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ORIGINAL RESEARCH

# Association Between the Atherogenic Index of Plasma and 90-Day Clinical Prognosis in Patients with Acute Pontine Infarction: A Single Center Study

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**Background:** The atherogenic index of plasma (AIP) is a biomarker for coronary heart disease, atherosclerosis, and metabolic syndrome. However, the mechanism of its action in the acute phase of acute pontine infarction remains unclear. This study investigated the association between the AIP and the short-term prognosis of acute pontine infarction.

**Methods:** Clinical and laboratory index data of patients admitted to the hospital for acute pontine infarction were continuously included, and these patients were followed up for 90 days after disease onset. The modified Rankin Scale (mRS) was used to evaluate the 90-day clinical outcomes of the patients, and an mRS score ≥3 was used to define adverse functional outcomes. Univariate analysis was used to detect differences in the indicators between the two groups. Patients were then divided into three groups according to the quantile of the AIP (T1: AIP ≤ 0.029; T2, 0.029 < AIP ≤ 0.248; T3, AIP > 0.248), and a binary logistic regression model was used to assess risk factors for prognosis shortly after acute pontine infarction.

**Results:** A total of 260 patients with acute pontine infarction (mean age=64.5±11.8 years) were included during the study period, and 68 (26.2%) patients had a poor 90-day prognosis. The AIP in the poor 90-day prognosis group was significantly greater (P <0.05) than that in the good 90-day prognosis group. The multivariate logistic regression analysis revealed that the AIP (OR=9.829; 95% CI: 2.837–34.051; p < 0.001), baseline NIHSS score (OR=1.663; 95% CI: 1.400–1.975; p < 0.001) and infarct volume (OR=1.762; 95% CI: 1.013–3.062; p=0.045) were significantly associated with poor 90-day prognosis in patients with acute pontine infarction.

**Conclusion:** In patients with acute pontine infarction, the AIP may serve as an important biological marker of poor clinical prognosis and is independently associated with poor 90-day prognosis.

**Keywords:** lipid metabolism, atherogenic index of plasma, pontine infarction, risk factors, outcome

## Introduction

Pontine infarction accounts for 7% of all ischaemic strokes, and its typical clinical manifestations include binocular synergism, crossed sensory deficits, crossed motor deficits, and quadriplegia.[1] Despite advances in therapeutic strategies and diagnostic methods with improvements in medical standards, a large proportion of patients still have severe clinical symptoms at the onset of the disease and are left with severe neurologic sequelae.[2,3] Therefore, it is of great practical importance to identify biomarkers that can accurately predict the prognosis of patients with pontine infarction. It is well known that atherosclerosis is the most basic aetiology of ischaemic stroke, and dyslipidaemia is the most dangerous risk factor associated with atherosclerosis.[4–7] In recent years, many lipid parameters, such as low-density lipoprotein cholesterol (LDL-C) and triglyceride (TG), have been used to assess the risk of stroke.[8–10] However, the predictive

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value of these indicators is limited, and traditional individual lipid parameters do not fully predict the development and prognosis of acute pontine infarction.

The plasma atherosclerotic index (AIP, log (TG/HDL-C)), a novel marker developed in recent years to monitor cardiovascular disease, is a logarithmic conversion of the ratio of TG levels to high-density lipoprotein-cholesterol (HDL-C) levels.[11,12] Numerous studies have shown that the AIP can indirectly reflect the particle size of small dense LDL-C (sdLDL-C) and is a reliable indicator for assessing cardiovascular risk.[6,11–16] However, there are fewer studies on the association between the AIP and stroke, and the role it plays in acute pontine infarction is reported even less. Therefore, in this study, we analysed the clinical data of patients with acute pontine infarction to explore the relationship between the AIP and acute pontine infarction to provide a foundation for clinical research on practical and effective prevention and treatment of this disease.

# Methods

## Subjects

We included consecutive patients with acute ischaemic stroke who were hospitalized at the Department of Neurology of Fuyang People's Hospital Affiliated with Anhui Medical University between December 2017 and June 2021. Patients >18 years of age who were admitted to the hospital within 3 days of disease onset and who had acute pontine infarction confirmed by perfect cranial diffusion-weighted imaging (DWI) were included in the analysis. The exclusion criteria were as follows: (1) had traumatic brain injury, severe inflammatory or infectious disease; (2) had severe liver disease or kidney failure; (3) had a history of oncological or haematological disorders or immunosuppressive drug use; (4) had incomplete medical or clinical information; (5) had a premorbid modified Rankin Scale (mRS) score >2; and (6) had used lipid-lowering drugs within the previous 3 months. The study protocol was approved by the Research Ethics Committee of Fuyang People's Hospital Affiliated with Anhui Medical University, and all patients or their relatives signed an informed consent form before inclusion.

## Clinical Data Collection

Baseline clinical information, including age, sex, smoking status, past history (including hypertension, diabetes mellitus, coronary artery disease, atrial fibrillation, history of previous stroke or transient ischaemic attack (TIA), smoking status, and alcohol consumption), blood pressure level (systolic or diastolic) at admission, and National Institutes of Health Stroke Scale (NIHSS) score, was collected at patient admission. Hypertension was identified by prior use of antihypertensive medications, a systolic blood pressure (SBP) ≥140 mmHg, or a diastolic blood pressure (DBP) ≥90 mmHg. Diabetes was identified by prior use of antidiabetic medications, fasting blood glucose ≥7.0 mmol/l or 2-hour postprandial blood glucose ≥11.1 mmol/l. The diagnosis of hyperlipidaemia was confirmed on the basis of serum total cholesterol (≥5.2 mmol/L), TG (≥1.7 mmol/L), LDL-C (≥3.4 mmol/L), HDL-C (<1.0 mmol/L), or a previous diagnosis of hyperlipidaemia. Subtypes of pontine infarction are categorized as vertebrobasilar large-artery disease (VLAD), small-artery disease (SAD), basilar artery branch disease (BABD), cardiac embolism (CE), or other determined or undetermined aetiologies.[17] Detailed documentation of discharge medications, including antiplatelet agents, statins, antihypertensive agents, and hypoglycaemic agents, was provided.

