Neuroendocrinology Letters Volume 47 No. 2 2026
ISSN: 0172-780X; ISSN-L: 0172-780X; Electronic/Online ISSN: 2354-4716
Web of Knowledge / Web of Science: Neuroendocrinol Lett
Pub Med / Medline: Neuro Endocrinol Lett

ORIGINAL ARTICLE

Uric acid-to-albumin ratio and mortality in stroke patients: a DAQS-stratified analysis.

Ping Zhuang[1], Zhen Yong Zheng[2], XiaoDie Zhang[1]

1 Department of Cerebrovascular Disease, Guangdong Provincial Hospital of Traditional Chinese Medicine, Guangzhou City, Guangdong Province, 510006 China.
2 School of Nursing, Guangzhou University of Chinese Medicine, Guangzhou City, Guangdong Province, 510006 China.

Correspondence to: Ping Zhuang
No. 55, Inner Ring West Road, University Town, Panyu District, Guangzhou City, 510006, Guangdong Province, P.R.China
tel.: +86-13826150512; e-mail: ZPzhuangping@gzucm.edu.cn

Submitted: 2025-12-25 Accepted: 2026-04-28 Published online: 2026-04-28

Key words: **stroke; mortality; uric acid; serum albumin; antioxidants; diet**

Neuroendocrinol Lett 2026; **47**(2):80–93 **PMID:** 42165794 470203

Abstract

OBJECTIVES: The objectives of our study are to explore the associations of uric acid to albumin ratio (UAR) with all-cause and cardiovascular mortality in stroke patients, and to examine whether UAR–mortality associations differ between stroke patients stratified by dietary antioxidant quality score (DAQS).

METHODS: This cohort study included 1125 stroke patients from the NHANES 2007-2018. The DAQS was calculated based on the intake of six anti-oxidative nutrients. Multivariate Cox proportional hazards models were used to investigate the associations of UAR with all-cause and cardiovascular mortality in the total stroke cohort and within subgroups stratified by DAQS.

RESULTS: UAR showed a positive linear association with all-cause mortality in unadjusted and adjusted models (HR = 1.49, $p = 0.003$). For cardiovascular mortality, the association with continuous UAR was significant before but not after adjustment (HR = 1.43, $p = 0.108$). Compared with low UAR (≤1.34), high UAR (>1.34) was associated with higher all-cause (HR = 1.37, $p = 0.030$) and cardiovascular mortality (HR = 1.64, $p = 0.040$). In exploratory DAQS-stratified analyses, elevated UAR was related to higher all-cause (HR = 1.58) and cardiovascular mortality (HR = 1.83; both $p < 0.05$) only among patients with low DAQS, whereas associations in the high-DAQS subgroup were generally non-significant and imprecise.

CONCLUSION: Higher UAR after stroke was robustly associated with increased all-cause mortality, with weaker and less consistent evidence for cardiovascular mortality. Exploratory DAQS-stratified analyses suggested excess risk with high UAR mainly among patients with low DAQS, while findings in the smaller high-DAQS subgroup were non-significant and imprecise; these subgroup and cardiovascular results are hypothesis-generating.

INTRODUCTION

Stroke is the third leading cause of age-standardized mortality worldwide (Collaborators 2024). Over the past three decades, the number of stroke cases and deaths increased in the elderly (Gou *et al.* 2025). Moreover, the age-standardized incidence and age-standardized prevalence are projected to increase significantly in the next ten years (Zhang *et al.* 2025), portending a substantial increase in the absolute number of stroke cases and deaths. This heavy disease burden underscores the importance and urgency to explore and address the risk factors of prognosis.

Numerous studies have examined the relationships between the uric acid and the prognosis of acute stroke, yielding conflicting conclusions (Zhang *et al.* 2023) since uric acid simultaneously possesses antioxidative and prooxidative properties (Zhu *et al.* 2025a). However, evidence of uric acid on long-term mortality of stroke survivors was still limited. In addition, albumin, a marker of inflammatory and nutritional status, is widely applied to identify prognostic risks. Findings from critically ill patients with acute stroke indicated that low albumin level was a risk factor for poor functional outcomes and increased mortality (Thuemmler *et al.* 2024; Zhu *et al.* 2025b), whereas research among long-term stroke survivors is still limited. Considering the intricate interplay of oxidative stress, inflammation and nutritional status on the prognosis of diseases, uric acid-to-albumin ratio (UAR; calculated as uric acid [mg/dL] ÷ albumin [g/dL]) has been proposed as a comprehensive composite marker. Elevated UAR showed negative impact on the severity or mortality among patients with coronary artery disease, myocardial infarction (Li *et al.* 2022; Yalcinkaya *et al.* 2024). Evidence also indicated the relationship between higher UAR and carotid atherosclerosis in patients with diabetes and hypertension (Yin *et al.* 2025; Şaylık *et al.* 2023). However, it remains unknown whether UAR is related to the prognosis of stroke.

Furthermore, dietary antioxidants, important components of the body's antioxidative defence system, have demonstrated a protective effect on stroke prognosis (Xu *et al.* 2023). However, evidence was still limited regarding the association between uric acid/albumin and stroke prognosis under the different level of dietary antioxidant quality. Dietary antioxidant quality score (DAQS), which combines six anti-oxidative vitamins and minerals, serves as a comprehensive indicator of the overall dietary antioxidant quality. DAQS have been examined in researches on the development and prognosis of chronic diseases (Shi & Fang 2024; Wang *et al.* 2024).

Therefore, based on the NHANES nationally representative cohort, the objectives of our study are to explore the associations of uric acid-to-albumin ratio (UAR) with all-cause and cardiovascular mortality in stroke patients, as well as the effect of dietary antioxidant quality on these associations.

METHODS

Study design and population

This study is based on publicly available data from the National Health and Nutrition Examination Survey (NHANES) 2007–2018, an anonymized, de-identified survey conducted in communities across the United States. It was approved by CDC's National Center for Health Statistics (NCHS) Ethics Review Board. The ethical approval number can be accessed on the website (https://www.cdc.gov/nchs/nhanes/about/erb.html). All participants in NHANES provided signed informed consent. This study is a secondary analysis of the original data set and does not require an ethics approval.

The target population of this study is stroke patients. Stroke patients were identified as participants who responded 'yes' to the question: 'Has a doctor or other health professional ever told you that you had a stroke?' A total of 1398 stroke patients were included initially from the NHANES 2007-2018. Patients were excluded if their measurement of uric acid or albumin was incomplete (n = 179). Patients were further excluded if their information of survival status was missing (n = 2). Another 92 patients were excluded since the data on anti-oxidative nutrient intake were incomplete. Finally, a total of 1125 stroke patients were used for analysis (Suppl Fig 1).

Uric acid-to-albumin ratio

UAR is defined as the uric acid (mg/dL) divided by the albumin (g/dL) (Liu *et al.* 2024a). Uric acid and albumin were measured by the Beckman Synchron LX20 at 2007, the Beckman Coulter UniCel DxC800 at 2008-2016 and the Roche Cobas 6000 (c501 module) analyzer at 2017-2018. Details for the laboratory procedure and quality control can be found at the following link: https://wwwn.cdc.gov/nchs/nhanes/. In the present study, UAR was dichotomised at the weighted sample median of 1.34 into high (>1.34, n = 618) and low (≤1.34, n = 507) categories; this data-derived cutoff facilitates balanced group comparison but has not been externally validated.

