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Association of Aortic Arch Atherosclerosis on Chest Radiography with Ischemic Stroke on Non-Contrast Head CT Scan at Royal Prima General Hospital, Medan

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ABSTRACT

Background: Aortic arch calcification (AAC) visible on chest radiography is a surrogate marker of atherosclerotic burden; it is not equivalent to complex aortic arch plaque, the established embolic source of ischemic stroke. Data on the association between radiographic AAC and ischemic stroke in Indonesian patients are limited.

Methods: This single-center retrospective cross-sectional study included 100 adults (≥18 years) who underwent non-contrast head CT for suspected stroke and a posteroanterior chest radiograph during the same hospital visit at Royal Prima General Hospital, Medan; all eligible records in the study period were included (total sampling). AAC was graded 0–3 using the Iijima criteria. Ischemic stroke was defined as a hypodense lesion in an arterial territory on CT without intracranial hemorrhage. Crude prevalence ratios (PR) with 95% confidence intervals (CI), chi-square and Cochran–Armitage trend tests, and Spearman correlation were used.

Results: Mean age was 63.7 ± 9.1 years and 60% were male. AAC was present in 70% (grades 2–3 in 40%) and ischemic stroke in 68% of this selected sample. The crude proportion with ischemic stroke increased across AAC grades: 33.3% (grade 0), 66.7% (grade 1), 90.0% (grade 2), and 100% (grade 3) ($p < 0.001$ for trend). Any AAC was associated with a higher crude prevalence of ischemic stroke (PR 2.49, 95% CI 1.48–4.17); the corresponding odds ratio (9.67, 95% CI 3.62–25.79) overstates this relative prevalence because the outcome was common and should not be read as a risk ratio. AAC grade correlated strongly with age (Spearman $\rho = 0.807$, 95% CI 0.71–0.87), and age ≥60 years was strongly associated with ischemic stroke (PR 3.69, 95% CI 2.08–6.52), whereas sex was not ($p = 0.93$). Because AAC grade and age were strongly correlated, the crude association may be substantially confounded by age.

Conclusion: In this selected hospital imaging cohort, radiographic AAC showed a graded, unadjusted association with ischemic stroke that was closely intertwined with age. Because no age-adjusted analysis was performed and major vascular risk factors were unavailable, whether AAC grading on clinically indicated chest radiographs adds information beyond age and conventional risk factors requires validation in prospective studies with comprehensive confounder adjustment and reliability assessment.

Keywords: aortic arch calcification, chest radiography, ischemic stroke, non-contrast head CT, atherosclerosis

Introduction

Stroke remains a leading cause of morbidity, mortality, and disability worldwide. According to the Global Burden of Disease (GBD) Study 2021, there were approximately 11.9 million incident strokes and 7.3 million stroke-related deaths globally in 2021, and ischemic stroke accounted for 65.3% of incident strokes (GBD 2021 Stroke Risk Factor Collaborators, 2024). The World Stroke Organization reports that stroke is the second leading cause of death and the third leading cause of death and disability combined, and that 86.0% of stroke deaths occur in lower-income and lower–middle-income countries (Feigin et al., 2022). Projections from the World Stroke Organization–Lancet Neurology Commission estimate that annual stroke deaths will increase from 6.6 million in 2020 to 9.7 million by 2050 unless prevention efforts are strengthened (Feigin et al., 2023).

In Indonesia, the National Basic Health Research (Riskesdas) reported that the prevalence of stroke among residents aged 15 years and older increased from 7.0 per 1,000 in 2013 to 10.9 per

1,000 in 2018 (Kementerian Kesehatan Republik Indonesia, 2018). The more recent Indonesian Health Survey (Survei Kesehatan Indonesia, SKI) 2023 reported a stroke prevalence of 8.3 per 1,000 population (Kementerian Kesehatan Republik Indonesia, 2024); because the two surveys differ in design and case ascertainment, these figures should not be read as a direct trend. Hospital-based data from an Indonesian tertiary referral center indicate that large-artery atherosclerosis is one of the most common ischemic stroke subtypes, underscoring the relevance of atherosclerotic markers in Indonesian patients with ischemic stroke (Harris et al., 2018).