Laboratory tests were routinely performed within 24 hours of admission to detect other biochemical parameters, such as urea nitrogen, creatinine, uric acid, TG, total cholesterol, HDL-C, and LDL-C. The AIP is calculated as log (TG/HDL).

All patients underwent DWI and magnetic resonance angiography (MRA) or computed tomography angiography (CTA) within 48 hours of admission. The type of lesion and the presence of arterial stenosis were studied. The infarct volume measured in the DWI sequence was calculated as (length*width*thickness)/2 of the infarct lesion.[18] The longest diameter of each infarct was the length, the widest diameter perpendicular to the longest diameter was the width, and the number of layers of the lesion was the thickness. The slice thickness for the MRI scan was 5 mm. Basilar artery (BA) stenosis (stenosis was diagnosed by reference to the North American Symptomatic Carotid Endarterectomy Test Measurement Criteria for BA stenosis ≥50%).[19] All imaging data were interpreted by experienced neurologists and neuroradiologists at each centre who were unaware of the patients' clinical factors.

## Stroke Severity and Prognosis

The severity of ischaemic stroke at the time of admission was assessed using the NIHSS score.[20] The prognosis of patients at 90 days after the onset of illness was assessed using the mRS. mRS scores of 0–2 points were considered to indicate a good 90-day prognosis, and mRS scores ≥3 points were considered to indicate a poor 90-day prognosis (severe disability or death).[21] Follow-up was conducted by an experienced neurologist specialist via phone or outpatient appointment; most patients were followed-up.

## Statistical Analysis

Data analysis was performed using SPSS version 22.0 for Windows (SPSS Inc., Chicago, IL, USA). Normally distributed data are expressed as $\bar{x} \pm s$ and were assessed using independent-samples *t*-tests or ANOVA. Nonnormally distributed data are expressed as medians and interquartile ranges, and the Mann–Whitney *U*-test was used for comparisons between groups. Count data are expressed as frequencies and percentages, and comparisons between groups were made using the $\chi^2$ test. The relationship between the AIP and clinical outcomes was investigated using binary logistic regression analysis, and the results were analysed using odds ratios (ORs) and 95% confidence intervals (CIs), with $P < 0.05$ considered to indicate statistical significance. Figures were generated using PowerPoint and GraphPad Prism software (version 8.0).

# Results

## Clinical and Demographic Data

We included 260 patients (157 (60.4%) males and 103 (39.6%) females) with acute pontine infarction, and their mean age was 64.5±11.8 years. The baseline NIHSS score was 4 [2–5] (interquartile range (IQR)). In terms of aetiological classification, 95 patients (36.5) had LAOD, 4 patients (1.5%) had CE, 75 patients (28.8%) had BABD, 61 patients (23.5%) had SAD, and 25 patients (9.6%) had acute pontine infarction with other or unknown causes. Fifty patients (19.2%) had basilar artery stenosis. The AIP value was 0.15±0.29. The detailed clinical and demographic data are shown in Table 1. According to the mRS scores, 192 patients (73.8%) were in the good 90-day prognosis group, and 68 patients (26.2%) were in the poor 90-day prognosis group.

**Table 1** Baseline Clinical Characteristics of Patients with Favourable and Unfavourable 90-d Outcomes

| Variable | Favourable Outcome (n=192) | Unfavourable Outcome (n=68) | P |
|---|---|---|---|
| Age (years) | 63.7±11.9 | 66.4±11.5 | 0.106 |
| Male, n (%) | 120 (62.5) | 37 (54.4) | 0.241 |
| **Risk factors, n (%)** | | | |
| Hypertension, n (%) | 164 (85.4) | 52 (76.5) | 0.091 |
| Diabetes, n (%) | 72 (37.5) | 33 (48.5) | 0.111 |
| Atrial fibrillation, n (%) | 2 (1.0) | 4 (5.9) | 0.042 |
| Ischaemic heart disease, n (%) | 13 (6.8) | 7 (10.3) | 0.349 |
| Stroke history, n (%) | 39 (25.5) | 20 (29.4) | 0.532 |
| Smoker, n (%) | 63 (32.8) | 23 (33.8) | 0.879 |
| Alcohol user, n (%) | 80 (41.7) | 22 (32.4) | 0.176 |
| **Etiological subtype, n (%)** | | | |
| LAOD | 68 (35.4) | 27 (39.7) | 0.300 |
| CE | 2 (1.0) | 2 (2.9) | |
| BABD | 53 (27.6) | 22 (32.4) | |
| SAD | 51 (26.6) | 10 (14.7) | |
| OE | 18 (9.4) | 7 (10.3) | |
| SBP (mmHg) | 148.1±20.3 | 149.3±22.2 | 0.697 |
| DBP (mmHg) | 83.4±14.9 | 83.2±13.7 | 0.953 |
| NIHSS score | 4 (3–6) | 8 (7–10) | <0.001 |

(*Continued*)

