagnosis, open surgery, endovascular repair, and intensive care, patients with AAD who require ICU treatment remain at substantial risk of early death. Therefore, identifying simple, reproducible prognostic indicators that are available early after admission is important for clinical risk stratification and resource allocation.

The onset and clinical progression of AAD are related not only to structural disruption of the aortic wall, blood pressure fluctuation, and hemodynamic abnormalities, but also to systemic inflammation, nutritional status, immune function, and activation of the coagulation system. The HALP score integrates four routine laboratory indicators, hemoglobin, albumin, lymphocyte count, and platelet count, and may reflect the patient's early physiological reserve across several dimensions, including oxygen-carrying capacity, nutritional and inflammatory status, immune response, and hematologic status.

Previous studies have suggested that the HALP score is associated with prognosis in critically ill patients and in patients with cardiovascular disease or malignant tumors. However, targeted evidence on the prognostic value of HALP in ICU patients with AAD remains limited, particularly regarding its association with in-hospital and short- to mid-term mortality. Therefore, using the MIMIC-IV database, this study evaluated the association between early admission HALP and in-hospital, 30-day, and 90-day all-cause mortality among ICU patients with AAD and tested the robustness of the findings through several sensitivity and supplementary analyses.

Study Objectives

1. To describe baseline characteristics and outcome distributions among patients with different in-hospital outcomes and across HALP quartile groups.

2. To construct crude, demographically adjusted, and fully adjusted multivariable logistic regression models to evaluate whether HALP is an independent risk factor for the primary outcome (in-hospital all-cause mortality) and the secondary outcomes (30-day and 90-day all-cause mortality).

3. To use restricted cubic spline analysis to explore the dose-response relationship between HALP as a continuous variable and mortality outcomes, assess potential nonlinear trends, and identify possible thresholds.

4. To evaluate the robustness of the association between HALP and in-hospital mortality using propensity score matching and post-matching logistic regression sensitivity analysis.

5. To perform subgroup analyses and interaction tests to examine whether the association between HALP and mortality outcomes is consistent across subgroups defined by demographic characteristics and comorbidities.

Methods

1. Data Source and Study Population

MIMIC-IV is a publicly available, de-identified critical care database that contains demographic information, diagnostic codes, vital signs, laboratory tests, treatment processes, and outcome data. This study used a retrospective cohort design and was reported with reference to the STROBE guidelines for study population selection, variable definitions, statistical analysis, and study limitations. All protected health information was de-identified in accordance with the Health Insurance Portability and Accountability Act (HIPAA), allowing secondary analysis without individual informed consent. The unified data architecture of MIMIC-IV supports real-time monitoring, treatment decision-making, and long-term outcome research. Patients were screened from the MIMIC-IV database according to the following inclusion and exclusion criteria (Figure 1):

The study population comprised patients in the MIMIC-IV database who were aged 18 years or older, had a first ICU admission, and were diagnosed with AAD. AAD cases were identified using ICD-9 and ICD-10 diagnostic codes. ICD-9 codes included 441.00, 441.01, 441.02, 441.03, and 4410%-related codes. ICD-10 codes included I71.00 (aortic dissection, unspecified site, without rupture), I71.01 (thoracic aortic dissection), I71.02 (abdominal aortic dissection), and I71.03 (thoracoabdominal aortic dissection).

Exclusion criteria were as follows: (1) repeated ICU admission records, with only the first ICU admission retained; (2) ICU length of stay <24 hours; and (3) death within 24 hours after admission.

Because HALP was calculated from laboratory measurements obtained within 24 hours after ICU admission, excluding patients who died early may have introduced selection bias. This issue is addressed further in the Discussion.

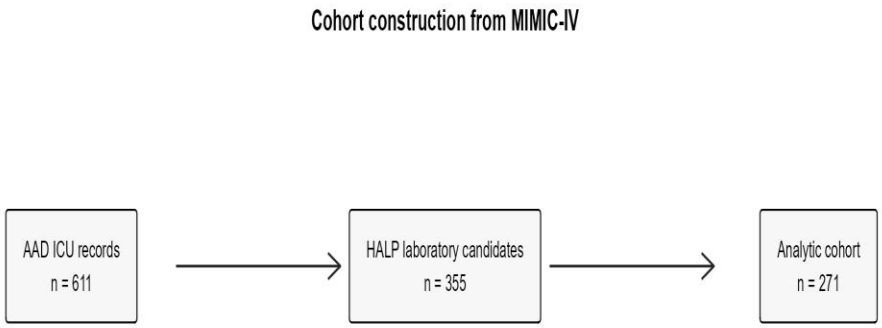


Figure 1. Cohort construction from the MIMIC-IV database.

2. Variable Definitions

Exposure variable:

Hemoglobin, Albumin, Lymphocyte and Platelet (HALP) score

The HALP score is a composite prognostic indicator that integrates nutritional, inflammatory, and immune status. It is calculated from four routine laboratory parameters: serum hemoglobin, serum albumin, peripheral blood lymphocyte count, and peripheral blood platelet count [PMID: 42116337]. Patients with acute aortic dissection often have acute stress, inflammatory activation, impaired nutritional status, and hematologic changes, all of which are closely related to adverse prognosis. Given the limited evidence on HALP in ICU patients with AAD, this study used HALP as the primary exposure variable and analyzed it both by quartiles and as a continuous variable.

HALP = hemoglobin (g/dL) x albumin (g/dL) x lymphocyte count (10^9/L) / platelet count (10^9/L). In this study, HALP was calculated using clinically common units in the MIMIC-IV laboratory fields, and units were kept consistent throughout the statistical analyses.

All laboratory indicators constituting HALP were taken from the first available measurement within 24 hours after ICU admission.

Primary outcome:

The primary outcome was in-hospital all-cause mortality, defined as death from any cause during the index hospitalization.

Secondary outcomes

The secondary outcomes were 30-day all-cause mortality and 90-day all-cause mortality, defined as death from any cause within 30 days and within 90 days after ICU admission, respectively.

Covariates:

Candidate covariates included demographic characteristics, early admission vital signs, comorbidities, laboratory indicators, disease severity, and treatment-related variables. Demographic characteristics included age, sex, and race. Vital signs included first systolic blood pressure, diastolic blood pressure, heart rate, mean arterial pressure, and oxygen saturation after admission. Comorbidities included hypertension, diabetes mellitus, coronary artery disease, congestive heart failure, atrial fibrillation, and chronic kidney disease. Laboratory and disease severity indicators included white blood cell count, serum creatinine, and the SOFA score on the first ICU day. The treatment-related variable was whether the patient underwent surgery. Because hemoglobin, albumin, lymphocyte count, and platelet count are components of HALP, these variables were not re-entered into the main model to reduce the risk of overadjustment.

3. Statistical Analysis

Continuous variables with a normal distribution are presented as mean +/- standard deviation, and non-normally distributed variables are presented as median (IQR). Categorical variables are presented as frequencies (percentages). Between-group comparisons were performed using the t test, Mann-Whitney U test, chi-square test, or Kruskal-Wallis test, as appropriate. Variables with a missing rate >20% were excluded. A P value <0.05 was considered statistically significant. The associations between HALP quartile groups and mortality outcomes were estimated using Cox models with HRs and 95% CIs. Sensitivity analysis after propensity score matching was performed using logistic regression. All statistical analyses were conducted using R software (version 4.6.0).

Results

1. Baseline Characteristics of the Study Population

In the MIMIC-IV cohort, baseline characteristics and clinical outcomes were compared according to in-hospital mortality status (Table 1).

A total of 271 eligible ICU patients with AAD were included, among whom 38 (14.0%) died during hospitalization. Compared with survivors, non-survivors had lower hemoglobin levels [9.79 (2.12) vs 10.72 (2.26), P=0.019], higher serum creatinine levels [1.78 (1.89) vs 1.32 (1.13), P=0.037], and higher SOFA scores [8.08 (4.15) vs 6.16 (3.79), P=0.005]. The distribution of HALP quartiles differed between the two groups (P=0.003). The proportions of Q3 and Q4 were 31.6% and 44.7% among non-survivors, respectively, compared with 24.0% and 21.9% among survivors. The 30-day and 90-day mortality rates were higher, and 30-day and 90-day survival times were shorter, in the non-survivor group (all P<0.001).