From a radiological perspective, neuroimaging is essential in the evaluation of suspected stroke. Non-contrast head computed tomography (CT) is the first-line modality in most acute stroke pathways because it is widely available and rapid; its principal role is to exclude intracranial hemorrhage and some stroke mimics before reperfusion therapy (Powers et al., 2019; Vilela & Rowley, 2017). However, non-contrast CT has limited sensitivity for hyperacute ischemia. In the first hours after symptom onset it may be normal or show only subtle early ischemic signs, such as loss of gray–white matter differentiation, the insular ribbon sign, and the hyperdense artery sign, whereas an established infarct appears as a hypodense lesion in a vascular territory later in the course (Abdalkader et al., 2023). Hypodense lesions may also represent chronic infarcts. The CT diagnosis of ischemic stroke therefore requires correlation with symptom onset, clinical findings, and, when needed, follow-up CT or magnetic resonance imaging (MRI). Likewise, identification of an embolic source requires dedicated vascular and cardiac evaluation beyond non-contrast CT and chest radiography (Beheshtian et al., 2020; Khenkina et al., 2024).

Aortic arch atheroma is a recognized but often underdiagnosed source of cerebral embolism. In the seminal study by the French Study of Aortic Plaques in Stroke Group, aortic arch plaque ≥4 mm thick on transesophageal echocardiography was present in 14.4% of patients with ischemic stroke compared with 2% of controls (odds ratio [OR] 9.1, 95% confidence interval [CI] 3.3–25.2) (The French Study of Aortic Plaques in Stroke Group, 1996). A meta-analysis of 12 studies including 3,918 participants reported a pooled OR of 3.93 (95% CI 2.86–5.40), increasing to 5.90 for complex plaque (Cui et al., 2014), and aortic arch atherosclerosis was a potential embolic source in 29% of patients with embolic stroke of undetermined source in the NAVIGATE-ESUS trial (Ntaios et al., 2020). The high-risk embolic phenotype in these studies is thick, ulcerated, or mobile (complex) plaque characterized by transesophageal echocardiography, CT angiography, or magnetic resonance angiography; because the arch gives rise to the great vessels, material released from such plaque can embolize antegradely into the cerebral circulation (Macleod et al., 2004). These plaque-based risk estimates cannot be transposed directly to calcification seen on plain radiographs.

Standard modalities for characterizing aortic arch plaque, namely transesophageal echocardiography and cross-sectional angiography, are not always available and are not performed routinely in all patients with suspected stroke. Chest radiography, in contrast, is inexpensive, rapid, and widely available, and in our hospital it is commonly obtained during the initial work-up of patients admitted for suspected stroke. Aortic arch calcification (AAC) visible on posteroanterior chest radiography is related to, but distinct from, high-risk arch plaque: it reflects calcified atherosclerotic burden (and partly age-related and metabolic medial calcification) and cannot depict plaque thickness, ulceration, mobility, or superimposed thrombus. A four-level grading system for AAC on chest radiography (grades 0–3) was associated with cardiovascular events beyond traditional risk factors in a Japanese cohort (Iijima et al., 2010), and the same grading has shown good interobserver agreement in Chinese (Ma et al., 2019) and Turkish (Çakan & Köktürk, 2026) patients (weighted κ 0.81 and κ 0.82, respectively). Large cohort studies have also reported that radiographic AAC is associated with coronary heart disease and stroke (Iribarren et al., 2000) and with mortality and cardiovascular events in a graded manner (Tian et al., 2022).