**Table 1** (Continued).

| Variable | Favourable Outcome (n=192) | Unfavourable Outcome (n=68) | P |
|---|---|---|---|
| **Medications at discharge, n (%)** | | | |
| Antiplatelet agents | 190 (99.0) | 67 (98.5) | 0.776 |
| Statins | 192 (100) | 68 (100) | – |
| Antihypertensives | 120 (62.5) | 33 (48.5) | 0.044 |
| Glucose-lowering agents | 56 (29.2) | 26 (38.2) | 0.167 |
| FBG (mmol/L) | 5.4 (4.9–6.9) | 5.6 (4.8–8.4) | 0.168 |
| TG (mmol/L) | 1.37 (0.94–1.88) | 1.62 (1.12–2.51) | 0.014 |
| HDL-C (mmol/L) | 1.07±0.27 | 1.01±0.22 | 0.129 |
| LDL-C (mmol/L) | 2.78±0.78 | 2.92±0.82 | 0.222 |
| TC (mmol/L) | 4.68±0.98 | 4.88±0.98 | 0.149 |
| BUN (mmol/L) | 5.1 (4.2–6.0) | 5.2 (4.5–6.3) | 0.383 |
| SCr (μmol/L) | 60.4 (50.7–69.8) | 60.5 (50.2–68.7) | 0.745 |
| UA (mmol/L) | 305.9±86.1 | 290.6±79.4 | 0.200 |
| AIP | 0.11±0.28 | 0.25±0.31 | 0.001 |
| AIP (n,%) | | | 0.022 |
| Low tertile | 70 (36.5) | 16 (23.5) | |
| Middle tertile | 66 (34.4) | 20 (29.4) | |
| High tertile | 56 (29.2) | 32 (47.1) | |
| Infarct volume ($mm^3$) | 0.45 (0.19–0.86) | 0.83 (0.44–1.46) | <0.001 |
| BA stenosis, n (%) | 32 (16.7) | 18 (26.5) | 0.078 |

**Note**: Values are expressed as the mean±standard deviation, n (%).
**Abbreviations**: OR, odds ratio; 95% CI, 95% confidence interval. LAOD, large artery occlusive disease; CE, cardiac embolism; BABD, basilar artery branch disease; SAD, small artery disease; OE, other aetiology; NIHSS, National Institutes of Health Stroke Scale; SBP, systolic blood pressure; DBP, diastolic blood pressure; NLR, neutrophil-to-lymphocyte ratio; PLR, platelet-to-lymphocyte ratio; FBG, fasting blood glucose; TC, total cholesterol; TG, triglyceride; LDL-C, low-density lipoprotein cholesterol; SCr, serum creatinine; BUN, blood urea nitrogen; UA, uric acid; BA, basilar artery.

## Comparison of Clinical Data Between the Group with a Good 90-Day Prognosis and the Group with a Poor 90-Day Prognosis in Acute Pontine Infarction

Compared with those in the good 90-day prognosis group, the baseline NIHSS score (P< 0.001) and infarct volume (P< 0.001) were significantly greater in the poor 90-day prognosis group than in the good 90-day prognosis group. Moreover, TG (P=0.014), the AIP (P=0.001), and the number of patients in the high-AIP-quartile group (P=0.022) were greater in the poor 90-day prognosis group than in the good 90-day prognosis group, and the proportion of discharged patients treated with antihypertensive medication was significantly lower in the poor 90-day prognosis group than in the good 90-day prognosis group (P< 0.05). The differences in other indicators were not statistically significant (Table 1 and Figure 1).

## Comparison of Clinical Characteristics After Grouping According to AIP Tertiles at Admission

We classified patients into three groups according to their AIP (T1, AIP ≤ 0.029; T2, 0.029 < AIP ≤ 0.248; and T3, AIP > 0.248). The baseline NIHSS score, infarct volume, proportion of patients with diabetes mellitus, proportion of patients treated with glucose-lowering medication, fasting glucose level, and TG level were significantly greater in patients in the high-AIP-tertile group than in those in the middle- and low-AIP-tertile groups (P < 0.005). In contrast, age and HDL-C were greater in the high-AIP-tertile group than in the middle- and low-AIP-tertile groups (P < 0.005) (Table 2 and Figure 2).

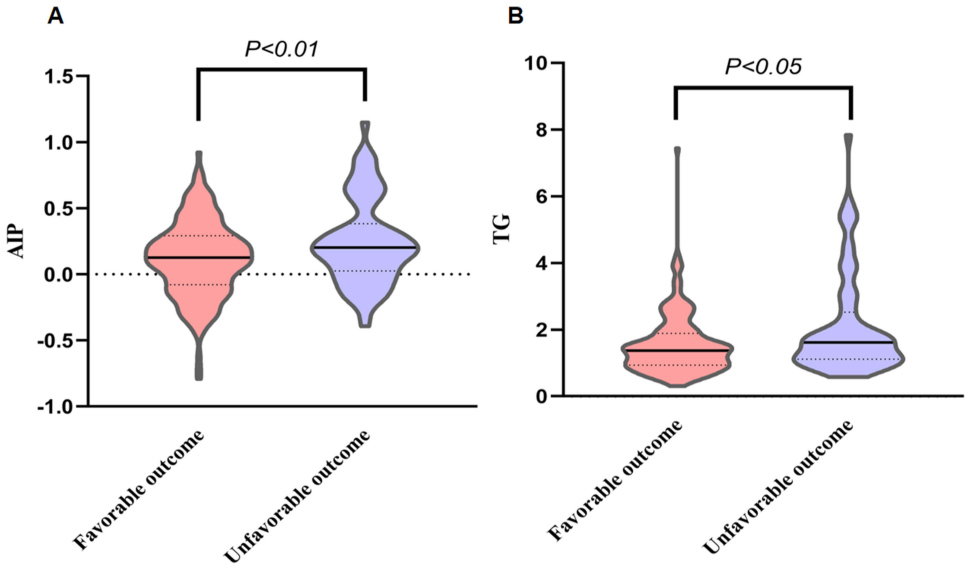


**Figure 1** (**A**) AIP levels in the favourable and unfavourable outcome groups. (**B**) TG levels in the favourable and unfavourable outcome groups.