After grouping patients by HALP quartiles, the sample sizes in Q1, Q2, Q3, and Q4 were 68, 67, 68, and 68, respectively. No statistically significant differences were observed across HALP groups in age, sex, race, early admission vital signs, major comorbidities, or the proportion of patients undergoing surgery. ICU length of stay differed among the four groups (P=0.003) and tended to decrease from Q1 to Q4. Hemoglobin levels increased with higher HALP groups (P=0.006), consistent with the composition of the HALP score. White blood cell count, creatinine, and SOFA score did not differ significantly across HALP groups.

In-hospital, 30-day, and 90-day mortality rates differed across HALP quartile groups. In-hospital mortality increased from 7.4% in Q1 and 6.0% in Q2 to 17.6% in Q3 and 25.0% in Q4 (P=0.003). The corresponding 30-day mortality rates were 5.9%, 4.5%, 16.2%, and 25.0% (P=0.001). The 90-day mortality rate was highest in Q3 (30.9%) and was 26.5% in Q4 (P=0.004). These findings suggest that patients in higher HALP quartiles had a greater risk of short- and mid-term mortality, indicating that HALP may be closely associated with adverse prognosis in patients with acute aortic dissection.

Table 1. Baseline characteristics and clinical outcomes according to in-hospital mortality status

	level	Overall	Death	Survive	p
n		271	38	233	
Icu_Los_Day (mean (SD))		8.76 (10.05)	10.59 (10.07)	8.46 (10.03)	0.227
Age (mean (SD))		68.64 (14.10)	69.00 (14.94)	68.58 (13.99)	0.865
Gender (%)	F	120 (44.3)	19 (50.0)	101 (43.3)	0.556
	M	151 (55.7)	19 (50.0)	132 (56.7)	
Race (%)	ASIAN	7 (2.6)	2 (5.3)	5 (2.1)	0.027
	BLACK	37 (13.7)	1 (2.6)	36 (15.5)	
	HISPANIC	15 (5.5)	2 (5.3)	13 (5.6)	
	OTHER	62 (22.9)	15 (39.5)	47 (20.2)	

	WHITE	150 (55.4)	18 (47.4)	132 (56.7)	
Systolic_Bp_First (mean (SD))		120.25 (22.41)	122.47 (27.33)	119.89 (21.54)	0.511
Diastolic_Bp_First (mean (SD))		63.79 (14.85)	65.34 (18.32)	63.53 (14.23)	0.488
Heart_Rate_First (mean (SD))		81.73 (16.59)	82.42 (21.14)	81.62 (15.77)	0.782
Mean_Arterial_Pressure_First (mean (SD))		80.67 (15.90)	83.71 (18.70)	80.17 (15.38)	0.203
Spo2_First (mean (SD))		96.77 (4.63)	96.16 (5.92)	96.87 (4.40)	0.38
Hypertension (%)	NO	45 (16.6)	9 (23.7)	36 (15.5)	0.303
	YES	226 (83.4)	29 (76.3)	197 (84.5)	
Diabetes (%)	NO	224 (82.7)	31 (81.6)	193 (82.8)	1
	YES	47 (17.3)	7 (18.4)	40 (17.2)	
Coronary_Heart_Disease (%)	NO	169 (62.4)	25 (65.8)	144 (61.8)	0.772
	YES	102 (37.6)	13 (34.2)	89 (38.2)	
Congestive_Heart_Failure (%)	NO	197 (72.7)	25 (65.8)	172 (73.8)	0.404
	YES	74 (27.3)	13 (34.2)	61 (26.2)	
Atrial_Fibrillation (%)	NO	145 (53.5)	22 (57.9)	123 (52.8)	0.682
	YES	126 (46.5)	16 (42.1)	110 (47.2)	
Chronic_Kidney_Disease (%)	NO	199 (73.4)	28 (73.7)	171 (73.4)	1
	YES	72 (26.6)	10 (26.3)	62 (26.6)	
Wbc_First (mean (SD))		11.43 (5.66)	11.43 (5.88)	11.43 (5.64)	0.996
Hemoglobin_First (mean (SD))		10.59 (2.26)	9.79 (2.12)	10.72 (2.26)	0.019
Creatinine_First (mean (SD))		1.39 (1.27)	1.78 (1.89)	1.32 (1.13)	0.037
Sofa_First_Day (mean (SD))		6.43 (3.89)	8.08 (4.15)	6.16 (3.79)	0.005
Surgical_Treatment (%)	NO	182 (67.2)	25 (65.8)	157 (67.4)	0.994
	YES	89 (32.8)	13 (34.2)	76 (32.6)	
Halp (%)	Q1	68 (25.1)	5 (13.2)	63 (27.0)	0.003
	Q2	67 (24.7)	4 (10.5)	63 (27.0)	
	Q3	68 (25.1)	12 (31.6)	56 (24.0)	
	Q4	68 (25.1)	17 (44.7)	51 (21.9)	

Hospital_Mortality (%)	Death	38 (14.0)	38 (100.0)	0 (0.0)	<0.001
	Survive	233 (86.0)	0 (0.0)	233 (100.0)	
Mortality_30d (%)	Death	35 (12.9)	35 (92.1)	0 (0.0)	<0.001
	Survive	236 (87.1)	3 (7.9)	233 (100.0)	
Mortality_90d (%)	Death	54 (19.9)	38 (100.0)	16 (6.9)	<0.001
	Survive	217 (80.1)	0 (0.0)	217 (93.1)	
Hospital_Survival_Time_Days (mean (SD))		16.63 (14.69)	12.58 (10.38)	17.29 (15.20)	0.067
Survival_Time_30d (mean (SD))		27.52 (7.14)	12.29 (9.74)	30.00 (0.00)	<0.001
Survival_Time_90d (mean (SD))		77.07 (27.98)	12.58 (10.38)	87.59 (10.07)	<0.001
Hospital_Los_Day (mean (SD))		17.60 (16.38)	13.36 (10.34)	18.29 (17.08)	0.085

Patients were then divided into four groups according to HALP quartiles (Q1-Q4), and baseline characteristics and outcome distributions were compared across groups (Table 2).

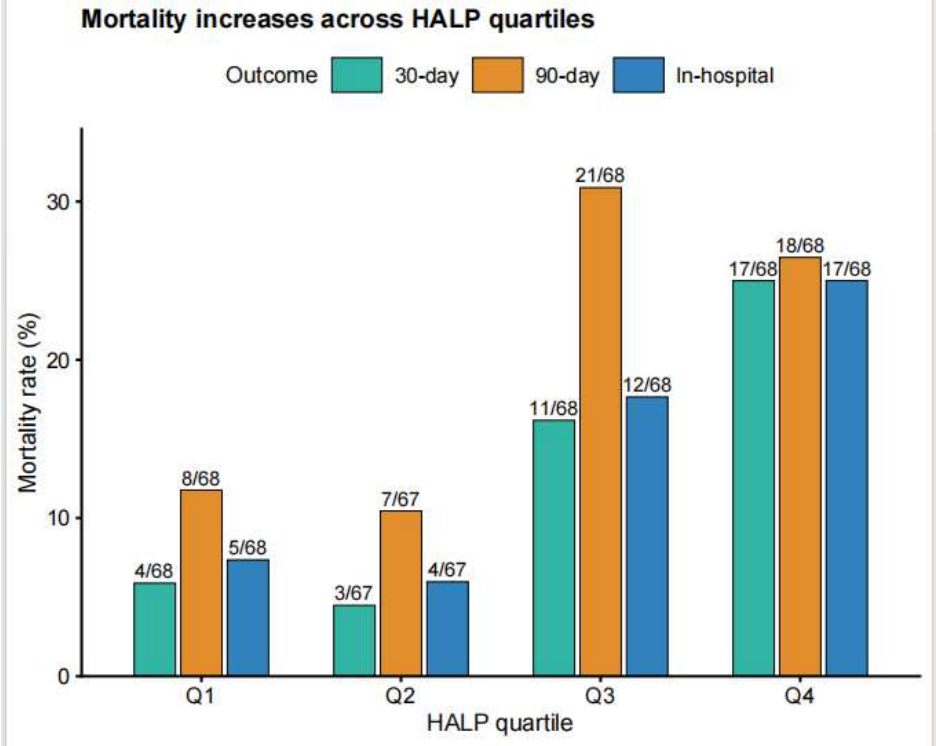
Table 2. Baseline characteristics and clinical outcomes according to HALP quartiles

	level	Overall	Q1	Q2	Q3	Q4	p
n		271	68	67	68	68	
Icu_Los_Day (mean (SD))		8.76 (10.05)	11.14 (11.76)	10.43 (11.65)	8.10 (9.15)	5.41 (5.55)	0.003
Age (mean (SD))		68.64 (14.10)	69.59 (12.65)	69.24 (14.52)	66.82 (14.84)	68.91 (14.43)	0.666
Gender (%)	F	120 (44.3)	31 (45.6)	26 (38.8)	32 (47.1)	31 (45.6)	0.772
	M	151 (55.7)	37 (54.4)	41 (61.2)	36 (52.9)	37 (54.4)	
Race (%)	ASIAN	7 (2.6)	1 (1.5)	1 (1.5)	3 (4.4)	2 (2.9)	0.433
	BLACK	37 (13.7)	15 (22.1)	5 (7.5)	6 (8.8)	11 (16.2)	