Evidence in stroke populations has accumulated over the past decade. AAC on chest radiography was an independent predictor of recurrent stroke during 1-year follow-up (hazard ratio 3.54; 95% CI 1.65–7.60) (Çakan et al., 2024), was present in 41.5% of patients with ischemic stroke

undergoing endovascular thrombectomy and was associated with lower recanalization rates (Jeong et al., 2023), and its severity differed among ischemic stroke subtypes (Lee et al., 2023). Using CT angiography-based Agatston scoring, AAC was present in 77.0% of patients with ischemic stroke (Zhou et al., 2017). These studies addressed recurrence, procedural outcomes, and subtype distribution in stroke-only cohorts. They suggest that AAC is a potentially relevant imaging marker, but they do not establish whether radiographic AAC grade is associated with the presence of ischemic stroke independently of age.

Thus, an unresolved question is whether AAC grade on a clinically indicated chest radiograph is associated with CT-defined ischemic stroke among patients undergoing stroke imaging, and to what extent any such association is independent of age. To our knowledge, no published study from North Sumatra has examined this question. A previous study at Royal Prima General Hospital, Medan, described the profile and management of hospitalized patients with ischemic stroke without examining imaging markers of aortic atherosclerosis (Zendrato & Barus, 2021), and another local study in Medan compared blood pressure between ischemic and hemorrhagic stroke (Safithri et al., 2025).

Therefore, this study aimed to evaluate the association between AAC grade on posteroanterior chest radiography and ischemic stroke on non-contrast head CT among adults who underwent both examinations at Royal Prima General Hospital, Medan; to examine the extent to which this association was explained by age and sex; and to describe the local distribution of AAC grades in this selected imaging cohort. We hypothesized that a higher AAC grade would be associated with a higher prevalence of ischemic stroke.

Methods

Study Design and Setting

This single-center retrospective cross-sectional study was conducted at the Radiology Installation of Royal Prima General Hospital, Medan, a 24-hour stroke referral hospital with conventional radiography, CT, and a picture archiving and communication system (PACS). All examinations that fulfilled the eligibility criteria during the study period were identified retrospectively from PACS and medical records. The exposure was AAC grade on posteroanterior chest radiography, and the outcome was ischemic stroke on non-contrast head CT. The study is reported in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement (von Elm et al., 2007).

Participants and Sampling

The source population comprised adults (≥18 years) who underwent non-contrast head CT for suspected stroke during the study period. Patients were eligible if they were aged ≥18 years; had an interpretable non-contrast head CT performed for clinical suspicion of stroke; had a technically adequate posteroanterior chest radiograph obtained during the same hospital visit or admission as the head CT; and had complete data on age and sex. Each patient contributed only one encounter (the first eligible examination). Exclusion criteria were hemorrhagic stroke or other intracranial hemorrhage on CT; a history of cardiac or aortic surgery, congenital cardiovascular anomaly, or aortic stent graft; and incomplete records precluding assessment of study variables. Because only patients with both examinations and a posteroanterior radiograph could be included, patients without a chest radiograph or with only an anteroposterior (portable) radiograph were not represented; this creates a selected diagnostic cohort that may under-represent bedbound or severely ill patients (see Limitations).

Patients whose head CT showed neither an ischemic lesion nor hemorrhage formed the comparison group. These patients were referred for head CT because of suspected stroke, and their final clinical diagnoses (such as transient neurological symptoms or stroke mimics) were not systematically available in the extracted dataset. Because they were selected from the same imaging pathway, they constitute neither a population-based nor an age-matched control group.

All eligible records during the study period were included (total sampling). The minimum sample size was originally estimated with the single-proportion formula $n = Z^2\alpha/2 \times P \times Q / d^2$ ($Z\alpha/2 = 1.96$, $P = 0.77$, $Q = 0.23$, $d = 0.10$; $n = 69$), using the prevalence of AAC among patients with ischemic stroke reported in a CT-based study (Zhou et al., 2017). Because this formula estimates a single prevalence and was not designed to power the association analysis, we emphasize the precision of the effect estimates (95% CIs) rather than statistical significance alone.