## Univariate and Multivariate Logistic Regression Analysis of Risk Factors Associated with 90-Day Prognosis in Acute Pontine Infarction Patients

According to the univariate logistic regression analysis, a greater AIP (OR=4.743; 95% CI: 1.775–12.675; p=0.002), atrial fibrillation (OR=5.937; 95% CI: 1.062–33.186; p=0.042), baseline NIHSS score (OR=1.654; 95% CI: 1.417–1.931; p < 0.001), TG level (OR=1.496; 95% CI: 1.167–1.917; p = 0.001), fasting glucose level (OR = 1.148; 95% CI: 1.034–

**Table 2** Demographic and Clinical Characteristics of Acute Pontine Infarction Patients According to AIP Tertiles

| | **Low Tertile (n=86)** | **Middle Tertile (n=86)** | **High Tertile (n=88)** | |
|---|---|---|---|---|
| Variable | AIP≤ 0.029 | 0.029<AIP≤ 0.248 | AIP>0.248 | *P* |
| Age (years) | 67.4±11.5 | 63.8±11.0 | 62.2±12.1 | 0.009 |
| Male, n (%) | 45 (52.3) | 56 (65.1) | 56 (63.6) | 0.171 |
| **Risk factors, n (%)** | | | | |
| Hypertension, n (%) | 73 (84.9) | 72 (83.7) | 71 (80.7) | 0.747 |
| Diabetes, n (%) | 23 (26.7) | 37 (43.0) | 45 (51.1) | 0.004 |
| Atrial fibrillation, n (%) | 2 (2.3) | 1 (1.2) | 3 (3.4) | 0.615 |
| Ischaemic heart disease, n (%) | 4 (4.7) | 8 (9.3) | 8 (9.1) | 0.432 |
| Stroke history, n (%) | 23 (26.7) | 17 (19.8) | 29 (33.0) | 0.144 |
| Smoker, n (%) | 27 (31.4) | 31 (36.0) | 28 (31.8) | 0.773 |
| Alcohol user, n (%) | 35 (40.7) | 38 (44.2) | 29 (33.0) | 0.299 |
| **Etiological Subtype, n (%)** | | | | |
| LAOD | 23 (26.7) | 35 (40.7) | 37 (42.0) | 0.221 |
| CE | 1 (1.2) | 1 (1.2) | 2 (2.3) | |
| BABD | 30 (34.9) | 22 (25.6) | 23 (26.1) | |
| SAD | 21 (24.4) | 24 (27.9) | 16 (18.2) | |
| OE | 11 (12.8) | 4 (4.7) | 10 (11.4) | |
| SBP (mmHg) | 149.9±20.1 | 146.8±18.3 | 148.7±23.7 | 0.609 |
| DBP (mmHg) | 82.7±16.3 | 82.9±13.4 | 84.5±13.5 | 0.658 |
| NIHSS score | 4 (2–5) | 4 (3–5) | 4 (3–5) | 0.769 |
| **Medications at discharge, n (%)** | | | | |
| Antiplatelet agents | 84 (97.7) | 86 (100) | 87 (98.8) | 0.361 |
| Statins | 86 (100) | 86 (100) | 88 (100) | – |
| Antihypertensives | 50 (58.1) | 51 (59.3) | 52 (59.1) | 0.986 |

(*Continued*)

**Table 2** (Continued).

| | Low Tertile (n=86) | Middle Tertile (n=86) | High Tertile (n=88) | |
|---|---|---|---|---|
| Glucose-lowering agents | 14 (16.3) | 29 (33.7) | 39 (44.3) | <0.001 |
| FBG (mmol/L) | 5.19 (4.75–5.81) | 5.43 (4.93–7.74) | 6.13 (5.03–8.12) | <0.001 |
| TG (mmol/L) | 0.85 (0.70–1.01) | 1.42 (1.23–1.63) | 2.44 (1.81–3.13) | <0.001 |
| HDL-C (mmol/L) | 1.23±0.24 | 1.04±0.21 | 0.88±0.19 | <0.001 |
| LDL-C (mmol/L) | 2.78±0.77 | 2.97±0.79 | 2.70±0.81 | 0.071 |
| TC (mmol/L) | 4.65±0.96 | 4.76±0.99 | 4.73±0.98 | 0.602 |
| BUN (mmol/L) | 5.3 (4.3–6.1) | 4.9 (4.2–6.0) | 5.2 (4.6–6.0) | 0.879 |
| SCr (μmol/L) | 59.0 (48.4–68.1) | 60.1 (50.6–67.6) | 61.9 (52.4–71.3) | 0.083 |
| UA (mmol/L) | 293.1±80.1 | 296.00±95.5 | 316.5±76.1 | 0.137 |
| Infarct volume ($mm^3$) | 0.43 (0.20–0.90) | 0.57 (0.31–0.91) | 0.58 (0.33–1.21) | 0.055 |
| BA stenosis, n (%) | 11 (12.8) | 21 (24.4) | 18 (20.5) | 0.144 |

**Note**: Values are expressed as the mean±standard deviation, n (%).

**Abbreviations**: OR, odds ratio; 95% CI, 95% confidence interval. LAOD, large artery occlusive disease; CE, cardiac embolism; BABD, basilar artery branch disease; SAD, small artery disease; OE, other aetiology; NIHSS, National Institutes of Health Stroke Scale; SBP, systolic blood pressure; DBP, diastolic blood pressure; AIP, atherogenic index of plasma; FBG, fasting blood glucose; TC, total cholesterol; TG, triglyceride; LDL-C, low-density lipoprotein cholesterol; SCr, serum creatinine; BUN, blood urea nitrogen; UA, uric acid; BA, basilar artery.