	HISPANIC	15 (5.5)	2 (2.9)	4 (6.0)	5 (7.4)	4 (5.9)	
	OTHER	62 (22.9)	14 (20.6)	20 (29.9)	13 (19.1)	15 (22.1)	
	WHITE	150 (55.4)	36 (52.9)	37 (55.2)	41 (60.3)	36 (52.9)	
Systolic_Bp_First (mean (SD))		120.25 (22.41)	121.55 (22.41)	119.25 (22.08)	121.63 (22.25)	118.57 (23.21)	0.804
Diastolic_Bp_First (mean (SD))		63.79 (14.85)	64.64 (17.63)	61.24 (14.60)	64.13 (12.48)	65.12 (14.29)	0.429
Heart_Rate_First (mean (SD))		81.73 (16.59)	82.60 (17.60)	82.51 (15.88)	81.57 (14.86)	80.26 (18.09)	0.835
Mean_Arterial_Pressure_First (mean (SD))		80.67 (15.90)	81.24 (17.56)	77.40 (16.56)	82.25 (13.99)	81.74 (15.17)	0.274
Spo2_First (mean (SD))		96.77 (4.63)	97.16 (3.27)	96.72 (4.01)	95.91 (7.05)	97.29 (2.99)	0.297
Hypertension (%)	NO	45 (16.6)	11 (16.2)	10 (14.9)	9 (13.2)	15 (22.1)	0.539
	YES	226 (83.4)	57 (83.8)	57 (85.1)	59 (86.8)	53 (77.9)	
Diabetes (%)	NO	224 (82.7)	54 (79.4)	57 (85.1)	53 (77.9)	60 (88.2)	0.347
	YES	47 (17.3)	14 (20.6)	10 (14.9)	15 (22.1)	8 (11.8)	
Coronary_Heart_Disease (%)	NO	169 (62.4)	42 (61.8)	48 (71.6)	37 (54.4)	42 (61.8)	0.23
	YES	102 (37.6)	26 (38.2)	19 (28.4)	31 (45.6)	26 (38.2)	
Congestive_Heart_Failure (%)	NO	197 (72.7)	49 (72.1)	48 (71.6)	49 (72.1)	51 (75.0)	0.97
	YES	74 (27.3)	19 (27.9)	19 (28.4)	19 (27.9)	17 (25.0)	

Atrial_Fibrillation (%)	NO	145 (53.5)	39 (57.4)	37 (55.2)	34 (50.0)	35 (51.5)	0.817
	YES	126 (46.5)	29 (42.6)	30 (44.8)	34 (50.0)	33 (48.5)	
Chronic_Kidney_Disease (%)	NO	199 (73.4)	44 (64.7)	47 (70.1)	51 (75.0)	57 (83.8)	0.076
	YES	72 (26.6)	24 (35.3)	20 (29.9)	17 (25.0)	11 (16.2)	
Wbc_First (mean (SD))		11.43 (5.66)	10.88 (5.02)	11.60 (5.98)	11.55 (6.09)	11.69 (5.57)	0.834
Hemoglobin_First (mean (SD))		10.59 (2.26)	10.07 (2.27)	10.32 (2.31)	10.59 (2.38)	11.35 (1.87)	0.006
Creatinine_First (mean (SD))		1.39 (1.27)	1.57 (1.48)	1.39 (1.32)	1.45 (1.46)	1.13 (0.57)	0.221
Sofa_First_Day (mean (SD))		6.43 (3.89)	6.32 (3.40)	6.63 (4.10)	7.03 (4.08)	5.74 (3.91)	0.261
Surgical_Treatment (%)	NO	182 (67.2)	48 (70.6)	46 (68.7)	43 (63.2)	45 (66.2)	0.817
	YES	89 (32.8)	20 (29.4)	21 (31.3)	25 (36.8)	23 (33.8)	
Hospital_Mortality (%)	Death	38 (14.0)	5 (7.4)	4 (6.0)	12 (17.6)	17 (25.0)	0.003
	Survive	233 (86.0)	63 (92.6)	63 (94.0)	56 (82.4)	51 (75.0)	
Mortality_30d (%)	Death	35 (12.9)	4 (5.9)	3 (4.5)	11 (16.2)	17 (25.0)	0.001
	Survive	236 (87.1)	64 (94.1)	64 (95.5)	57 (83.8)	51 (75.0)	
Mortality_90d (%)	Death	54 (19.9)	8 (11.8)	7 (10.4)	21 (30.9)	18 (26.5)	0.004
	Survive	217 (80.1)	60 (88.2)	60 (89.6)	47 (69.1)	50 (73.5)	

Hospital_Survival_Time_Days	16.63	20.30	20.86	14.39	11.03	<0.001
(mean (SD))	(14.69)	(15.20)	(20.05)	(10.21)	(8.40)	
Survival_Time_30d (mean (SD))	27.52	29.20	29.49	26.91	24.49	<0.001
	(7.14)	(4.19)	(2.65)	(7.84)	(10.14)	
Survival_Time_90d (mean (SD))	77.07	83.03	84.48	72.21	68.67	0.001
	(27.98)	(20.33)	(17.96)	(30.55)	(36.10)	
Hospital_Los_Day (mean (SD))	17.60	22.27	21.72	14.65	11.83	<0.001
	(16.38)	(20.55)	(19.77)	(10.46)	(9.11)	



2. Multivariable Association Between HALP and Mortality Outcomes

Multivariable logistic regression was used to evaluate the associations between HALP quartiles and in-hospital, 30-day, and 90-day mortality. Model I was the unadjusted model. Model II was adjusted for age, race, sex, hypertension, first systolic blood pressure after admission, first diastolic blood pressure after admission, and diabetes mellitus. Model III was further adjusted for coronary artery disease, congestive heart failure, atrial fibrillation, and chronic kidney disease in addition to the covariates in Model II. Q1 was used as the reference group, and results are presented as ORs (95% CIs). These models further explored the associations between HALP and the primary and secondary outcomes (Table 3).

For in-hospital mortality, HALP Q2 did not differ significantly from Q1. HALP Q3 showed a trend toward increased risk, with an OR of 2.901 (95% CI: 0.972-8.653, P=0.056) in the fully adjusted model. HALP Q4 was associated with a higher risk of in-hospital mortality in all three models, with an OR of 5.404 (95% CI: 1.860-15.705, P=0.002) in the fully adjusted model.

For 30-day mortality, HALP Q2 showed no significant difference, whereas HALP Q3 showed a trend toward increased risk but did not reach statistical significance (fully adjusted model: OR=3.151, 95% CI: 0.960-10.349, P=0.058). HALP Q4 was associated with a higher risk of 30-day mortality in the fully adjusted model (OR=6.413, 95% CI: 1.999-20.579, P=0.002). These results indicate that patients in the highest HALP quartile still had a significantly higher risk of 30-day mortality after adjustment for demographic characteristics, blood pressure levels, metabolic disease, and cardio-renal comorbidities.

For 90-day mortality, HALP Q2 did not differ significantly from Q1. HALP Q3 and Q4 were associated with a higher risk of 90-day mortality in all three models, with ORs of 3.326 (95% CI: 1.416-7.814, P=0.006) and 3.115 (95% CI: 1.307-7.424, P=0.010), respectively, in the fully adjusted model. Overall, higher HALP groups, particularly Q3 and Q4, were closely associated with increased short- and mid-term mortality risk in patients with acute aortic dissection. The risk effect of Q4 was most pronounced for in-hospital and 30-day mortality, suggesting that HALP may be an important clinical indicator of adverse prognosis in this population.