Variables and Data Sources

Data on age, sex, AAC grade, and head CT findings were extracted from medical records and PACS onto a structured, coded case report form. Age was categorized as <60 and ≥60 years for descriptive and crude analyses, consistent with the Indonesian legal definition of older persons (Law No. 13 of 1998 on the Welfare of Older Persons). Data on hypertension, diabetes mellitus, smoking, dyslipidemia, chronic kidney disease, atrial fibrillation, coronary or carotid disease, prior stroke, and medication use were not systematically available in the retrospective records; therefore, these variables were not included in the analysis, and residual confounding is discussed as a major limitation.

Assessment of Aortic Arch Calcification

Only technically adequate posteroanterior radiographs (adequate inspiration, no substantial rotation, and adequate penetration) were assessed. Images were reviewed on PACS workstations, and the aortic knob was inspected using digital zoom of the original posteroanterior image rather than a separate magnified acquisition; digital zoom facilitates visual inspection but does not increase intrinsic spatial resolution. AAC was graded according to Iijima et al. (Iijima et al., 2010): grade 0, no visible calcification; grade 1, small spots of calcification or a single thin area of calcification of the aortic knob; grade 2, one or more areas of thick calcification; and grade 3, circular calcification of the aortic knob. This system was developed in a Japanese cohort using standard posteroanterior radiographs and has since been applied with good interobserver agreement in Chinese (Ma et al., 2019) and Turkish (Çakan & Köktürk, 2026) populations; it has not been validated against a reference standard in Indonesian patients. Grading was performed by the research team on PACS using these predefined criteria, without adaptation. Formal blinding to head CT findings and inter- and intraobserver agreement were not assessed in this retrospective study, and this is acknowledged as a limitation.

Outcome Ascertainment

Ischemic stroke status was determined from the head CT images and the corresponding radiology reports in PACS. Ischemic stroke was defined as a hypodense lesion in an arterial vascular territory on standard parenchymal/stroke windows, without intracranial hemorrhage. Because the time from symptom onset and follow-up CT or magnetic resonance imaging were not consistently available, acute or subacute infarcts could not be reliably distinguished from chronic infarcts, and early ischemic strokes with a normal initial CT may have been classified as non-stroke. This potential outcome misclassification is addressed in the Limitations.

Statistical Analysis

Analyses were performed using IBM SPSS Statistics version 31. Categorical variables are presented as frequencies and percentages. The distribution of age was assessed using the Shapiro–Wilk test together with visual inspection of histograms, and age is presented as mean ± SD and median (range). The association between AAC grade and ischemic stroke was assessed using the Pearson chi-square test (4 × 2 table) and the Cochran–Armitage test for trend; because no expected cell count was <5, no categories were merged. For the dichotomized exposure (any AAC, grades 1–3, vs grade 0), the crude prevalence ratio (PR) was calculated as the ratio of the two prevalences, with the 95% CI derived using the log (Katz) method; the odds ratio (OR) with a Woolf 95% CI is reported only for comparison because, when the outcome is common, the OR substantially overstates the PR (Barros & Hirakata, 2003). Associations of AAC grade with age group and sex were assessed using chi-square tests. Because age variances were unequal across grades, mean age was compared using Welch's ANOVA, followed by Games–Howell post hoc

comparisons, which control the family-wise error rate. The correlation between AAC grade (ordinal) and age (continuous) was assessed using Spearman's rank correlation coefficient (ρ), with a 95% CI based on Fisher's z-transformation.
All tests were two-sided with α = 0.05. The AAC grade–ischemic stroke association was the primary analysis; all other analyses were considered secondary or exploratory. No multivariable (age- or risk factor-adjusted) analysis was performed; therefore, all associations between AAC and ischemic stroke are reported as crude (unadjusted) estimates, and the strong relationship of age with both AAC and ischemic stroke is examined descriptively.