Ascertainment of all-cause mortality and cardiovascular mortality

The outcomes of the present study are all-cause mortality and cardiovascular mortality. The survival status was determined by records from the National Death Index (NDI) maintained by the NCHS up to December 31, 2019 (https://www.cdc.gov/nchs/linked-data/mortality-files/?CDC_AAref_Val=https://www.cdc.gov/nchs/data-linkage/mortality.htm). The International Statistical Classification of Diseases, 10th Revision (ICD-10) codes are used

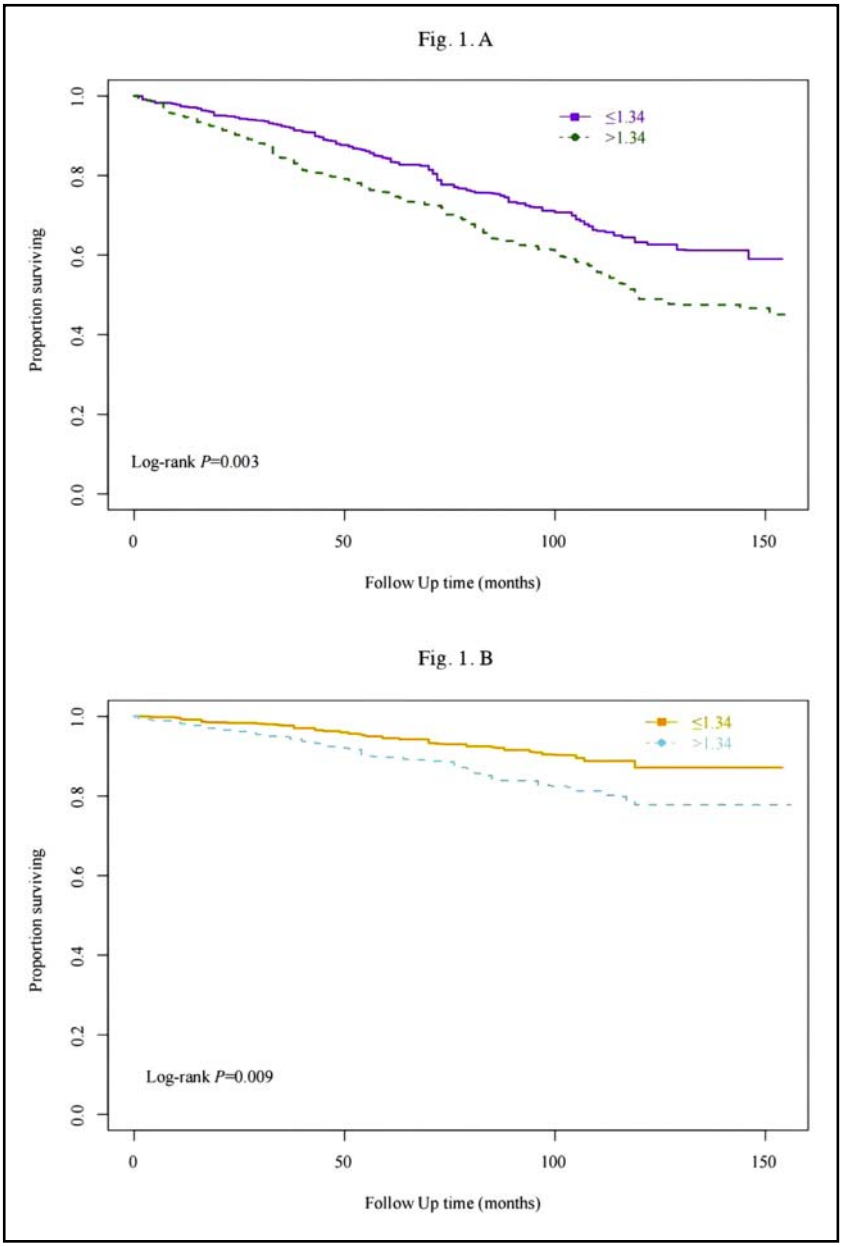


Fig. 1. Kaplan-Meier survival curves for stroke patients stratified by UAR level (Low: ≤1.34, n = 507; High: >1.34, n = 618). A) Overall survival (Log-rank P = 0.003). B) Cardiovascular-specific survival (Log-rank P = 0.009). Participants were followed until death or December 31, 2019 (median follow-up: 66.49 months). Analysis incorporates NHANES sample weights. UAR: uric acid-to-albumin ratio.

to identify cardiovascular deaths (I00-I09, I11, I13, I20-I51, I60-I69), which is consistent with previous studies (Li *et al.* 2025).

Dietary antioxidant quality

The intakes of the anti-oxidative vitamins and minerals were obtained through the 24-hour dietary recall method, including dietary source and the supplement. The DAQS is calculated based on the intake of six dietary antioxidants including vitamins A, vitamin C, vitamin E, zinc, selenium and magnesium. Compared with the corresponding recommended daily intake (RDI) for US adults, a score of 0 is defined as the intake < 2/3 of the RDI while a score of 1 for the intake ≥ 2/3 of the RDI. The range of DAQS is from 0 to 6, with higher score indicating higher level of dietary antioxidant quality. In the present study, the dietary antioxidant quality was dichotomized as high (DAQS ≥5) and low (DAQS <5), following the cutoff used in previous NHANES-based studies (Shi & Fang 2024; Lin *et al.* 2024). Of note, this threshold produced a markedly asymmetric split: only 336 participants (32.5%) met the high-DAQS criterion, while 789 (67.5%) were classified as low DAQS (Table 1), which may limit statistical power in high-DAQS subgroup analyses.

Covariables

Covariates included age, sex, race, education level, poverty income ratio (PIR), smoking status, drinking status, physical activity level, energy intake, history of diseases and medication use were collected through questionnaires. Systolic blood pressure, diastolic blood pressure, height and weight were obtained from anthropometry. Fasting glucose, glycated hemoglobin, total

Tab. 1. Characteristics of the study population

Variables	Total (n=1125)	Low UAR Level (≤ 1.34) (n=507)	High UAR Level (>1.34) (n=618)	*p*
Age, years, Mean (S.E)	64.18 (0.73)	61.75 (1.08)	66.56 (0.81)	<.001
Gender, n (%)				0.010
Male	554 (43.48)	217 (37.58)	337 (49.25)	
Female	571 (56.52)	290 (62.42)	281 (50.75)	
Race, n (%)				<.001
Non-Hispanic White	560 (68.15)	265 (68.47)	295 (67.83)	
Non-Hispanic Black	304 (15.54)	106 (11.90)	198 (19.11)	
Others	261 (16.31)	136 (19.62)	125 (13.05)	
Education, n (%)				0.974
High school and below	689 (58.58)	308 (58.51)	381 (58.64)	
College and above	436 (41.42)	199 (41.49)	237 (41.36)	
PIR, n (%)				0.305
< 1.3	471 (33.97)	229 (35.89)	242 (32.08)	
≥ 1.3	654 (66.03)	278 (64.11)	376 (67.92)	
Smoking, n (%)				0.312
Never	442 (41.54)	204 (43.50)	238 (39.63)	
Ever	683 (58.46)	303 (56.50)	380 (60.37)	
Drink, n (%)				0.272
< 1 time/week	939 (81.61)	422 (79.86)	517 (83.32)	
≥ 1 time/week	186 (18.39)	85 (20.14)	101 (16.68)	
Physical activity, n (%)				0.324
< 450 MET·min/week	106 (8.13)	50 (9.05)	56 (7.22)	
≥ 450 MET·min/week	454 (44.28)	208 (46.10)	246 (42.50)	
Unknown	565 (47.59)	249 (44.85)	316 (50.27)	
Energy intake, kcal, Mean (S.E)	1818.05 (40.43)	1874.10 (59.09)	1763.10 (54.18)	0.168
BMI, kg/m^2, Mean (S.E)	30.14 (0.30)	28.69 (0.45)	31.57 (0.36)	<.001
BMI category, n (%)				<.001
< 25 kg/m^2	268 (24.48)	157 (30.74)	111 (18.34)	
≥ 25 kg/m^2	857 (75.52)	350 (69.26)	507 (81.66)	
Hypertension, n (%)				0.003
No	139 (16.60)	87 (21.62)	52 (11.68)	
Yes	986 (83.40)	420 (78.38)	566 (88.32)	
Diabetes, n (%)				0.212
No	652 (61.09)	313 (63.70)	339 (58.53)	
Yes	473 (38.91)	194 (36.30)	279 (41.47)	
Dyslipidemia, n (%)				0.310
No	119 (9.97)	63 (11.17)	56 (8.80)	
Yes	1006 (90.03)	444 (88.83)	562 (91.20)	
CVDs, n (%)				0.053
No	700 (63.12)	337 (67.90)	363 (58.44)	
Yes	425 (36.88)	170 (32.10)	255 (41.56)	
NLR, Mean (S.E)	2.56 (0.06)	2.44 (0.08)	2.67 (0.08)	0.030
AST, U/L, Mean (S.E)	24.76 (0.41)	24.00 (0.50)	25.50 (0.68)	0.088