Table 3. Association between HALP groups and risk of in-hospital mortality

Variable	Model I (95%CI)	P	Model II (95%CI)	P	Model III (95%CI)	P
HalpQ1	Ref	Ref	Ref	Ref	Ref	Ref
HalpQ2	0.803 (0.216-2.992)	0.744	0.692 (0.184-2.594)	0.585	0.682 (0.182-2.564)	0.571
HalpQ3	2.575 (0.907-7.311)	0.076	2.403 (0.828-6.975)	0.107	2.901 (0.972-8.653)	0.056
HalpQ4	3.926 (1.448-10.644)	0.007	4.127 (1.499-11.363)	0.006	5.404 (1.860-15.705)	0.002

Note: Q1 was used as the reference group. Results are presented as ORs (95% CIs). P values are shown to three decimal places.

Table 4. Association between HALP groups and risk of 30-day mortality

Variable	Model I (95%CI)	P	Model II (95%CI)	P	Model III (95%CI)	P

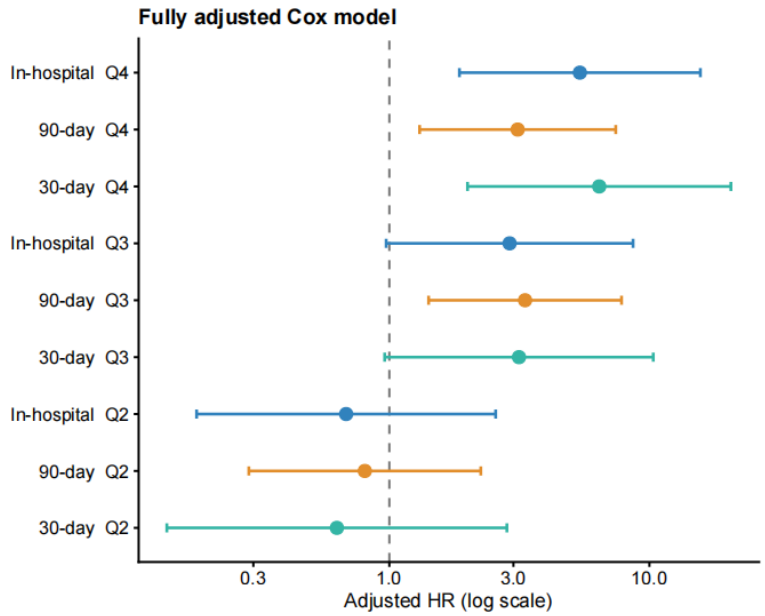
HalpQ1	Ref	Ref	Ref	Ref	Ref	Ref
HalpQ2	0.753 (0.169-3.367)	0.711	0.637 (0.142-2.860)	0.556	0.629 (0.140-2.832)	0.545
HalpQ3	2.939 (0.936-9.232)	0.065	2.678 (0.837-8.569)	0.097	3.151 (0.960-10.349)	0.058
HalpQ4	4.875 (1.640-14.492)	0.004	5.017 (1.653-15.226)	0.004	6.413 (1.999-20.579)	0.002

Note: Q1 was used as the reference group. Results are presented as ORs (95% CIs). P values are shown to three decimal places.

Table 5. Association between HALP groups and risk of 90-day mortality

Variable	**Model I (95%CI)**	**P**	**Model II (95%CI)**	**P**	**Model III (95%CI)**	**P**
HalpQ1	Ref	Ref	Ref	Ref	Ref	Ref
HalpQ2	0.875 (0.317-2.412)	0.796	0.781 (0.280-2.176)	0.636	0.805 (0.288-2.248)	0.679
HalpQ3	2.895 (1.282-6.537)	0.011	2.976 (1.288-6.876)	0.011	3.326 (1.416-7.814)	0.006
HalpQ4	2.640 (1.148-6.072)	0.022	2.638 (1.136-6.125)	0.024	3.115 (1.307-7.424)	0.010

Note: Q1 was used as the reference group. Results are presented as ORs (95% CIs). P values are shown to three decimal places.

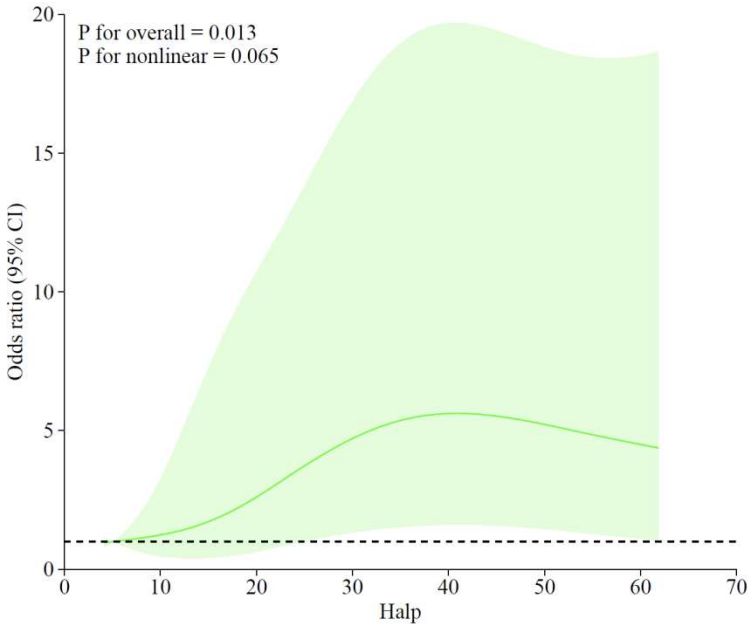


3. Dose-Response Relationship Between HALP and Mortality Risk

Restricted cubic spline (RCS) analyses were performed in Model I, Model II, and Model III to fit the relationship between HALP as a continuous variable and the primary outcome (in-hospital all-cause mortality) and secondary outcomes (30-day and 90-day all-cause mortality) (Figure 2).

The overall association P values for HALP with in-hospital mortality, 30-day mortality, and 90-day mortality were 0.013, 0.005, and 0.028, respectively. The spline curves suggested an increasing trend in mortality risk for all three outcomes as HALP levels increased. The increase in risk became more apparent at HALP levels around 30-40, followed by a slower increase or a slight decline at higher levels, although the risk generally remained elevated. In nonlinear association tests, the P values for in-hospital all-cause mortality and 90-day all-cause mortality were 0.065 and 0.058, respectively. Although these did not meet the conventional threshold for statistical significance, both were close to significance, suggesting a possible nonlinear trend between HALP and these two outcomes. The nonlinear test for 30-day all-cause mortality was statistically significant (P=0.041), indicating a clear nonlinear relationship between HALP and 30-day mortality risk. Taken together, the spline curves for all three outcomes showed a gradual increase in risk with higher HALP levels and reached a relative peak in the mid-to-high range, suggesting that higher HALP levels may be associated with increased short- and mid-term mortality risk in patients with acute aortic dissection.

Given the wide confidence intervals at both ends of the spline curves, this study does not propose a definitive clinical threshold. The RCS results primarily support a continuous association between HALP and mortality risk.