Ethical Considerations
The study protocol, including a waiver of informed consent for the use of anonymized retrospective data, was approved by the Health Research Ethics Committee, Faculty of Medicine, Dentistry, and Health Sciences, Universitas Prima Indonesia. Permission was also obtained from Royal Prima General Hospital. The study involved no additional imaging, radiation, cost, or delay in care. Data were coded, stored in encrypted form, and reported only in aggregate without individual identification.

Result

Baseline Characteristics of the Study Population
During the study period, 100 participants fulfilled the inclusion criteria and none of the exclusion criteria; all were included in the analysis. Baseline characteristics are presented in Table 1.

Table 1. Baseline characteristics and univariate distributions (n = 100)

Variable	n	%
Age (years)		—
Mean ± SD	63.67 ± 9.13	—
Median (min–max)	63.00 (41–82)	
Age group		
<60 years	36	36.0
≥60 years	64	64.0
Sex		
Male	60	60.0
Female	40	40.0
Aortic arch calcification (AAC) grade		
Grade 0	30	30.0
Grade 1	30	30.0
Grade 2	20	20.0
Grade 3	20	20.0
AAC (any grade)		
Absent (grade 0)	30	30.0
Present (grades 1–3)	70	70.0
Ischemic stroke		
Yes	68	68.0
No	32	32.0

The mean age of participants was 63.67 ± 9.13 years (median 63.00 years; range 41–82 years). Age was normally distributed (Shapiro–Wilk $p > 0.05$) and is therefore presented as mean ± SD. Most participants were aged 60 years or older (64.0%), and 60.0% were male.
AAC of any grade (grades 1–3) was present in 70 participants (70.0%), and grades 2–3 in 40 (40.0%); 30 participants (30.0%) had no visible AAC. Ischemic stroke was present in 68

participants (68.0%) and absent in 32 (32.0%). These proportions describe this selected imaging cohort and should not be interpreted as hospital or population prevalence.

Association Between Aortic Arch Calcification and Ischemic Stroke

The crude association between AAC grade and ischemic stroke is presented in Table 2.

Table 2. Crude association between aortic arch calcification (AAC) grade on chest radiography and ischemic stroke on non-contrast head CT (n = 100)

Aortic Arch Calcification	Ischemic Stroke Yes, n (%)	Ischemic Stroke No, n (%)	Total, n (%)	p
Grade (4 levels)				<0.001*
Grade 0	10 (33.3)	20 (66.7)	30 (100.0)	
Grade 1	20 (66.7)	10 (33.3)	30 (100.0)	
Grade 2	18 (90.0)	2 (10.0)	20 (100.0)	
Grade 3	20 (100.0)	0 (0.0)	20 (100.0)	
Any AAC (dichotomized)				<0.001†
Present (grades 1–3)	58 (82.9)	12 (17.1)	70 (100.0)	
Absent (grade 0)	10 (33.3)	20 (66.7)	30 (100.0)	
Total	68 (68.0)	32 (32.0)	100 (100.0)	

*Pearson χ^2 = 30.45, df = 3, p < 0.001; Cochran–Armitage test for trend, z = 5.38, p < 0.001. Smallest expected cell count = 6.40.

†Pearson χ^2 = 23.67, df = 1, p < 0.001; crude prevalence ratio 2.49 (95% CI 1.48–4.17); odds ratio 9.67 (95% CI 3.62–25.79).

The crude proportion of participants with ischemic stroke increased monotonically with AAC grade, from 33.3% in grade 0 to 66.7% in grade 1, 90.0% in grade 2, and 100.0% in grade 3 (Cochran–Armitage z = 5.38, p < 0.001). Compared with grade 0, the crude PRs were 2.00 (95% CI 1.14–3.52) for grade 1, 2.70 (95% CI 1.59–4.57) for grade 2, and 3.00 (95% CI 1.81–4.98) for grade 3. No participant with grade 3 AAC was free of ischemic stroke. This zero cell does not invalidate the chi-square test (smallest expected count 6.40).