1.275; p = 0.010), and infarct volume (OR = 2.926; 95% CI: 1.850–4.627; p < 0.001) were associated with a poor 90-d prognosis in acute pontine infarction patients, whereas discharge hypertensive drug treatment (OR = 0.566; 95% CI: 0.324–0.989; p = 0.045) was associated with a good 90-d prognosis in acute pontine infarction patients (Figure 3). Further analysis using multifactorial logistic regression showed that a greater AIP (OR=9.829; 95% CI: 2.837–34.051; p < 0.001), baseline NIHSS score (OR=1.663; 95% CI: 1.400–1.975; p < 0.001) and infarct volume (OR=1.762; 95% CI: 1.013–3.062; p = 0.045) were significantly associated with a poor 90-d prognosis in acute pontine infarction patients,

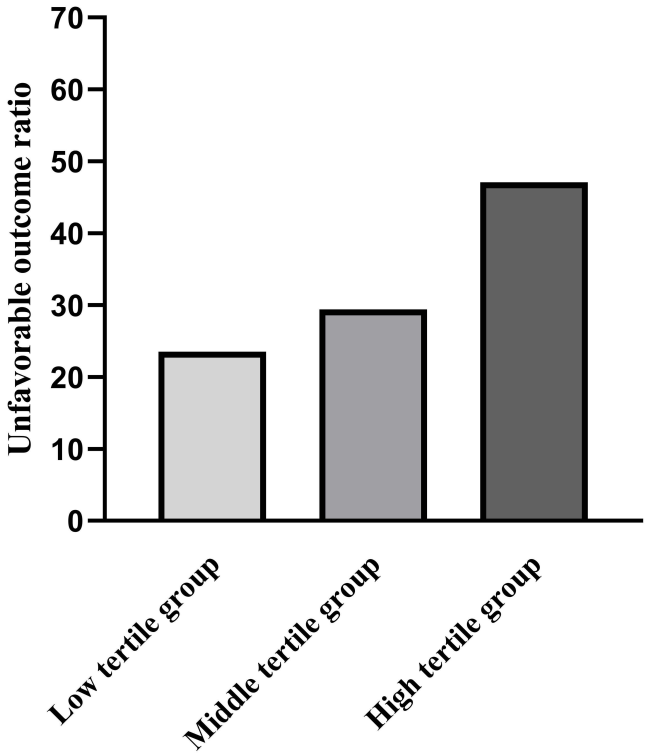


**Figure 2** Percentage of patients with unfavourable outcomes stratified by the AIP tertile.

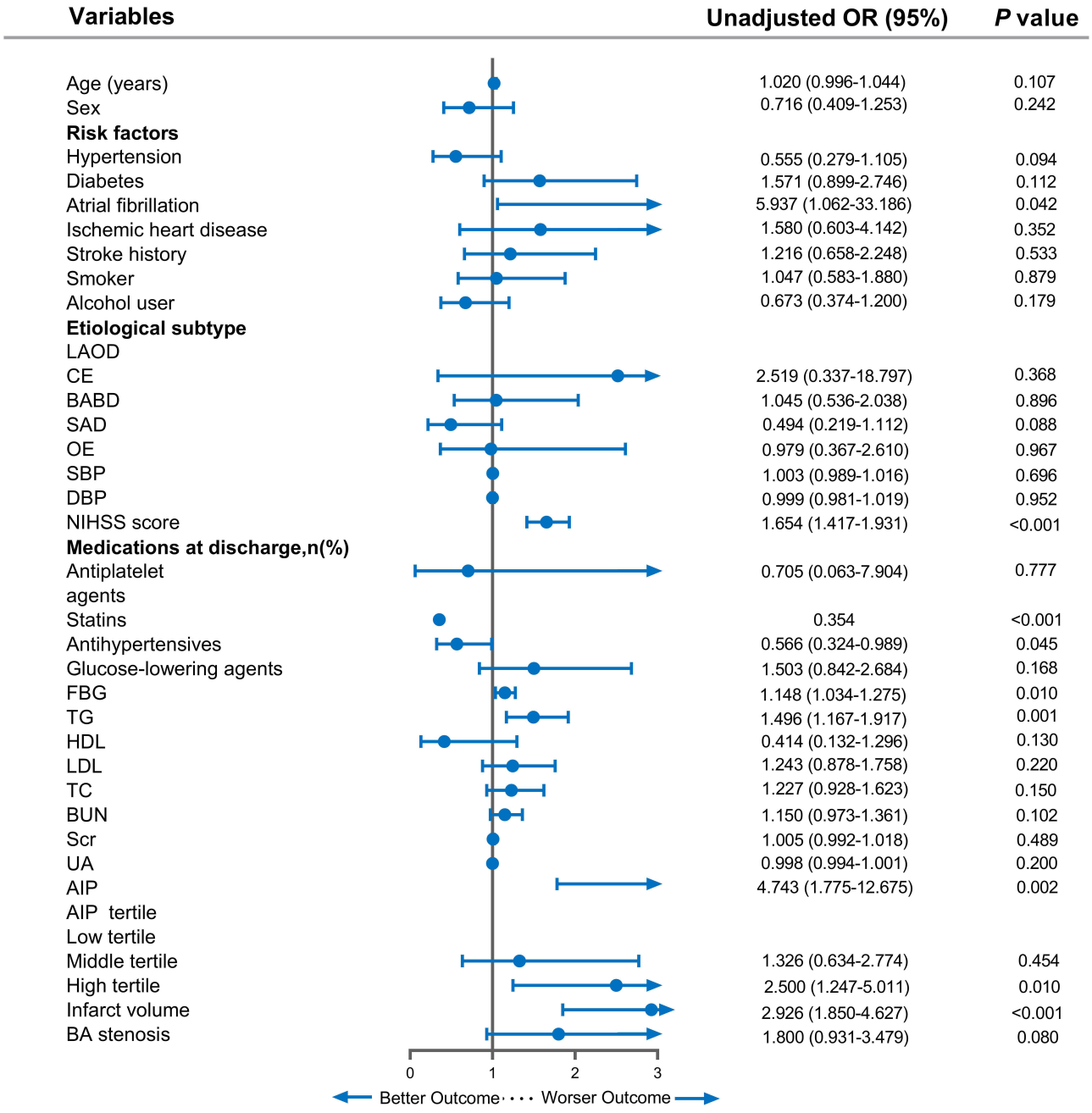


**Figure 3** Univariate logistic regression analysis of risk factors associated with an unfavourable 90-day outcome in acute pontine infarction patients.

whereas discharge antihypertensive medication treatment (OR = 0.464; 95% CI: 0.235–0.914; p = 0.026) was associated with a good 90-d prognosis in acute pontine infarction patients (Figure 4).