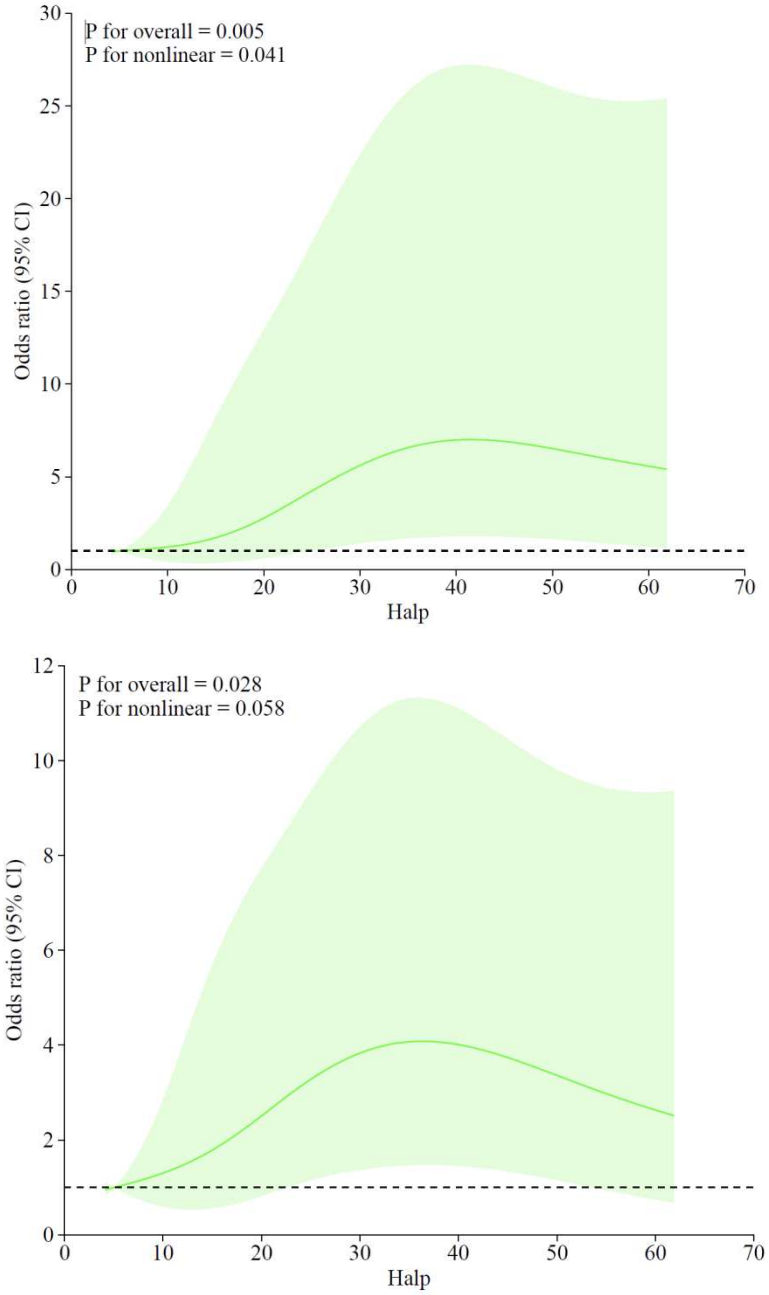


Figure 2. Restricted cubic spline analysis of HALP with in-hospital, 30-day, and 90-day mortality

4. Survival Curves and Discrimination Assessment

Kaplan-Meier survival curves were plotted by HALP quartiles to describe unadjusted survival differences among patients with different HALP levels (Figure 3).

Receiver operating characteristic (ROC) curves were constructed in the MIMIC-IV cohort to evaluate the discriminatory ability of HALP for predicting the primary outcome (in-hospital all-cause

mortality) and secondary outcomes (30-day and 90-day all-cause mortality) in patients with AAD (Figure 4), with detailed ROC information presented for each indicator.

Kaplan-Meier analysis showed more pronounced separation of the survival curves for 30-day all-cause mortality (log-rank P=0.00049). For 90-day all-cause mortality, between-group survival differences were also significant (log-rank P=0.0027). Overall, patients in higher HALP groups, especially Q4, had a faster decline in survival probability and consistently lower survival during follow-up, whereas Q1 and Q2 generally maintained higher survival probabilities and Q3 fell between these groups. These results suggest that the risk of in-hospital and short- to mid-term mortality in patients with AAD increased gradually with higher HALP levels.

ROC curve analysis was further used to evaluate the predictive performance of HALP for the primary and secondary outcomes in patients with acute aortic dissection. HALP showed some discriminatory ability for in-hospital all-cause mortality, with an AUC of 0.66 (95% CI: 0.56-0.75). The predictive performance was relatively highest for 30-day all-cause mortality, with an AUC of 0.68 (95% CI: 0.59-0.77), and relatively lower for 90-day all-cause mortality, with an AUC of 0.62 (95% CI: 0.53-0.70). All three ROC curves were above the reference line, suggesting that HALP has some value for risk identification across mortality outcomes at different time scales.

Overall, HALP discriminated 30-day mortality better than in-hospital and 90-day mortality, suggesting that HALP may be more suitable for early assessment of short-term mortality risk in patients with acute aortic dissection. Although the AUC values for HALP were generally moderate and insufficient for HALP to serve as a standalone clinical prognostic marker, HALP is derived from routine laboratory indicators, is easy to calculate, and is readily available. It may therefore serve as an auxiliary risk stratification tool for identifying patients at higher mortality risk. Together with the Cox proportional hazards regression, restricted cubic spline, and Kaplan-Meier survival analyses described above, these results show a relatively consistent association between HALP and adverse prognosis in patients with acute aortic dissection, suggesting potential clinical value for early prognostic assessment.

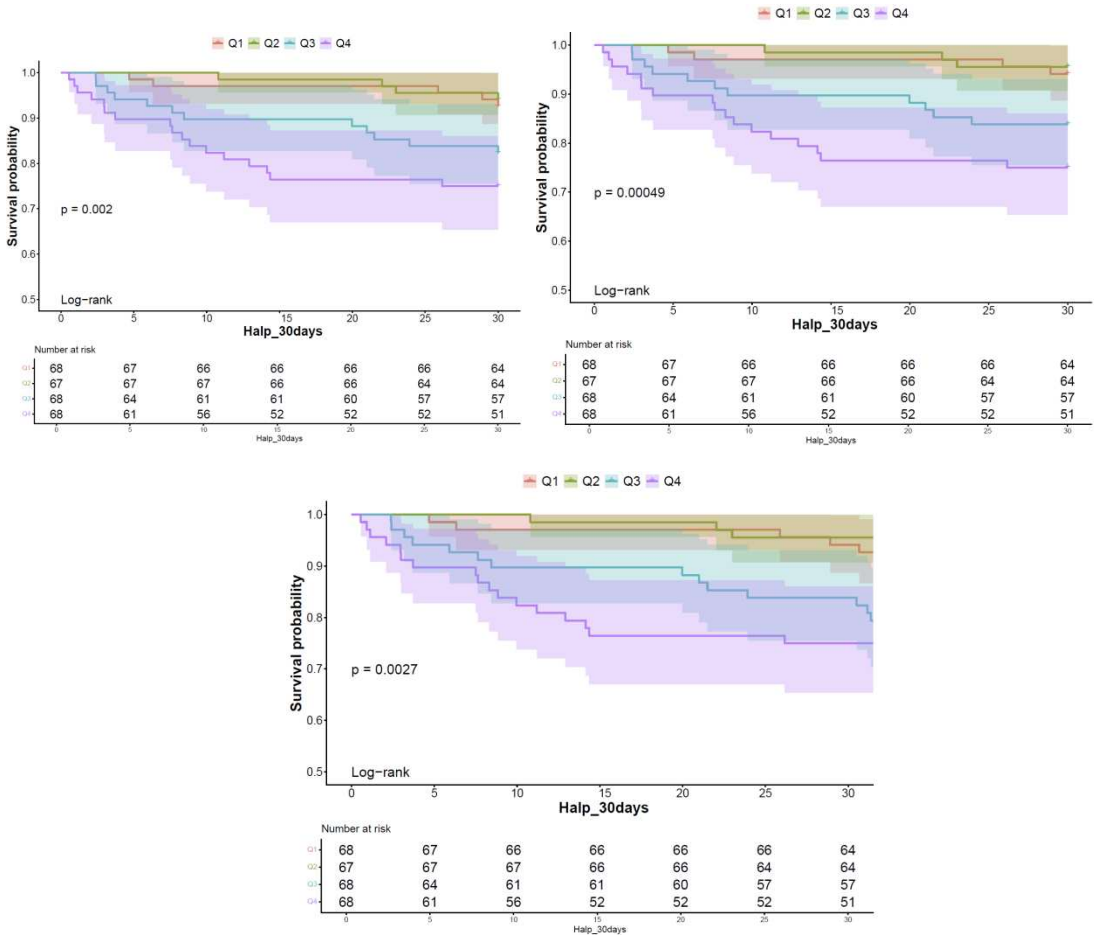


Figure 3. Kaplan-Meier survival curves among patients in different HALP quartile groups

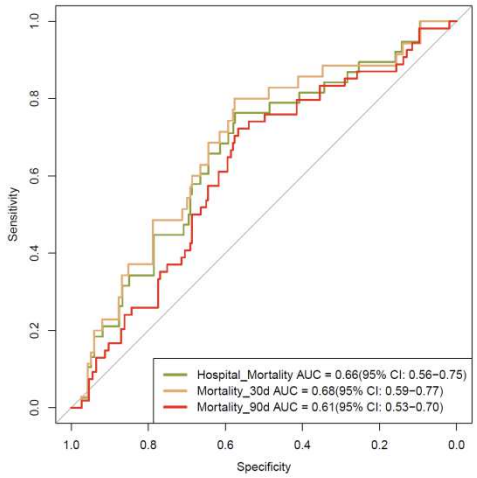


Figure 4. ROC curves for HALP in predicting in-hospital, 30-day, and 90-day mortality

5. Subgroup and Interaction Analyses

To evaluate whether subgroup characteristics, such as sex (male vs female), age (<65 years vs >=65 years), and hypertension (yes vs no), modified the association of interest, Cox proportional hazards models were fitted within each subgroup for the primary outcome (in-hospital all-cause mortality) and secondary outcomes (30-day and 90-day all-cause mortality). Interaction terms between HALP and each subgroup variable were then included, and likelihood ratio tests were used to compare models with and without interaction terms to assess effect modification (Figure 5).