When AAC was dichotomized, ischemic stroke was present in 58 of 70 participants with AAC (82.9%) and in 10 of 30 participants without AAC (33.3%), corresponding to a crude PR of 2.49 (95% CI 1.48–4.17; p < 0.001). The crude OR was 9.67 (95% CI 3.62–25.79); because ischemic stroke was common in this sample (68%), the OR lies much farther from the null than the PR and should not be interpreted as a risk ratio. These crude estimates are not adjusted for age, which was strongly associated with both AAC grade and ischemic stroke.

Association Between Demographic Factors and Ischemic Stroke

The associations of age and sex with ischemic stroke are presented in Table 3. Ischemic stroke was present in 59 of 64 participants aged ≥60 years (92.2%) and in 9 of 36 participants aged <60 years (25.0%) (χ^2 = 47.80, p < 0.001; PR 3.69, 95% CI 2.08–6.52). Together with the strong correlation between age and AAC grade (see below), this indicates that age is a major confounder of the crude AAC–stroke association.

Table 3. Association between age, sex, and ischemic stroke (n = 100)

Variable	Ischemic Stroke Yes, n (%)	Ischemic Stroke No, n (%)	Total, n (%)	p	Prevalence Ratio (95% CI)

Age group				<0.001	3.69 (2.08–6.52)
<60 years	9 (25.0)	27 (75.0)	36 (100.0)		
≥60 years	59 (92.2)	5 (7.8)	64 (100.0)		
Sex				0.930	1.01 (0.77–1.33)
Male	41 (68.3)	19 (31.7)	60 (100.0)		
Female	27 (67.5)	13 (32.5)	40 (100.0)		
Total	68 (68.0)	32 (32.0)	100 (100.0)		

Ischemic stroke did not differ by sex (41 of 60 men, 68.3%, vs 27 of 40 women, 67.5%; $\chi^2 = 0.01$, p = 0.930; PR 1.01, 95% CI 0.77–1.33).

Association Between Aortic Arch Calcification Grade and Demographic Characteristics

The associations of AAC grade with age group, sex, and mean age are presented in Table 4. The proportion of participants aged ≥60 years increased with AAC grade, from 26.7% in grade 0 to 60.0% in grade 1, 90.0% in grade 2, and 100.0% in grade 3 ($\chi^2 = 35.47$, df = 3, p < 0.001; linear-by-linear association p < 0.001). The proportion of men was 60.0% in every grade ($\chi^2 = 0.00$, df = 3, p = 1.000).

Mean age increased with AAC grade, from 55.33 ± 7.06 years in grade 0 to 61.37 ± 4.42, 67.10 ± 4.76, and 76.20 ± 3.22 years in grades 1, 2, and 3, respectively. Because variances were unequal across grades, Welch's ANOVA was used (F = 95.17; df = 3 and 50.9; p < 0.001). Games–Howell post hoc comparisons showed that mean age differed between every pair of grades: grade 0 vs 1, 6.04 years (95% CI 1.99–10.09; adjusted p = 0.001); grade 0 vs 2, 11.77 years (7.32–16.22; p < 0.001); grade 0 vs 3, 20.87 years (16.93–24.81; p < 0.001); grade 1 vs 2, 5.73 years (2.14–9.32; p < 0.001); grade 1 vs 3, 14.83 years (11.95–17.71; p < 0.001); and grade 2 vs 3, 9.10 years (5.63–12.57; p < 0.001). AAC grade was strongly correlated with age (Spearman ρ = 0.807, 95% CI 0.71–0.87; p < 0.001).