## Discussion

To our knowledge, this study is the first to investigate the relationship between the AIP and the prognosis of acute pontine infarction, which not only provides an important clinical basis for the secondary prevention of acute pontine infarction but also provides data supporting this type of research. The key finding of this study is that the AIP is an independent risk factor for acute pontine infarction. We recommend the establishment of a scientifically effective secondary prevention system to improve the quality of life of patients with acute pontine infarction through chronic comorbidity management, safe medication use, and the promotion of healthy lifestyles.

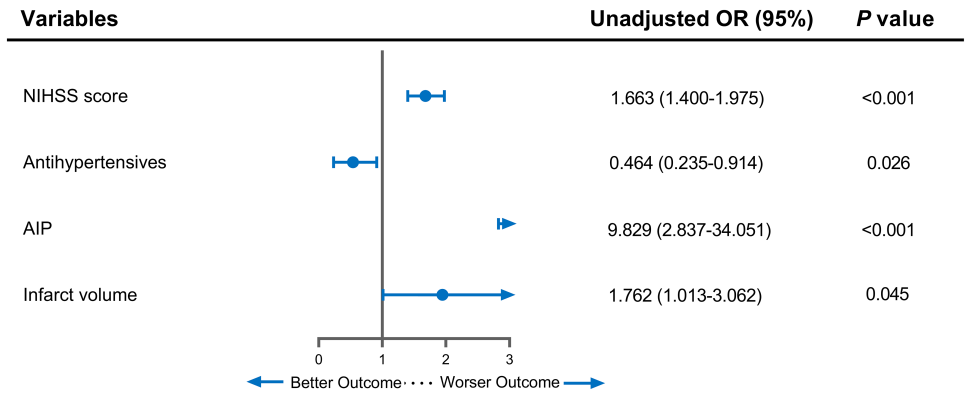


**Figure 4** Multivariate logistic regression analysis of risk factors associated with an unfavourable 90-day outcome in acute pontine infarction patients.

Pontine infarcts are the most common brainstem infarcts,[1] and the clinical presentation of patients at onset is more severe due to the relative concentration of fibrous conduction bundles caused by pontine infarction.[22] Atherosclerosis is the most basic aetiology of ischaemic stroke, and dyslipidaemia is the most important risk factor for atherosclerosis.[4–7] Therefore, active control of lipid levels is crucial for preventing acute ischaemic stroke. Previous studies have identified LDL-C in lipid profiles as a core lipid component contributing to atherosclerosis,[23] but its clinical value as a traditional individual lipid parameter for assessing stroke prognosis remains limited. Recent studies have shown[6,11–16] that the AIP index, which can indirectly reflect the particle size of sdLDL-C, is a new and novel marker for monitoring dyslipidaemia. Not only is the AIP more stable than other conventional lipid parameters, but more importantly, it has excellent potential for clinical use.

Several studies have clearly indicated that the AIP is a good marker for monitoring coronary heart disease, metabolic syndrome, and atherosclerosis.[11–16,24,25] In a case–control study conducted by Chen et al[6] which involved 340 individuals, the AIP was identified as an independent risk factor for acute myocardial infarction after adjusting for traditional risk factors. A study indicated that the AIP was not only the sole lipid parameter independently associated with symptomatic carotid artery stenosis but also that the AIP could serve as a valid alternative to sdLDL in patients with symptomatic carotid artery stenosis.[26] A cross-sectional study which included 1488 patients who underwent coronary computed tomography angiography and was aimed at evaluating the relationship between the AIP and rapid progression of coronary atherosclerosis (AS), ultimately revealed that the AIP was an independent predictor of rapid progression of AS.[11] Liu et al[12] conducted a prospective study involving 1463 patients with acute ischaemic stroke, and multifactorial logistic regression analysis revealed that the AIP was associated with a poor 3-month prognosis in patients with acute ischaemic stroke. However, there are no studies examining the relationship between the AIP and acute pontine infarction.

In this study, the AIP was found to be an independent risk factor for acute pontine infarction. This may be related to the fact that the AIP can indirectly reflect the particle size of sdLDL-C. During the development of stroke, lipid particles of different sizes have different effects, especially sdLDL-C, which has been shown to be an independent risk factor for acute ischaemic stroke.[27] sdLDL-C is more likely to bind to anionic proteoglycans in the arterial wall as it passes through the vascular endothelium due to its smaller particle diameter, greater density, and greater penetration, thus adhering to the vascular wall to form lipid deposits.[12,28] Moreover, sdLDL-C has a much lower affinity for the LDL receptor, has a longer half-life in plasma, and is eliminated slowly. This would increase the risk of sdLDL-C being oxidated in the vasculature and transformed into foam cells by macrophage phagocytosis.[29] In addition, sdLDL-C is susceptible to oxidative modification to oxidized LDL, which is cytotoxic, damages the vascular endothelium and stimulates the proliferation and migration of vascular smooth muscle cells to the endothelium.[30] In addition to this phenotype of LDL, Lp-PLA2 is highly susceptible to binding to sdLDL-C, thereby producing lysophosphatidylcholine, which promotes the release of inflammatory factors and increases oxidative stress.[16] Thus, it is evident that there is an overall association between sdLDL-C and atherogenicity,[31] and the AIP, as an indirect indicator of sdLDL-C, allows for a more accurate evaluation of lipid-induced stroke trends.