For in-hospital mortality, HALP as a continuous variable was associated with an increased mortality risk (OR=1.01, 95% CI: 1.00-1.02, P=0.014). Stratified analyses showed that this association was more apparent among patients aged <=65 years [HR=1.03, 95% CI: 1.01-1.06, P=0.008], male patients [HR=1.03, 95% CI: 1.00-1.05, P=0.019], patients without diabetes mellitus [HR=1.01, 95% CI: 1.00-1.03, P=0.017], patients with hypertension [HR=1.03, 95% CI: 1.01-1.05, P=0.009], patients without coronary artery disease [HR=1.01, 95% CI: 1.00-1.03, P=0.022], patients without congestive heart failure [HR=1.02, 95% CI: 1.01-1.04, P=0.011], patients without atrial fibrillation [HR=1.03, 95% CI: 1.01-1.06, P=0.001], and patients without chronic kidney disease [HR=1.02, 95% CI: 1.00-1.04, P=0.016]. Interaction tests suggested significant effect modification by race (P for interaction=0.035) and atrial fibrillation (P for interaction=0.040) for the association between HALP and in-hospital mortality, whereas interactions for age, sex, diabetes mellitus, hypertension, coronary artery disease, congestive heart failure, and chronic kidney disease were not statistically significant.

For 30-day all-cause mortality, HALP was also significantly associated with increased mortality risk, with an overall effect estimate of 1.01 (95% CI: 1.00-1.03, P=0.006). This association was more pronounced among patients aged <=65 years [HR=1.04, 95% CI: 1.01-1.06, P=0.003], male patients [HR=1.03, 95% CI: 1.01-1.05, P=0.006], patients without diabetes mellitus [HR=1.01, 95% CI: 1.00-1.03, P=0.011], patients with hypertension [HR=1.03, 95% CI: 1.01-1.05, P=0.006], patients without coronary artery disease [HR=1.02, 95% CI: 1.00-1.03, P=0.009], patients without congestive heart failure [HR=1.03, 95% CI: 1.01-1.05, P=0.006], patients without atrial fibrillation [HR=1.04, 95% CI: 1.02-1.06, P<0.001], and patients without chronic kidney disease [HR=1.02, 95% CI: 1.01-1.04, P=0.009]. Interaction analysis showed that race (P for interaction=0.048) and atrial fibrillation (P for interaction=0.017) still significantly modified the association between HALP and 30-day mortality risk, whereas no clear interaction effect was observed for the remaining subgroup variables. These findings suggest potential heterogeneity in the effect of HALP on short-term mortality risk across racial groups and according to atrial fibrillation status.

For 90-day all-cause mortality, the association between HALP and overall mortality risk did not reach statistical significance [HR=1.01, 95% CI: 1.00-1.02, P=0.079]. Although an increased mortality trend associated with HALP was still observed in some subgroups, such as patients with hypertension [HR=1.02, 95% CI: 1.00-1.04, P=0.021], patients without atrial fibrillation [HR=1.02, 95% CI: 1.01-1.04, P=0.008], and Hispanic patients [HR=1.12, 95% CI: 1.00-1.24, P=0.046], the associations were unstable in most subgroups, and none of the interaction tests reached statistical significance (all P for interaction >0.05). Overall, subgroup analyses indicated that the associations of HALP with in-hospital all-cause mortality and 30-day all-cause mortality were relatively robust, particularly among younger patients, male patients, patients with hypertension, patients without atrial fibrillation, and selected patients without severe underlying disease. For 90-day mortality, however, the predictive association was relatively weaker.

Variable	Count	Percent	HR (95% CI)	P value	P for interaction
Overall	271	100	1.01 (1.00 to 1.02)	0.014	
Age					0.11
<=65	101	37.3	1.03 (1.01 to 1.06)	0.008	
>65	170	62.7	1.01 (0.99 to 1.02)	0.229	
Gender					0.212
F	120	44.3	1.01 (0.99 to 1.02)	0.257	
M	151	55.7	1.03 (1.00 to 1.05)	0.019	
Race					0.035
ASIAN	7	2.6	1.00 (0.93 to 1.07)	0.908	
BLACK	37	13.7	0.93 (0.71 to 1.20)	0.569	
HISPANIC	15	5.5	1.16 (0.97 to 1.39)	0.104	
OTHER	62	22.9	1.02 (1.00 to 1.04)	0.048	
WHITE	150	55.4	1.01 (0.99 to 1.03)	0.315	
Diabetes					0.914
NO	224	82.7	1.01 (1.00 to 1.03)	0.017	
YES	47	17.3	1.02 (0.96 to 1.08)	0.561	
Hypertension					0.124
NO	45	16.6	1.00 (0.99 to 1.02)	0.611	
YES	226	83.4	1.03 (1.01 to 1.05)	0.009	
Coronary_Heart_Disease					0.979
NO	169	62.4	1.01 (1.00 to 1.03)	0.022	
YES	102	37.6	1.01 (0.98 to 1.05)	0.42	
Congestive_Heart_Failure					0.177
NO	197	72.7	1.02 (1.01 to 1.04)	0.011	
YES	74	27.3	1.01 (0.99 to 1.02)	0.437	
Atrial_Fibrillation					0.04
NO	145	53.5	1.03 (1.01 to 1.06)	0.001	
YES	126	46.5	1.00 (0.99 to 1.02)	0.635	
Chronic_Kidney_Disease					0.274
NO	199	73.4	1.02 (1.00 to 1.04)	0.016	
YES	72	26.6	1.01 (0.99 to 1.03)	0.414	



Variable	Count	Percent	HR (95% CI)	P value	P for interaction
Overall	271	100	1.01 (1.00 to 1.03)	0.006	
Age					0.062
<=65	101	37.3	1.04 (1.01 to 1.06)	0.003	
>65	170	62.7	1.01 (1.00 to 1.02)	0.18	
Gender					0.102
F	120	44.3	1.01 (0.99 to 1.02)	0.257	
M	151	55.7	1.03 (1.01 to 1.05)	0.006	
Race					0.048
ASIAN	7	2.6	1.00 (0.93 to 1.07)	0.908	
BLACK	37	13.7			
HISPANIC	15	5.5	1.16 (0.97 to 1.39)	0.104	
OTHER	62	22.9	1.02 (1.00 to 1.04)	0.031	
WHITE	150	55.4	1.01 (0.99 to 1.03)	0.315	
Diabetes					0.684
NO	224	82.7	1.01 (1.00 to 1.03)	0.011	
YES	47	17.3	1.03 (0.97 to 1.09)	0.372	
Hypertension					0.124
NO	45	16.6	1.01 (0.99 to 1.02)	0.457	
YES	226	83.4	1.03 (1.01 to 1.05)	0.006	
Coronary_Heart_Disease					0.901
NO	169	62.4	1.02 (1.00 to 1.03)	0.009	
YES	102	37.6	1.01 (0.98 to 1.05)	0.42	
Congestive_Heart_Failure					0.152
NO	197	72.7	1.03 (1.01 to 1.05)	0.006	
YES	74	27.3	1.01 (0.99 to 1.02)	0.348	
Atrial_Fibrillation					0.017
NO	145	53.5	1.04 (1.02 to 1.06)	<0.001	
YES	126	46.5	1.00 (0.99 to 1.02)	0.635	
Chronic_Kidney_Disease					0.279
NO	199	73.4	1.02 (1.01 to 1.04)	0.009	
YES	72	26.6	1.01 (0.99 to 1.03)	0.344	