Variables	Total (n=1125)	Low UAR Level (≤ 1.34) (n=507)	High UAR Level (>1.34) (n=618)	*p*
ALT, U/L, Mean (S.E)	22.90 (0.60)	23.03 (0.97)	22.77 (0.98)	0.866
UAR, Mean (S.E)	1.41 (0.01)	1.08 (0.02)	1.73 (0.02)	<.001
Uric acid, mg/dL, Mean (S.E)	5.72 (0.06)	4.51 (0.07)	6.90 (0.07)	<.001
Albumin, g/dL, Mean (S.E)	4.10 (0.01)	4.18 (0.02)	4.02 (0.02)	<.001
DAQS score, Mean (S.E)	3.56 (0.07)	3.68 (0.10)	3.45 (0.09)	0.074
DAQS category, n (%)				0.314
High level (≥5)	336 (32.49)	165 (34.59)	171 (30.43)	
Low/median level (<5)	789 (67.51)	342 (65.41)	447 (69.57)	
All-cause mortality, n (%)				0.001
No	769 (72.61)	370 (77.84)	399 (67.48)	
Yes	356 (27.39)	137 (22.16)	219 (32.52)	
Cardiovascular mortality, n (%)				0.009
No	1000 (90.93)	464 (93.57)	536 (88.35)	
Yes	125 (9.07)	43 (6.43)	82 (11.65)	
Follow-up time, months, Mean (S.E)	66.49 (1.99)	68.54 (2.72)	64.47 (2.25)	0.185

S.E: Standard Error. The *p* value was obtained by t-test for continuous variables and chi-square test for categorical variables. All proportions and means are weighted to account for the complex sampling design of NHANES. The UAR cutoff of 1.34 represents the weighted sample median. "Unknown" in the physical activity category reflects participants who did not complete the physical activity questionnaire (n = 565, 47.59% of the sample).

cholesterol, triglyceride, high density lipoprotein, low-density lipoprotein, aspartate aminotransferase (AST), alanine aminotransferase (ALT), neutrophil percent and lymphocyte percent were obtained through laboratory testing.

Overweight is defined as the body mass index (BMI) ≥25 kg/m^2. Hypertension is defined as the systolic blood pressure ≥140 mmHg, or the diastolic blood pressure ≥90 mmHg, or self-report of hypertension/ use of drugs for hypertension. Diabetes is defined as fasting glucose ≥126 mg/dL, or glycated hemoglobin ≥6.5%, or self-report of diabetes/use of drugs for diabetes. Dyslipidemia is defined as total cholesterol ≥200 mg/dL, or triglyceride ≥150 mg/dL, or low-density lipoprotein cholesterol ≥130 mg/dL, or high-density lipoprotein cholesterol ≤40 mg/dL, or self-report of hypercholesteremia/use of drugs for dyslipidemia. Cardiovascular diseases (CVDs) are defined as self-report of at least had one of the diseases below: congestive heart failure, coronary heart disease, angina and heart attack. The neutrophil-to- lymphocyte ratio (NLR) is defined as the neutrophil percent divided by the lymphocyte percent.

Statistical analysis

The two sample t-test was applied for the comparison of the continuous variables between the low and high UAR groups, while chi-square test for categorical variables. Univariate and multivariate Cox proportional hazards models were used to investigate the associations of UAR with all-cause and cardiovascular mortality in the whole stroke population as well as among the different dietary antioxidant quality subgroups. Model I was unadjusted. In Model II, age, race, education, energy intake, physical activity, diabetes, hypertension, CVDs and ALT were adjusted for the all-cause mortality, while age, physical activity, hypertension, dyslipidemia and CVDs were adjusted for the cardiovascular mortality. These covariables were adjusted if they were significantly associated with the corresponding outcome in univariate Cox analysis ($p < 0.05$); this data-driven selection approach may introduce selection bias and should be considered when interpreting the adjusted estimates. The proportional hazards assumption for UAR and other covariates was evaluated using Schoenfeld residuals, and no material violations were detected. Of note, gender, although significantly imbalanced between UAR strata ($p = 0.010$, Table 1), did not reach univariable significance for either mortality outcome and was thus not included in the primary model; gender-adjusted sensitivity analyses (Suppl Tables 2–3) confirmed materially unchanged estimates, supporting the robustness of Model II. In addition, the Kaplan–Meier curves were applied to describe the likelihood of survival and the Log-rank test was used to compare it between the high and the low UAR groups. Finally, the restricted cubic spline (RCS) curves were applied to detect the linear/non-linear relationships of UAR with all-cause mortality and cardiovascular mortality. Sample weights were utilized in all analyses for accounting for unequal selection probabilities. Statistical analyses were conducted with

Tab. 2. Associations of UAR with all-cause and cardiovascular mortality in stroke patients

	Model I		Model II	
	HR (95%CI)	***p***	**HR (95%CI)**	***p***
All-cause mortality				
UAR as continuous	1.88 (1.49-2.37)	<.001	1.49 (1.15-1.93)	0.003
UAR level category				
Low (UAR ≤ 1.34)	Reference		Reference	
High (UAR > 1.34)	1.56 (1.19-2.05)	0.002	1.37 (1.03-1.82)	0.030
Cardiovascular mortality				
UAR as continuous	1.98 (1.31-2.99)	0.001	1.43 (0.92-2.23)	0.108
UAR level category				
Low (UAR ≤ 1.34)	Reference		Reference	
High (UAR > 1.34)	1.92 (1.21-3.05)	0.006	1.64 (1.02-2.62)	0.040

HR: Hazard Ratio; CI: Confidence Interval. All models incorporate NHANES sample weights. UAR as a continuous variable represents the hazard ratio per 1-unit increase in UAR (mg/dL per g/dL). The total number of all-cause deaths was 356 (27.39%); cardiovascular deaths, 125 (9.07%).
Model I: Unadjusted.
Model II (fully adjusted): All-cause mortality - age, race, education, physical activity, energy intake, diabetes, hypertension, CVDs, ALT; Cardiovascular mortality - age, physical activity, hypertension, dyslipidemia, CVDs. Covariates were selected based on univariate significance ($p < 0.05$).

SAS 9.4 (SAS Institute Inc., Cary, NC, USA) and a two-tailed $p < 0.05$ indicated statistically significant. Python 3.9 was used for data cleaning, imputation of missing values and figure generation. The multiple imputation method of the chain equation in random forest was used (miceforest package). There was no significant difference before and after imputations (Suppl Table 1). Physical activity (47.59% missing) was not imputed due to its categorical structure and the large missing fraction; instead, a three-level coding (below recommended, above recommended, unknown) was used as a categorical covariate in all models. Restricting to participants with known physical activity (n = 560), only the continuous UAR was significant for all-cause mortality and marginal significance for cardiovascular mortality (Suppl Table 4).