This study also revealed that infarct volume was significantly greater in patients in the poor 90-day prognosis group than in those in the good 90-day prognosis group. This may be due to the relative concentration of fibrous conduction bundles caused by acute pontine infarcts, and the larger the infarct volume is, the greater the damage to the conduction bundles, the more severe the clinical symptoms are at onset, and the poorer the prognosis of the patient. Second, the larger the infarct is, the more severe the reactive oedema around the lesion, which can cause significant compression of peripheral vessels. This affects the establishment of collateral circulation and leads to more extensive conduction bundle involvement.[9,32] Patients with pontine infarcts with larger infarct volumes are more likely to have early disease progression, further leading to a poor prognosis.[33] Consistent with previous studies, the baseline NIHSS score was significantly lower in the good 90-day prognosis group than in the poor 90-day prognosis group, and a high NIHSS score is a risk factor for poor 90-day prognosis in acute ischaemic stroke patients.[22]

In the present study, treatment with antihypertensive medications after discharge was associated with a good 90-day prognosis in patients with acute pontine infarction after adjusting for other confounders in a multivariate analysis. Previous studies have shown that regular use of antihypertensive medications to control blood pressure reduces the risk of death in stroke patients. A 10 mmHg reduction in systolic blood pressure or a 5 mmHg reduction in diastolic blood pressure reduces the risk of stroke by 40%.[34] It also reduces the recurrence rate of stroke by 30%. Beckett et al also showed that a reduction in SBP reduced all-cause mortality in stroke patients.[35] Therefore, in clinical practice, blood pressure should be controlled in acute pontine infarction patients, and patients should be encouraged to pay attention to the management and monitoring of blood pressure to reduce the number of deaths and improve their quality of life and prognosis.

The present study demonstrated for the first time the impact of the AIP on the prognosis of patients with acute pontine infarction, but there are some limitations. First, this was a single-centre study with a small sample size, and there was selection bias. Second, we only measured baseline AIP levels and did not dynamically monitor changes in the AIP during follow-up in real time. In the future, prospective multicentre studies with larger sample sizes are needed to validate this conclusion.

## Conclusion

The AIP may serve as an important biological marker for predicting poor clinical prognosis in patients with acute pontine infarction, and the AIP was independently associated with poor 90-day prognosis in patients with acute pontine infarction.

## Data Sharing Statement

The data used and analysed in the study can be obtained from the corresponding author upon reasonable request.

## Ethics Statement

The study protocol was approved by the Research Ethics Committee of The Affiliated Fuyang People's Hospital of Anhui Medical University (approval number: [2022] 180), and all patients or their relatives signed an informed consent form before inclusion. All procedures were performed in accordance with the declaration of Helsinki.

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## Disclosure

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as potential conflicts of interest.