012345

Variable	Count	Percent	HR (95% CI)	P value	P for interaction
Overall	271	100	1.01 (1.00 to 1.02)	0.079	
Age					0.256
<=65	101	37.3	1.02 (1.00 to 1.04)	0.055	
>65	170	62.7	1.01 (0.99 to 1.02)	0.386	
Gender					0.44
F	120	44.3	1.01 (0.99 to 1.02)	0.395	
M	151	55.7	1.02 (1.00 to 1.03)	0.096	
Race					0.091
ASIAN	7	2.6	1.00 (0.95 to 1.05)	0.927	
BLACK	37	13.7	1.01 (0.95 to 1.07)	0.756	
HISPANIC	15	5.5	1.12 (1.00 to 1.24)	0.046	
OTHER	62	22.9	1.01 (0.99 to 1.03)	0.17	
WHITE	150	55.4	1.00 (0.99 to 1.02)	0.577	
Diabetes					0.941
NO	224	82.7	1.01 (1.00 to 1.02)	0.08	
YES	47	17.3	1.01 (0.96 to 1.06)	0.754	
Hypertension					0.103
NO	45	16.6	1.00 (0.98 to 1.02)	0.884	
YES	226	83.4	1.02 (1.00 to 1.04)	0.021	
Coronary_Heart_Disease					0.731
NO	169	62.4	1.01 (1.00 to 1.02)	0.07	
YES	102	37.6	1.01 (0.98 to 1.03)	0.651	
Congestive_Heart_Failure					0.385
NO	197	72.7	1.02 (1.00 to 1.03)	0.07	
YES	74	27.3	1.00 (0.99 to 1.02)	0.564	
Atrial_Fibrillation					0.084
NO	145	53.5	1.02 (1.01 to 1.04)	0.008	
YES	126	46.5	1.00 (0.98 to 1.02)	0.844	
Chronic_Kidney_Disease					0.412
NO	199	73.4	1.01 (1.00 to 1.03)	0.073	
YES	72	26.6	1.01 (0.99 to 1.02)	0.563	

012345

Figure 5. Associations between HALP and mortality outcomes in different subgroups

6. Sensitivity Analysis

To evaluate the robustness of the association between HALP and the primary outcome (in-hospital all-cause mortality) in patients with AAD, a propensity score model was constructed by classifying patients into low-HALP and high-HALP groups according to the median and including age, sex, race, blood pressure, heart rate, oxygen saturation, hypertension, diabetes mellitus, coronary artery disease, congestive heart failure, atrial fibrillation, chronic kidney disease, and other variables. Covariate balance before and after matching is shown in Figure 6. The covariate balance plot showed that the standardized mean differences for most variables improved after matching and moved closer to zero overall, suggesting that matching improved the comparability of baseline characteristics between the two groups to some extent. Propensity score matching was therefore used as a sensitivity analysis to evaluate the robustness of the association between HALP and in-hospital mortality. However, some variables, such as chronic kidney disease, coronary artery disease, Asian race, mean arterial pressure, and age, still showed residual imbalance after matching, and potential confounding should therefore be considered when interpreting the subsequent results.

Further logistic regression analysis in the propensity score-matched cohort showed that the low-HALP group was significantly associated with a lower risk of in-hospital all-cause mortality. Compared with the high-HALP group, the low-HALP group had a markedly reduced risk of in-hospital mortality (OR=0.273, 95% CI: 0.123-0.603, P=0.001). In other words, when the low-HALP group was used as the reference, patients in the high-HALP group had an approximately 3.67-fold higher risk of in-hospital mortality. This result was directionally consistent with the preceding quartile-based Cox proportional hazards regression, restricted cubic spline analysis, and Kaplan-Meier survival curves, further supporting a stable association between higher HALP levels and increased in-hospital mortality risk in patients with acute aortic dissection. Overall, sensitivity analysis showed that, even after propensity score matching was used to reduce baseline confounding, the result remained directionally consistent with quartile-based logistic regression, RCS, and Kaplan-Meier analyses, suggesting that HALP may be a robust correlate of adverse in-hospital prognosis in this population.

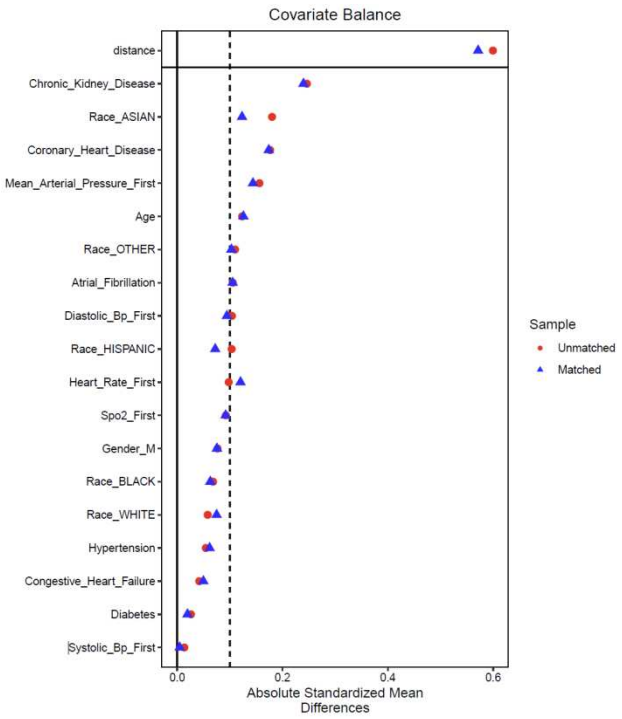


Figure 6. Distribution of covariate balance before and after PSM

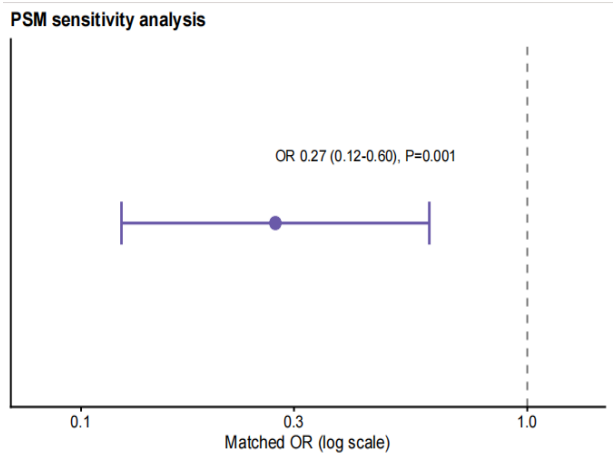


Table 6. Robustness analysis of the association between HALP and in-hospital all-cause mortality

	OR	Lower 95% CI	Upper 95% CI	P value
Low HALP group (relative to high HALP group)	0.273	0.123	0.603	0.001

Discussion

This study included 271 ICU patients with acute aortic dissection from the MIMIC-IV database and found that HALP levels were closely associated with the risks of in-hospital, 30-day, and 90-day

mortality. After grouping by HALP quartiles, patients in higher HALP groups had markedly higher in-hospital, 30-day, and 90-day mortality rates and significantly shorter survival times. Cox proportional hazards regression further showed that, after adjustment for age, sex, race, blood pressure, diabetes mellitus, and cardio-renal comorbidities, the highest HALP quartile remained significantly associated with increased risks of in-hospital and 30-day mortality. For 90-day mortality, HALP Q3 and Q4 also showed stable increases in risk, suggesting that HALP is an important factor associated with adverse prognosis in patients with AAD.

Restricted cubic spline analysis showed significant overall associations between HALP and in-hospital, 30-day, and 90-day mortality, with a clear nonlinear relationship for 30-day mortality, suggesting that the effect of HALP on short-term mortality risk may not increase in a simple linear manner. Kaplan-Meier survival analysis further confirmed significant separation of survival curves across HALP quartile groups. Patients in higher HALP groups, especially Q4, had a faster decline in survival probability. ROC curve analysis showed that HALP had some discriminatory ability for in-hospital, 30-day, and 90-day mortality, with relatively higher predictive performance for 30-day mortality. Subgroup analysis suggested that the associations between HALP and in-hospital and 30-day mortality were relatively consistent in most subgroups, although race and atrial fibrillation may have modified the association to some extent. Sensitivity analysis after propensity score matching continued to support an association between higher HALP levels and increased in-hospital mortality risk, further confirming the robustness of the findings.