RESULTS

Characteristics of the study population

For the current study population, the average age was 64.18 and the male participants accounted for 43.48%. The characteristics grouped by median of UAR were described in Table 1. The weighted all-cause mortality and cardiovascular mortality in stroke patients were 27.39% and 9.07%, respectively, which were significantly higher in patients with high level of UAR than those with low level of UAR. Patients with high UAR also had higher age (66.56 vs. 61.75 years), BMI (31.57 vs. 28.69 kg/m^2), NLR (2.67 vs. 2.44), and greater hypertension prevalence (88.32% vs. 78.38%) compared to those with low UAR. Additionally, the high-UAR group had significantly lower albumin levels (4.02 vs. 4.18 g/dL) and higher uric acid levels (6.90 vs. 4.51 mg/dL), confirming the composite nature of UAR. Gender distribution also differed significantly (49.25% male in the high-UAR group vs. 37.58%, $p = 0.010$).

Associations of UAR with all-cause and cardiovascular mortality in stroke patients

UAR was positively associated with the all-cause and cardiovascular mortality in stroke patients in unadjusted analysis. However, only the association between UAR (as continuous) and all-cause mortality was still significant in the multivariate model (all-cause mortality: HR: 1.49, $p = 0.003$; cardiovascular mortality: HR: 1.43, $p = 0.108$). Compared to the patients with low levels of UAR, the risks of all-cause and cardiovascular mortality were significantly increased among those with high UAR levels (all-cause mortality: HR: 1.37, $p = 0.03$; cardiovascular mortality: HR: 1.64, $p = 0.04$) in the fully adjusted model. (Table 2)

Both overall and cardiovascular-specific survival decreased with increasing UAR; lower survival rates were observed in patients with high UAR levels (overall survival: Log-rank $p = 0.003$, Fig. 1 A; cardiovascular-specific survival: Log-rank $p = 0.009$, Fig. 1 B).

Detection of linear/non-linear relationship

Linear trends were detected for the associations of UAR with all-cause and cardiovascular mortality in stroke patients (all-cause mortality: p for overall < 0.001, p for nonlinear = 0.225, Fig. 2 A; cardiovascular mortality: p for overall < 0.001, p for nonlinear = 0.920, Fig. 2 B).

Effect of DAQS on the relationship between UAR with all-cause and cardiovascular mortality in stroke patients

In exploratory analyses stratified by DAQS, high UAR was associated with higher all-cause (HR 1.58, p = 0.003) and cardiovascular mortality (HR 1.83, p = 0.017) among patients with low DAQS (<5). In the high-DAQS subgroup (≥5), categorical UAR associations with both outcomes were non-significant (all-cause: HR 1.17, p = 0.578; cardiovascular: HR 1.47, p = 0.267), and a nominal continuous UAR–cardiovascular mortality association (HR 2.27, 95% CI 1.02–5.08, p = 0.046) was based on few events with wide confidence intervals. Overall, DAQS-stratified results are imprecise and should be regarded as hypothesis-generating (Table 3).

In the subgroup of low dietary antioxidant quality (DAQS <5), both overall and cardiovascular-specific survival decreased with increasing UAR, with lower survival observed among those with high UAR levels (overall survival: Log-rank p <0.0001, Fig. 3 B; cardiovascular-specific survival: Log-rank p = 0.008, Fig. 3 D). However, in the subgroup of high dietary antioxidant quality (DAQS ≥5), the difference of survival proportion between high and low UAR levels were not significant (Both Log-rank p >0.05, Fig. 3 A and Fig. 3 C).

Sensitivity analysis

The T3 (>1.54) of UAR got marginal significance for all-cause mortality (HR T3 vs T1 = 1.35, p = 0.081) (Suppl Table 5). No significant association was found between UAR tertiles and cardiovascular mortality, indicating the association between categorical UAR and CVD mortality was influenced by the cutoff, which should be interpreted with caution. The influence of the

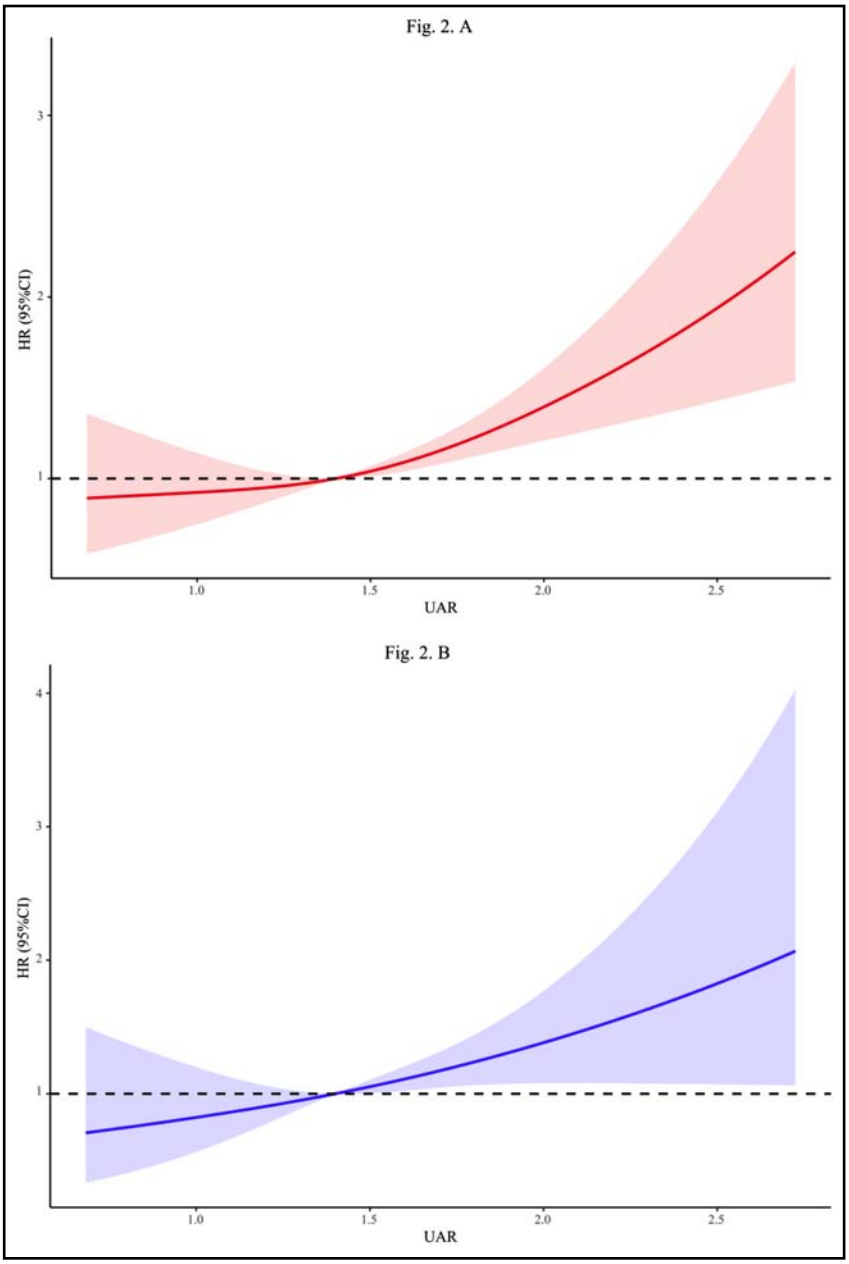


Fig. 2. Restricted cubic spline curves depicting the association between UAR (continuous) and A) all-cause mortality and B) cardiovascular mortality in stroke patients (n = 1,125). Solid lines indicate estimated hazard ratios; shaded areas represent 95% confidence intervals. Models are adjusted for the same covariates as Model II in Table 2. p for overall association: A) <0.001, B) <0.001. p for nonlinearity: A) 0.225, B) 0.920. Analysis incorporates NHANES sample weights. UAR: uric acid-to-albumin ratio.