## References


1. Maeshima S, Osawa A, Miyazaki Y, et al. Functional outcome in patients with pontine infarction after acute rehabilitation. *Neurol Sci*. 2012;33(4):759–764. doi:10.1007/s10072-011-0812-0
2. Zhou M, Wang H, Zeng X, et al. Mortality, morbidity, and risk factors in China and its provinces, 1990–017: a systematic analysis for the Global Burden of Disease Study 2017. *Lancet*. 2019;394(10204):1145–1158. doi:10.1016/S0140-6736(19)30427-1
3. Radu RA, Terecoasă EO, Băjenaru OA, Tiu C. Etiologic classification of ischemic stroke: where do we stand? *Clin Neurol Neurosurg*. 2017;159:93–106. doi:10.1016/j.clineuro.2017.05.019
4. Lawler PR, Kotrri G, Koh M, et al. Real-world risk of cardiovascular outcomes associated with hypertriglyceridaemia among individuals with atherosclerotic cardiovascular disease and potential eligibility for emerging therapies. *Eur Heart J*. 2020;41(1):86–94. doi:10.1093/eurheartj/ehz767
5. Toth PP, Philip S, Hull M, et al. Association of elevated triglycerides with increased cardiovascular risk and direct costs in statin-treated patients. *Mayo Clin Proc*. 2019;94(9):1670–1680. doi:10.1016/j.mayocp.2019.03.028
6. Chen M, Fang CY, Guo JC, et al. Predictive value of atherogenic index of plasma and atherogenic index of plasma combined with low-density lipoprotein cholesterol for the risk of acute myocardial infarction. *Front Cardiovasc Med*. 2023;10:1117362. doi:10.3389/fcvm.2023.1117362
7. Kim YG, Cho YR, Park GM, et al. High-density lipoprotein cholesterol and the risk of obstructive coronary artery disease beyond low-density lipoprotein cholesterol in non-diabetic individuals. *Eur J Prev Cardiol*. 2020;27(7):706–714. doi:10.1177/2047487319844364
8. Huang YQ, Huang JY, Liu L, et al. Relationship between triglyceride levels and ischaemic stroke in elderly hypertensive patients. *Postgrad Med J*. 2020;96(1133):128–133. doi:10.1136/postgradmedj-2019-136961
9. Wang A, Dai L, Zhang N, et al. Oxidized low-density lipoprotein (LDL) and LDL cholesterol are associated with outcomes of minor stroke and TIA. *Atherosclerosis*. 2020;297:74–80. doi:10.1016/j.atherosclerosis.2020.02.003
10. Wang Y, Song Q, Cheng Y, et al. Association between non-high-density lipoprotein cholesterol and haemorrhagic transformation in patients with acute ischaemic stroke. *BMC Neurol*. 2020;20(1):47. doi:10.1186/s12883-020-1615-9
11. Won KB, Heo R, Park HB, et al. Atherogenic index of plasma and the risk of rapid progression of coronary atherosclerosis beyond traditional risk factors. *Atherosclerosis*. 2021;324:46–51. doi:10.1016/j.atherosclerosis.2021.03.009
12. Liu H, Liu K, Pei L, et al. Atherogenic Index of plasma predicts outcomes in acute ischemic stroke. *Front Neurol*. 2021;12:741754. doi:10.3389/fneur.2021.741754
13. Wu J, Zhou Q, Wei Z, et al. Atherogenic Index of plasma and coronary artery disease in the adult population: a meta-analysis. *Front Cardiovasc Med*. 2021;8:817441. doi:10.3389/fcvm.2021.817441
14. Kammar-García A, López-Moreno P, Hernández-Hernández ME, et al. Atherogenic index of plasma as a marker of cardiovascular risk factors in Mexicans aged 18 to 22 years. *Proc*. 2020;34(1):22–27. doi:10.1080/08998280.2020.1799479
15. Fernández-Macías JC, Ochoa-Martínez AC, Varela-Silva JA, et al. Atherogenic Index of plasma: novel predictive biomarker for cardiovascular illnesses. *Arch Med Res*. 2019;50(5):285–294. doi:10.1016/j.arcmed.2019.08.009
16. Wang Q, Jiang G, Yan L, et al. Association of atherogenic index of plasma with early neurological deterioration in patients with acute ischemic stroke. *Clin Neurol Neurosurg*. 2023;234:108014. doi:10.1016/j.clineuro.2023.108014
17. Kumral E, Bayülkem G, Evyapan D. Clinical spectrum of pontine infarction. Clinical-MRI correlations. *J Neurol*. 2002;249(12):1659–1670. doi:10.1007/s00415-002-0879-x
18. Liu Y, Peng H, Wang J, et al. Risk factors for early neurological deterioration in acute isolated pontine infarction without any causative artery stenosis. *BMC Neurol*. 2022;22(1):332. doi:10.1186/s12883-022-02861-5
19. Barnett HJM, Taylor DW. North American Symptomatic Carotid Endarterectomy Trial Collaborators. Beneficial effect of carotid endarterectomy in symptomatic patients with high-grade carotid stenosis. *N Engl J Med*. 1991;325(7):445–453. doi:10.1056/NEJM199108153250701
20. Kniep H, Bechstein M, Broocks G, et al. Early surrogates of outcome after thrombectomy in posterior circulation stroke. *Eur J Neurol*. 2022;29(11):3296–3306. doi:10.1111/ene.15519
21. Lima FO, Furie KL, Silva GS, et al. The pattern of leptomeningeal collaterals on CT angiography is a strong predictor of long-term functional outcome in stroke patients with large vessel intracranial occlusion. *Stroke*. 2010;41(10):2316–2322. doi:10.1161/STROKEAHA.110.592303
22. Zhai M, Cao S, Wang X, et al. Increased neutrophil-to-lymphocyte ratio is associated with unfavorable functional outcomes in acute pontine infarction. *BMC Neurol*. 2022;22(1):445. doi:10.1186/s12883-022-02969-8
23. Falk E. Pathogenesis of atherosclerosis. *J Am Coll Cardiol*. 2006;47(8 Suppl):C7–C12. doi:10.1016/j.jacc.2005.09.068
24. Huang H, Yu X, Li L, et al. Atherogenic index of plasma is related to coronary atherosclerotic disease in elderly individuals: a cross-sectional study. *Lipids Health Dis*. 2021;20(1):68. doi:10.1186/s12944-021-01496-8
25. Qin Z, Zhou K, Li Y, et al. The atherogenic index of plasma plays an important role in predicting the prognosis of type 2 diabetic subjects undergoing percutaneous coronary intervention: results from an observational cohort study in China. *Cardiovasc Diabetol*. 2020;19(1):23. doi:10.1186/s12933-020-0989-8
26. Garg R, Knox N, Prasad S, et al. The atherogenic index of plasma is independently associated with symptomatic carotid artery stenosis. *J Stroke Cerebrovasc Dis*. 2020;29(12):105351. doi:10.1016/j.jstrokecerebrovasdis.2020.105351
27. Duran EK, Aday AW, Cook NR, et al. Triglyceride-rich lipoprotein cholesterol, small dense LDL Cholesterol, and incident cardiovascular disease. *J Am Coll Cardiol*. 2020;75(17):2122–2135. doi:10.1016/j.jacc.2020.02.059
28. Santos HO, Earnest CP, Tinsley GM, et al. Small dense low-density lipoprotein-cholesterol (sdLDL-C): analysis, effects on cardiovascular endpoints and dietary strategies. *Prog Cardiovasc Dis*. 2020;63(4):503–509. doi:10.1016/j.pcad.2020.04.009
29. Higashioka M, Sakata S, Honda T, et al. Small dense low-density lipoprotein cholesterol and the risk of coronary heart disease in a Japanese community. *J Atheroscler Thromb*. 2020;27(7):669–682. doi:10.5551/jat.51961

30. Shen SW, Lu Y, Li F, et al. Atherogenic index of plasma is an effective index for estimating abdominal obesity. *Lipids Health Dis*. 2018;17(1):11. doi:10.1186/s12944-018-0656-1
31. Ikezaki H, Lim E, Cupples LA, et al. Small dense low-density lipoprotein cholesterol is the most atherogenic lipoprotein parameter in the Prospective Framingham Offspring Study. *J Am Heart Assoc*. 2021;10(5):e019140. doi:10.1161/JAHA.120.019140
32. Yu C, Zhu C, Zhang Y, et al. A longitudinal diffusion tensor imaging study on Wallerian degeneration of corticospinal tract after motor pathway stroke. *Neuroimage*. 2009;47(2):451–458. doi:10.1016/j.neuroimage.2009.04.066
33. Li H, Dai Y, Wu H, et al. Predictors of early neurologic deterioration in acute pontine infarction. *Stroke*. 2020;51(2):637–640. doi:10.1161/STROKEAHA.119.027239
34. Law MR, Morris JK, Wald NJ. Use of blood pressure lowering drugs in the prevention of cardiovascular disease: meta-analysis of 147 randomised trials in the context of expectations from prospective epidemiological studies. *BMJ*. 2009;338:b1665. doi:10.1136/bmj.b1665
35. Beckett NS, Peters R, Fletcher AE, et al. Treatment of hypertension in patients 80 years of age or older. *N Engl J Med*. 2008;358(18):1887–1898. doi:10.1056/NEJMoa0801369