In summary, the HALP score, as a composite indicator comprising hemoglobin, albumin, lymphocyte count, and platelet count, can reflect the nutritional, inflammatory, immune, and hematologic status of patients with AAD and was significantly associated with in-hospital and short- to mid-term mortality risk. Because HALP is easy to calculate, based on readily available laboratory indicators, and clinically accessible, it may serve as an auxiliary tool for early risk stratification and prognostic assessment in ICU patients with acute aortic dissection. However, this study was a retrospective analysis of a single-center database and may still be subject to selection bias, residual confounding, and limited sample size. Future multicenter, large-sample, prospective studies are needed to further validate the clinical value of HALP for prognostic assessment in patients with AAD.

Conclusion

In the MIMIC-IV database, higher early admission HALP levels were associated with increased risks of in-hospital, 30-day, and 90-day mortality among ICU-treated patients with AAD. This

association was generally consistent in multivariable logistic regression and several supplementary analyses, although the discriminatory ability of HALP alone was limited.

From a clinical perspective, HALP is derived from routine laboratory tests, is readily available, and is easy to calculate. It may therefore serve as an auxiliary indicator for early risk stratification in ICU patients with AAD. Its value is more likely to emerge when combined with disease severity, imaging classification, and treatment information rather than when used as a standalone predictive tool.

Future studies should validate these findings in multicenter prospective cohorts and incorporate Stanford classification, imaging-based severity, timing of surgery, organ support treatments, and external validation models to clarify the incremental value of HALP in AAD risk stratification.

Declarations

1.Ethics Statement:This study used the publicly available, de-identified MIMIC-IV database for secondary analysis. The original data collection for MIMIC-IV was approved by the relevant institutional review boards, and all patient privacy information was de-identified. This study was conducted in accordance with the PhysioNet data use agreement and did not involve re-contacting patients.we have added the statement Clinical trial number : not applicable in the manuscript as requested.

2.Consent for Publication：Not Applicable. No identifiable photographs, distinguishable clinical records, personal demographic particulars or other participant-related sensitive content that could undermine participant anonymity are included within this manuscript. Therefore, dedicated written publication consent from study participants is not demanded.

3.All relevant data are contained within the paper and its Supporting Information files.

4.Funding : This work had no financial support .

5.Author contributions：

Conceptualization : Le Li, Liyong Ma .

Data curation : Le Li.

Investigation : Le Li,yaqing Li, Liyong Ma .

Methodology : Le Li ,Liyong Ma .

Project administration : Le Li,Rui Zhuang .

Resources : Le Li .

Supervision : Liyong Ma .

Writing - original draft :Le Li,Rui Zhuang .

Writing - review & editing : Le Li，yaqing Li, Liyong Ma.

6.Acknowledgements：The authors appreciate all participants for volunteering in this research.

7.Data and Code Availability Statement:The MIMIC-IV database is available through PhysioNet upon application.

References

1、Gawinecka J, Schönrath F, von Eckardstein A. Acute aortic dissection: pathogenesis, risk factors and diagnosis. Swiss Med Wkly. 2017 Aug 25;147:w14489. doi: 10.4414/smw.2017.14489. PMID: 28871571.

2、Evangelista A, Isselbacher EM, Bossone E, Gleason TG, Eusanio MD, Sechtem U, Ehrlich MP, Trimarchi S, Braverman AC, Myrmel T, Harris KM, Hutchinson S, O'Gara P, Suzuki T, Nienaber CA, Eagle KA; IRAD Investigators. Insights From the International Registry of Acute Aortic Dissection: A 20-Year Experience of Collaborative Clinical Research. Circulation. 2018 Apr 24;137(17):1846-1860. doi: 10.1161/CIRCULATIONAHA.117.031264. PMID: 29685932.

3、Bjurbom M, Franco-Cereceda A, Olsson C. Management of acute type A aortic dissection in the Nordic countries. Scand Cardiovasc J. 2026 Dec;60(1):2613535. doi: 10.1080/14017431.2026.2613535. Epub 2026 Jan 13. PMID: 41508851.

4、Dungan KM, Braithwaite SS, Preiser JC. Stress hyperglycaemia. Lancet. 2009 May 23;373(9677):1798-807. doi: 10.1016/S0140-6736(09)60553-5. PMID: 19465235; PMCID: PMC3144755.

5、Roberts GW, Quinn SJ, Valentine N, Alhawassi T, O'Dea H, Stranks SN, Burt MG, Doogue MP. Relative Hyperglycemia, a Marker of Critical Illness: Introducing the Stress Hyperglycemia Ratio. J Clin Endocrinol Metab. 2015 Dec;100(12):4490-7. doi: 10.1210/jc.2015-2660. Epub 2015 Oct 20. PMID: 26485219.

6、Shuai Y, Liu Y, Yang X, Chen Z, Wan Q, Zhao J, Wang X. Prognostic value of stress hyperglycemia ratio in critically Ill patients with acute kidney injury: a machine learning-driven retrospective cohort analysis. Health Inf Sci Syst. 2026 Mar 18;14(1):46. doi: 10.1007/s13755-026-00443-0. PMID: 41867166; PMCID: PMC13000052.

7、Xie K, Gao S, Liu X, Cheng A, Liang R, Wang J, Li J, Liu J. Stress hyperglycemia ratio emerges as a novel independent predictor of acute kidney injury among critically ill patients with acute heart failure: A retrospective analysis of the MIMIC-IV database. Clin Nephrol. 2026 Jun;105(6):399-413. doi: 10.5414/CN111989. PMID: 41879485.

8、Gao X, Li C, Wang Y, Luo J, Zhan C. Nonlinear relationship between stress hyperglycemic ratio and prognosis in patients with cardiac surgery-related kidney injury: a retrospective cohort study. Ren

Fail. 2026 Dec;48(1):2613479. doi: 10.1080/0886022X.2026.2613479. Epub 2026 Jan 28. PMID: 41605900; PMCID: PMC12857695.

9、Yang J, Ma Y, Wang J, Shen S, Zou T. Stress hyperglycemia ratio improves 28-day mortality prediction beyond GRACE score in critically ill patients with acute coronary syndrome: a retrospective cohort study from MIMIC-IV. BMC Cardiovasc Disord. 2026 May 26. doi: 10.1186/s12872-026-06014-1. Epub ahead of print. PMID: 42185965.

10、Tang S, Zhang Z, Cheng Y, Zhang L, Wang Q, Wang C. Glycemic variability and mortality in patients with aortic diseases: A multicenter retrospective cohort study. PLoS One. 2025 Jun 25;20(6):e0325006. doi: 10.1371/journal.pone.0325006. PMID: 40561102; PMCID: PMC12193046.

11、Johnson AEW, Bulgarelli L, Shen L, Gayles A, Shammout A, Horng S, Pollard TJ, Hao S, Moody B, Gow B, Lehman LH, Celi LA, Mark RG. Author Correction: MIMIC-IV, a freely accessible electronic health record dataset. Sci Data. 2023 Apr 18;10(1):219. doi: 10.1038/s41597-023-02136-9. Erratum for: Sci Data. 2023 Jan 3;10(1):1. doi: 10.1038/s41597-022-01899-x. PMID: 37072428; PMCID: PMC10113185.

11、Roberts GW, Quinn SJ, Valentine N, Alhawassi T, O'Dea H, Stranks SN, Burt MG, Doogue MP. Relative Hyperglycemia, a Marker of Critical Illness: Introducing the Stress Hyperglycemia Ratio. J Clin Endocrinol Metab. 2015 Dec;100(12):4490-7. doi: 10.1210/jc.2015-2660. Epub 2015 Oct 20. PMID: 26485219.

12、Zhen K, Li J, Jiang H. The relationship between hemoglobin, albumin, lymphocyte, and platelet (HALP) score and prognosis in patients with heart failure: A retrospective analysis of the MIMIC-IV database. Medicine (Baltimore). 2026 May 8;105(19):e48530. doi: 10.1097/MD.0000000000048530. PMID: 42116337; PMCID: PMC13166640.