Tab. 3. Stratified analysis for the associations of UAR with all-cause mortality and cardiovascular mortality in stroke patients based on different level of DAQS

	High dietary antioxidant quality (DAQS ≥5)		Low dietary antioxidant quality (DAQS <5)	
	HR (95%CI)	***p***	**HR (95%CI)**	***p***
All-cause mortality[1]				
UAR as continuous	1.64 (0.79-3.41)	0.178	1.50 (1.15-1.95)	0.003
UAR level category				
Low (UAR ≤ 1.34)	Reference		Reference	
High (UAR > 1.34)	1.17 (0.66-2.08)	0.578	1.58 (1.17-2.14)	0.003
Cardiovascular mortality[2]				
UAR as continuous	2.27 (1.02-5.08)	0.046	1.26 (0.80-2.01)	0.316
UAR level category				
Low (UAR ≤ 1.34)	Reference		Reference	
High (UAR > 1.34)	1.47 (0.74-2.92)	0.267	1.83 (1.12-2.99)	0.017

HR: Hazard Ratio; CI: Confidence Interval.
All models incorporate NHANES sample weights. UAR as a continuous variable represents the hazard ratio per 1-unit increase in UAR. This is a stratified analysis by DAQS level. A formal UAR × DAQS interaction term was added to the fully adjusted Cox model; *p* for interaction = 0.52 for all-cause mortality and 0.71 for cardiovascular mortality. Given the small high-DAQS subgroup (n = 336), these stratified results should be interpreted as hypothesis-generating regardless of interaction *p*-value.
Subgroup sizes: High DAQS (≥5), n = 336 (32.49%), all-cause deaths = [n = 106], cardiovascular deaths = [n = 44]; Low DAQS (<5), n = 789 (67.51%), all-cause deaths = [n = 250], cardiovascular deaths = [n = 81]. The wide confidence intervals in the high-DAQS subgroup reflect limited statistical power due to the smaller subgroup size.
[1]All-cause mortality: adjusted for age, race, education, physical activity, diabetes, hypertension, CVDs, energy intake, ALT.
[2]Cardiovascular mortality: adjusted for age, physical activity, hypertension, dyslipidemia, CVDs.

limited cardiovascular mortality event cannot be ruled out, especially when UAR was divided by three groups.

DISCUSSION

This cohort study showed a clear linear association between higher UAR and increased all-cause mortality in stroke patients after adjustment. Evidence for cardiovascular mortality was modest and model-dependent, and DAQS-stratified patterns were exploratory, with excess risk associated with high UAR mainly in the low-DAQS subgroup and imprecise estimates in the high-DAQS subgroup.

To the best of our knowledge, this is the first study exploring the relationship between UAR and mortality in stroke patients. The positive linear associations of UAR with all-cause and cardiovascular mortality were different from the nonlinear or non-significant associations between uric acid and prognosis of acute stroke patients in previous studies (Liu *et al.* 2022; Zhang *et al.* 2023). This dose-response relationship highlighted pro-oxidative properties of chronic hyperuricemia on long-term mortality of stroke survivors. Similar correlations have been observed among heart diseases and diabetes. The extent of stenosis or occlusion was more severe in coronary artery disease patients with higher UAR than those with low UAR (Çakmak *et al.* 2021; Yalcinkaya *et al.* 2024). Elevated UAR was related to increased long-term cardiac mortality in patients with unstable angina pectoris after percutaneous coronary intervention (Li *et al.* 2022). UAR was identified as an independent risk factor for long-term all-cause and cardiovascular mortality in diabetic patients (Chen *et al.* 2024).

In addition, the findings emphasized the importance of overall dietary antioxidant quality for stroke prognosis especially for those with elevated UAR. Previous evidence suggested that the hyperuricemia-related mortality risk was mitigated among chronic kidney disease patients with higher DAQS (Shi & Fang 2024), demonstrating a similar modifying effect of high dietary antioxidant quality as observed in our study. One study found that the associations between hyperuricemia and all-cause and cardiovascular mortality were non-significant among coronary heart disease patients with adequate magnesium intake and low level of magnesium depletion (Liu *et al.* 2024b).

Of note, continuous UAR remained significantly associated with cardiovascular mortality in the high-DAQS subgroup (HR 2.27, 95% CI 1.02–5.08, $p = 0.046$), a finding that appears inconsistent with the non-significant categorical result (HR 1.47, $p = 0.267$) in the same stratum. This divergence likely reflects the extreme sparsity of cardiovascular events in this subgroup (n = 336, ~30 estimated cardiovascular deaths) combined with the different mathematical scaling of continuous versus categorical UAR, which can produce artefactual significance in small samples.

This finding should be interpreted as spurious pending replication in a larger high-DAQS cohort.

Several mechanisms may underlie the UAR-mortality relationship observed in this cohort. First, chronic systemic inflammation, characterized by elevated uric acid levels and decreased albumin levels, plays a crucial role in the prognosis of stroke (He *et al.* 2025). In the present study, the high-UAR group showed significantly elevated NLR (2.67 vs. 2.44, p = 0.030), consistent with the proposed role of chronic systemic inflammation in post-stroke prognosis; this inflammatory difference may partly explain why the UAR–mortality association was attenuated in those with higher dietary antioxidant quality, given that DAQS has been inversely correlated with inflammatory cytokines (Luu *et al.* 2015). Second, uric acid and UAR were positively related to insulin resistance (Dikker *et al.* 2023), which was an independent risk factor for poor prognosis of stroke (Yang *et al.* 2023), while higher DAQS showed an antagonistic effect with insulin resistance (Wang *et al.* 2025). Third, hyperuricemia had been demonstrated to cause endothelial dysfunction, which also exerted influence on the mortality of stroke patients (Huang *et al.* 2025). Dietary antioxidants could improve endothelial function by reducing reactive oxygen species and preventing oxidative modification of the low-density lipoprotein (Ashor *et al.* 2015). Fourth, the lower albumin levels in the high-UAR group (4.02 vs. 4.18 g/dL, $p < 0.001$; Table 1) independently signal nutritional deficiency, as hypoalbuminaemia has been linked to poor functional outcomes and increased mortality in stroke patients (Thuemmler *et al.* 2024; Zhu *et al.* 2025b).

In terms of the clinical implication, UAR provides a cost-effective tool for identifying high risk stroke patients with poor prognosis by using routine clinical markers, which could be considered in the regular monitoring for stroke patients. In addition, since the levels of antioxidants decreases after stroke (Sánchez-Moreno

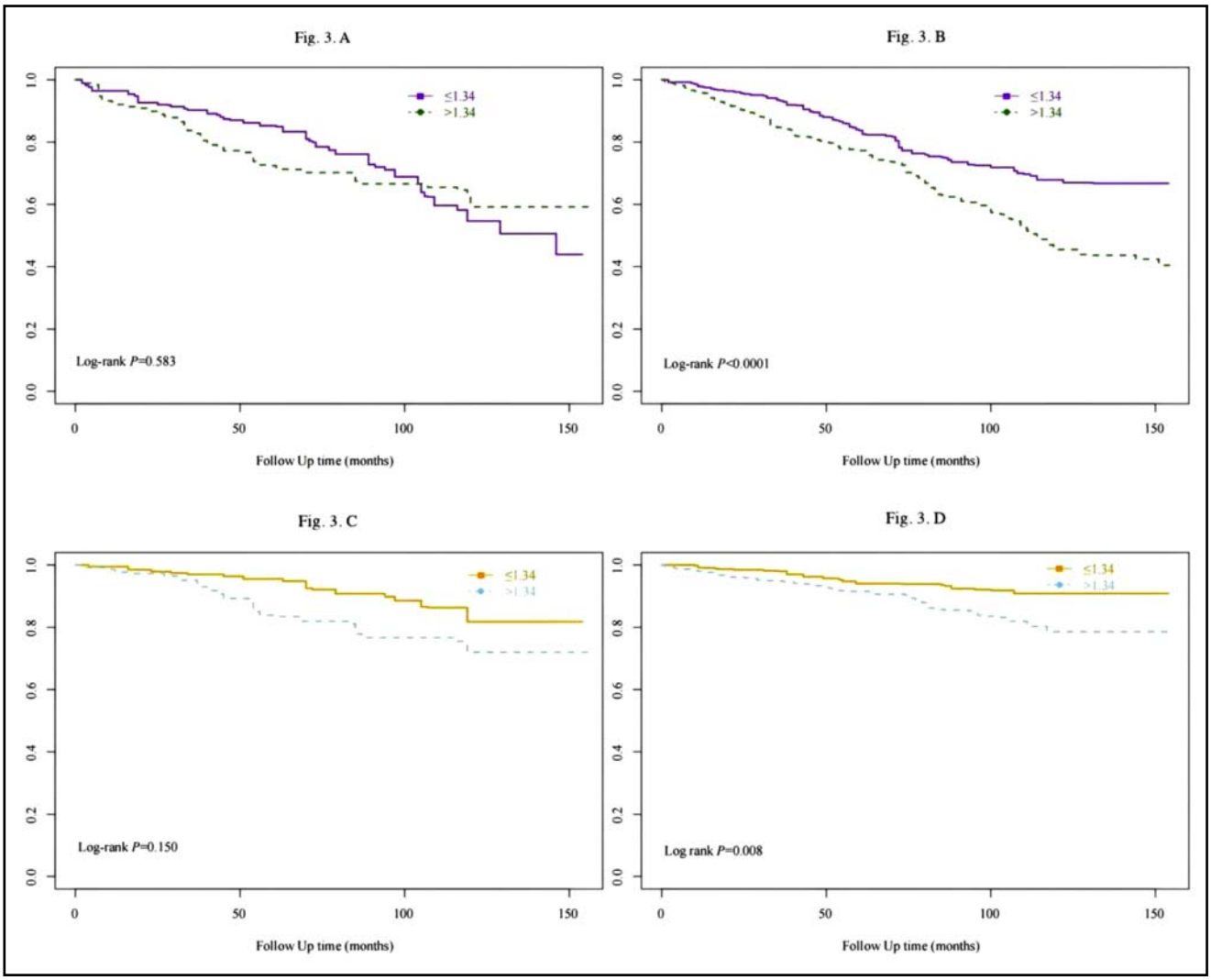


Fig. 3. Kaplan-Meier survival curves stratified by dietary antioxidant quality score (DAQS) and UAR level. Overall survival: A) High DAQS (≥5, n = 336; Log-rank $p > 0.05$) and B) Low DAQS (<5, n = 789; Log-rank $p < 0.0001$). Cardiovascular-specific survival: C) High DAQS (≥5; Log-rank $p > 0.05$) and D) Low DAQS (<5; Log-rank $p = 0.008$). Within each panel, patients are stratified as Low UAR (≤1.34) vs. High UAR (>1.34). Participants were followed until death or December 31, 2019. Analysis incorporates NHANES sample weights. UAR: uric acid-to-albumin ratio; DAQS: dietary antioxidant quality score

et al. 2004), adequate intake of various anti-oxidative nutrients from diet or supplement may provide potential long-term benefits for stroke patients, especially for those with high levels of UAR.

There are several strengths of our study. First, to the best of our knowledge, this is the first study focused on the relationship of UAR with mortality among stroke patients, and the potential effect of dietary antioxidant quality on these associations. This study addresses a critical gap in the literature and broadens the potential clinical utility of UAR, as well as emphasizes the importance of adequate dietary antioxidants on mitigating specific mortality risk in stroke prognosis management. Second, based on the nationally representative data collected by stratified, multistage probability sampling, our sample can well represent the whole US stroke survivors. Third, the median follow-up of 66.49 months ensured sufficient mortality events for robust Cox regression analyses. Despite these strengths, our study has certain limitations. First, although based on the cohort study design, it still cannot establish a causality, clinical trials in stroke patients are warranted to confirm the protective effect of antioxidant supplementation on the elevated mortality risk associated with high UAR. Second, our study was conducted only among US participants, studies in ethnically and geographically diverse populations are needed to confirm the generalizability of these findings. In addition, information on the stroke subtypes was not available in the database, limiting further stratified analyses. Furthermore, physical activity data were unavailable for 565 participants (47.59% of the sample), the largest single source of missing covariate data in this study (Table 1). Although physical activity was included as a categorical covariate with three levels - below recommended, above recommended, and unknown - the high proportion of missing values limits the precision of its adjustment and may introduce residual confounding. Unlike other missing covariates (Table S1 imputation rate ≤7.56%), physical activity was not imputed due to its categorical structure and the large missing fraction; future analyses should explore its sensitivity using available-case restriction. Additionally, despite adjusting for many conventional variables, the possibility of residual confounding cannot be ruled out. Finally, reverse causation cannot be excluded: terminal illness may reduce albumin and elevate uric acid independently, artificially inflating UAR in patients already at high mortality risk. The significantly lower albumin levels in the high-UAR group (4.02 vs. 4.18 g/dL, $p < 0.001$; Table 1) are consistent with this possibility and should be addressed in future studies with repeat UAR measurements.

CONCLUSION

High UAR after stroke was associated with increased all-cause mortality, and to a lesser and less consistent extent with cardiovascular mortality. UAR, derived from routine laboratory tests, may serve as a pragmatic prognostic marker, identifying patients with about 37% higher all-cause mortality risk and, in some models, 64% higher cardiovascular mortality risk. Exploratory DAQS-stratified analyses suggested that excess mortality risk with high UAR was most evident among patients with low DAQS, whereas findings in those with high DAQS were non-significant and imprecise, and should be considered hypothesis-generating.

FUNDING

2023 Guangdong Provincial Hospital of Traditional Chinese Medicine Special Project for Research on Traditional Chinese Medicine Science and Technology, Project Number: YN2023HL15.

REFERENCES

1 Ashor AW, Siervo M, Lara J, Oggioni C, Afshar S, Mathers JC (2015). Effect of vitamin C and vitamin E supplementation on endothelial function: a systematic review and meta-analysis of randomised controlled trials. The British journal of nutrition. **113**(8): 1182–1194. doi: 10.1017/s0007114515000227.

2 Çakmak E, Bayam E, Çelik M, Kahyaoğlu M, Eren K, Imanov E, et al. (2021). Uric Acid-to-Albumin Ratio: A Novel Marker for the Extent of Coronary Artery Disease in Patients with Non-ST-Elevated Myocardial Infarction. Pulse (Basel, Switzerland). **8**(3–4): 99–107. doi: 10.1159/000514533.

3 Chen S, Zhang M, Hu S, Shao X, Liu L, Yang Z, et al. (2024). Uric acid to albumin ratio is a novel predictive marker for all-cause and cardiovascular death in diabetic patients: a prospective cohort study. Frontiers in endocrinology. **15**: 1388731. doi: 10.3389/fendo.2024.1388731.

4 Collaborators GCOD (2024). Global burden of 288 causes of death and life expectancy decomposition in 204 countries and territories and 811 subnational locations, 1990-2021: a systematic analysis for the Global Burden of Disease Study 2021. Lancet (London, England). **403**(10440): 2100–2132. doi: 10.1016/s0140-6736(24)00367-2.

5 Dikker O, Aktaş A, Şahin M, Doğan M, Dağ H (2023). The Association of Serum Uric Acid Levels and Various Uric Acid-Related Ratios with Insulin Resistance and Obesity: A Preliminary Study in Adolescents. Children (Basel, Switzerland). **10**(9): doi: 10.3390/children10091493.

6 Gou R, Luo C, Liang X, Qin S, Wu H, Li B, et al. (2025). Elderly stroke burden: a comprehensive global study over three decades. Frontiers in aging. **6**: 1489914. doi: 10.3389/fragi.2025.1489914.

7 He Y, You J, Fan Z, Wang Z, Qian M (2025). Inflammation mediates the association between hyperuricemia and stroke mortality: a cohort study. Frontiers in neurology. **16**: 1599730. doi: 10.3389/fneur.2025.1599730.

8 Huang Y, Li Z, Wang J, Wang D, Yin X (2025). Endothelial activation and stress index is a reliable predictor for the prevalence and mortality outcomes of stroke. Scientific reports. **15**(1): 23285. doi: 10.1038/s41598-025-06595-5.

9 Li L, Zhao J, Yuan M, Jiang H (2025). Association between the atherogenic index of plasma and mortality in the chronic kidney disease population: evidence from NHANES. Frontiers in medicine. **12**: 1575657. doi: 10.3389/fmed.2025.1575657.

10 Li S, Chen H, Zhou L, Cui H, Liang S, Li H (2022). The uric acid to albumin ratio: a novel predictor of long-term cardiac mortality in patients with unstable angina pectoris after percutaneous coronary intervention. Scandinavian journal of clinical and laboratory investigation. **82**(4): 304–310. doi: 10.1080/00365513.2022.2084698.

11 Lin W, Lin J, Lai F, Shi J (2024). Effect of dietary antioxidant quality score on tobacco smoke exposure and asthma in children and adolescents: a cross-sectional study from the NHANES database. BMC pediatrics. **24**(1): 535. doi: 10.1186/s12887-024-05009-1.

12 Liu CY, Hsiao CL, Chen PY, Tsou A, Tzeng IS, Lin SK (2022). J-Shaped Relationship of Serum Uric Acid with Unfavorable Short-Term Outcomes among Patients with Acute Ischemic Stroke. Biomedicines. **10**(9): doi: 10.3390/biomedicines10092185.

13 Liu X, Chu A, Ding X (2024a). Elevated uric acid to serum albumin ratio: a predictor of short-term outcomes in Chinese heart failure patients. Frontiers in nutrition. **11**: 1481155. doi: 10.3389/fnut.2024.1481155.

14 Liu Y, Wang S, Chen H, Qian X (2024b). Association between dietary magnesium intake, magnesium depletion score and hyperuricemia-related all-cause mortality or cardiovascular mortality in patients with coronary heart disease. Magnesium research. **37**(4): 177–188. doi: 10.1684/mrh.2024.0538.

15 Luu HN, Wen W, Li H, Dai Q, Yang G, Cai Q, et al. (2015). Are dietary antioxidant intake indices correlated to oxidative stress and inflammatory marker levels? Antioxidants & redox signaling. **22**(11): 951–959. doi: 10.1089/ars.2014.6212.

16 Sánchez-Moreno C, Dashe JF, Scott T, Thaler D, Folstein MF, Martin A (2004). Decreased levels of plasma vitamin C and increased concentrations of inflammatory and oxidative stress markers after stroke. Stroke. **35**(1): 163–168. doi: 10.1161/01.Str.0000105391.62306.2e.

17 Şaylık F, Çınar T, Selçuk M, Tanboğa İ H (2023). The Relationship between Uric Acid/Albumin Ratio and Carotid Intima-Media Thickness in Patients with Hypertension. Arquivos brasileiros de cardiologia. **120**(5): e20220819. doi: 10.36660/abc.20220819.

18 Shi S, Fang Q (2024). The association between dietary antioxidant quality score and uric acid related mortality in patients with chronic kidney disease. Frontiers in nutrition. **11**: 1408898. doi: 10.3389/fnut.2024.1408898.

19 Thuemmler RJ, Pana TA, Carter B, Mahmood R, Bettencourt-Silva JH, Metcalf AK, et al. (2024). Serum Albumin and Post-Stroke Outcomes: Analysis of UK Regional Registry Data, Systematic Review, and Meta-Analysis. Nutrients. **16**(10): doi: 10.3390/nu16101486.

20 Wang G, Zhang Y, Li F (2025). Regulating effect of dietary antioxidant quality on association between estimated glucose disposal rate and moderate to severe periodontitis. Frontiers in nutrition. **12**: 1561497. doi: 10.3389/fnut.2025.1561497.

21 Wang J, Wang J, Wang S, Ma J, Yin L, Guo Y, et al. (2024). Association Between Dietary Antioxidant Quality Score (DAQS) and All-Cause Mortality in Hypertensive Adults: A Retrospective Cohort Study from the NHANES Database. Biological trace element research. **202**(11): 4978–4987. doi: 10.1007/s12011-024-04087-7.

22 Xu Q, Qian X, Sun F, Liu H, Dou Z, Zhang J (2023). Independent and joint associations of dietary antioxidant intake with risk of post-stroke depression and all-cause mortality. Journal of affective disorders. **322**: 84–90. doi: 10.1016/j.jad.2022.11.013.

23 Yalcinkaya D, Karacali K, Ilhan BC, Yarlioglues M (2024). Relation Between Serum Uric Acid to Albumin Ratio and Severity of Chronic Coronary Artery Disease. Angiology. **75**(4): 386–393. doi: 10.1177/00033197231161902.

24 Yang Y, Huang X, Wang Y, Leng L, Xu J, Feng L, et al. (2023). The impact of triglyceride-glucose index on ischemic stroke: a systematic review and meta-analysis. Cardiovascular diabetology. **22**(1): 2. doi: 10.1186/s12933-022-01732-0.

25 Yin Y, Zhang L, Zhang J, Jin S (2025). Predictive value of uric acid to albumin ratio for carotid atherosclerosis in type 2 diabetes mellitus: A retrospective study. PloS one. **20**(3): e0320738. doi: 10.1371/journal.pone.0320738.

26 Zhang W, Cheng Z, Fu F, Zhan Z (2023). Serum uric acid and prognosis in acute ischemic stroke: a dose-response meta-analysis of cohort studies. Frontiers in aging neuroscience. **15**: 1223015. doi: 10.3389/fnagi.2023.1223015.

27 Zhang Z, Wu S, Jin T, Duan Z, Du X (2025). Comparative analysis of different stroke subtype burden and future trends over 15 years in China and globally from 1990 to 2021. Frontiers in neurology. **16**: 1631775. doi: 10.3389/fneur.2025.1631775.

28 Zhu B, Huang X, Zhang J, Wang X, Tian S, Zhan T, et al. (2025a). A New Perspective on the Prediction and Treatment of Stroke: The Role of Uric Acid. Neuroscience bulletin. **41**(3): 486–500. doi: 10.1007/s12264-024-01301-3.

29 Zhu Y, Xue G, Xu S, Qin Q, Liu P, Ji L, et al. (2025b). U-Shaped Relationship of Serum Albumin and Neurological Functional Outcomes After Acute Ischemic Stroke: A Prospective Cohort Study. Neurology and therapy. **14**(3): 949–964. doi: 10.1007/s40120-025-00729-7.

SUPPLEMENTARY TABLES AND FIGURE

Supp. Tab. 1A. Variable missing proportion

Variables	Missing proportion
Education	1 (0.09%)
PIR	85 (7.56%)
Drink	75 (6.67%)
BMI	49 (4.36%)
Neutrophils percent	8 (0.71%)
Lymphocyte percent	8 (0.71%)

Supp. Tab. 1B. Variable distribution before and after imputation

Variables	Before imputation	After imputation	*p*
Education, n (%)			0.320
High school and below	688 (58.54)	689 (58.58)	
College and above	436 (41.46)	436 (41.42)	
PIR, n(%)			0.187
<1.3	430 (33.39)	471 (33.97)	
≥1.3	610 (66.61)	654 (66.03)	
Drink, n(%)			0.257
< 1 time/week	873 (81.31)	939 (81.61)	
≥ 1 time/week	177 (18.69)	186 (18.39)	
BMI, kg/m^2, Mean (S.E)	30.15 (0.32)	30.14 (0.30)	0.882
Neutrophils percent, %, Mean (S.E)	60.30 (0.39)	60.29 (0.39)	0.569
Lymphocyte percent, %, Mean (S.E)	27.69 (0.37)	27.69 (0.37)	0.858

S.E: Standard Error. The P value was obtained by t-test for continuous variables and chi-square test for categorical variables. The multiple imputation method of the chain equation in random forest was used, and the imputation processing was carried out using the miceforest package in Python 3.9.

Supp. Tab. 2. Associations of UAR with all-cause and cardiovascular mortality in stroke patients (further adjusted gender)

	Model III	
	HR (95%CI)	*p*
All-cause mortality		
UAR as continuous	1.48 (1.14-1.91)	0.004
UAR level category		
Low (UAR ≤ 1.34)	Reference	
High (UAR > 1.34)	1.34 (1.01-1.79)	0.047
Cardiovascular mortality		
UAR as continuous	1.43 (0.92-2.21)	0.107
UAR level category		
Low (UAR ≤ 1.34)	Reference	
High (UAR > 1.34)	1.63 (1.03-2.58)	0.039

HR: Hazard Ratio; CI: Confidence Interval. All models incorporate NHANES sample weights. UAR as a continuous variable represents the hazard ratio per 1-unit increase in UAR (mg/dL per g/dL). The total number of all-cause deaths was 356 (27.39%); cardiovascular deaths, 125 (9.07%).
Model III (fully adjusted): All-cause mortality - age, gender, race, education, physical activity, energy intake, diabetes, hypertension, CVDs, ALT; Cardiovascular mortality - age, physical activity, hypertension, dyslipidemia, CVDs. Covariates were selected based on univariate significance (P < 0.05).

Supp. Tab. 3. Stratified analysis for the associations of UAR with all-cause mortality and cardiovascular mortality in stroke patients based on different level of DAQS (further adjusted gender)

	High dietary antioxidant quality (DAQS ≥5)		Low dietary antioxidant quality (DAQS <5)	
	HR (95%CI)	***p***	**HR (95%CI)**	***p***
All-cause mortality[1]				
UAR as continuous	1.63 (0.79-3.39)	0.185	1.49 (1.14-1.95)	0.004
UAR level category				
Low (UAR ≤ 1.34)	Reference		Reference	
High (UAR > 1.34)	1.15 (0.66-2.02)	0.613	1.54 (1.13-2.10)	0.007
Cardiovascular mortality[2]				
UAR as continuous	2.26 (1.02-5.00)	0.044	1.26 (0.80-2.00)	0.318
UAR level category				
Low (UAR ≤ 1.34)	Reference		Reference	
High (UAR > 1.34)	1.45 (0.76-2.80)	0.258	1.82 (1.12-2.96)	0.016

HR: Hazard Ratio; CI: Confidence Interval.
All models incorporate NHANES sample weights. UAR as a continuous variable represents the hazard ratio per 1-unit increase in UAR. This is a stratified analysis by DAQS level; no formal UAR × DAQS interaction test was performed. Subgroup sizes: High DAQS (≥5), n = 336 (32.49%), all-cause deaths = [n = 106]; Low DAQS (<5), n = 789 (67.51%), all-cause deaths = [n = 250]. Wide confidence intervals in the high-DAQS subgroup reflect limited statistical power due to the smaller subgroup size.
[1]All-cause mortality: adjusted for age, gender, race, education, physical activity, diabetes, hypertension, CVDs, energy intake, ALT.
[2]Cardiovascular mortality: adjusted for age, gender, physical activity, hypertension, dyslipidemia, CVDs.

Supp. Tab. 4. Associations of UAR with all-cause and cardiovascular mortality in stroke patients [Sensitivity analysis in stroke patients with complete physical activity (n = 560)]

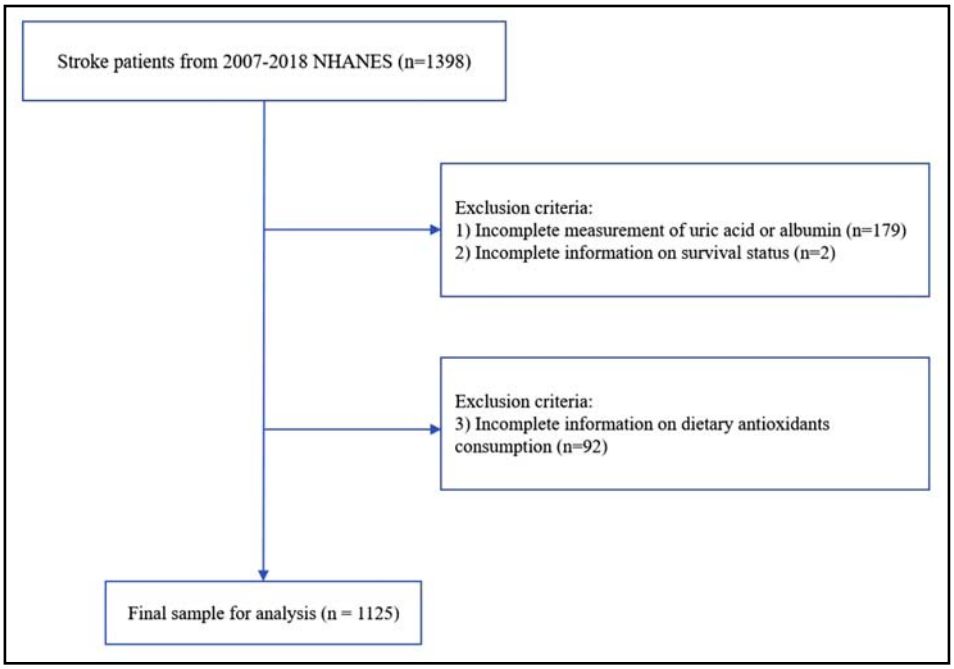
	Model II	
	HR (95%CI)	***p***
All-cause mortality		
UAR as continuous	2.05 (1.08-3.87)	0.028
UAR level category		
Low (UAR ≤ 1.34)	Reference	
High (UAR > 1.34)	1.32 (0.83-2.09)	0.239
Cardiovascular mortality		
UAR as continuous	2.19 (0.96-5.00)	0.061
UAR level category		
Low (UAR ≤ 1.34)	Reference	
High (UAR > 1.34)	1.24 (0.67-2.27)	0.491

HR: Hazard Ratio; CI: Confidence Interval. All models incorporate NHANES sample weights. UAR as a continuous variable represents the hazard ratio per 1-unit increase in UAR (mg/dL per g/dL).
Model II (fully adjusted): All-cause mortality - age, race, education, physical activity, energy intake, diabetes, hypertension, CVDs, ALT; Cardiovascular mortality - age, physical activity, hypertension, dyslipidemia, CVDs. Covariates were selected based on univariate significance ($P < 0.05$).

Supp. Tab. 5. Associations of UAR with all-cause and cardiovascular mortality in stroke patients (Sensitivity analysis based on UAR tertiles)

	Model II	
	HR (95%CI)	***p***
All-cause mortality		
UAR level category		
≤1.20	Reference	
1.20~1.54	0.91 (0.61-1.36)	0.651
>1.54	1.35 (0.96-1.90)	0.081
Cardiovascular mortality		
UAR level category		
≤1.20	Reference	
1.20~1.54	1.02 (0.51-2.04)	0.960
>1.54	1.20 (0.65-2.21)	0.563

HR: Hazard Ratio; CI: Confidence Interval. All models incorporate NHANES sample weights. UAR as a continuous variable represents the hazard ratio per 1-unit increase in UAR (mg/dL per g/dL).
Model II (fully adjusted): All-cause mortality - age, race, education, physical activity, energy intake, diabetes, hypertension, CVDs, ALT; Cardiovascular mortality - age, physical activity, hypertension, dyslipidemia, CVDs. Covariates were selected based on univariate significance ($P < 0.05$).



Supp. Fig. 1. Flowchart of participant selection from the National Health and Nutrition Examination Survey (NHANES) 2007–2018. Stroke patients were identified from the total NHANES sample by self-report. Exclusions were applied sequentially: missing uric acid or albumin (n = 179), missing survival status (n = 2), and incomplete dietary antioxidant data (n = 92), yielding a final analytic sample of n = 1,125.