Table 4. Association between aortic arch calcification (AAC) grade on chest radiography and demographic characteristics (n = 100)

Grade	n	Age <60 years, n (%)	Age ≥60 years, n (%)	p (Age Group)	Male, n (%)	Female, n (%)	p (Sex)	Age (years), Mean ± SD	Median (Min–Max)	p (Mean Age)
Grade 0	30	22 (73.3)	8 (26.7)	<0.001*	18 (60.0)	12 (40.0)	1.000†	55.33 ± 7.06	56.50 (41–67)	<0.001‡
Grade 1	30	12 (40.0)	18 (60.0)		18 (60.0)	12 (40.0)		61.37 ± 4.42	61.00 (54–71)	
Grade 2	20	2 (10.0)	18 (90.0)		12 (60.0)	8 (40.0)		67.10 ± 4.76	67.50 (58–75)	
Grade 3	20	0 (0.0)	20 (100.0)		12 (60.0)	8 (40.0)		76.20 ± 3.22	76.00 (70–82)	
Total	100	36 (36.0)	64 (64.0)		60 (60.0)	40 (40.0)		63.67 ± 9.13	63.00 (41–82)	

*Pearson $\chi^2 = 35.47$, df = 3, p < 0.001 (linear-by-linear association p < 0.001).
†Pearson $\chi^2 = 0.00$, df = 3, p = 1.000.

‡Welch's ANOVA, F = 95.17 (df = 3 and 50.9), p < 0.001; Games–Howell post hoc comparisons are reported in the text.

Discussion

In this selected cohort of 100 adults who underwent both non-contrast head CT and posteroanterior chest radiography, AAC was present in 70% and ischemic stroke in 68%. The crude proportion with ischemic stroke increased monotonically across AAC grades, and any AAC was associated with an approximately 2.5-fold higher crude prevalence of ischemic stroke. However, AAC grade was strongly correlated with age, and age was strongly associated with ischemic stroke. Because no age-adjusted analysis was performed, the extent to which the AAC–stroke association is independent of age could not be determined. The principal finding is therefore an unadjusted graded association that may be largely confounded by age.

Several mechanisms could plausibly link AAC with ischemic stroke, although none was tested in this study. Complex aortic arch plaque can cause cerebral embolism because material released from the arch is carried antegradely into the great vessels (Ali et al., 2021). Radiographic AAC is a surrogate marker of calcified atherosclerotic burden (Cai et al., 2022); however, vascular calcification is heterogeneous and may reflect intimal atherosclerosis, medial calcification, ageing, chronic kidney disease, and metabolic factors, which plain radiography cannot distinguish. Because this study did not characterize plaque thickness, ulceration, mobility, or thrombus, nor classify stroke mechanism (e.g., by TOAST criteria), our data cannot show that a higher AAC grade indicates a greater likelihood of arterio-arterial embolism. AAC may instead act as a marker of generalized atherosclerosis and cumulative vascular risk-factor exposure, which predispose to ischemic stroke through several mechanisms, including large-artery atherosclerosis and small-vessel disease. Consistent with this interpretation, higher AAC grade has been associated with endothelial dysfunction and cardiovascular events independently of traditional risk factors (Iijima et al., 2010) and with the severity of coronary artery disease (Ma et al., 2019).

The 70% prevalence of AAC in our cohort is close to the 77% reported among patients with ischemic stroke (Zhou et al., 2017); however, that study quantified AAC using CT angiography and included only stroke patients, whereas our denominator included 32 participants without ischemic stroke and AAC was assessed on plain radiographs, so the two figures are not directly comparable. A higher proportion of grade 0 has been reported in outpatients without cardiovascular events (Iijima et al., 2010), which is directionally consistent with AAC being a marker of atherosclerotic burden associated with cardiovascular (Tian et al., 2022) and cerebrovascular disease (Iribarren et al., 2000). Our prevalence is higher than the 41.5% reported among patients undergoing endovascular thrombectomy (Jeong et al., 2023) and lower than the 98% detected using automated CT analysis (Lee et al., 2023). Possible explanations include differences in age structure, referral patterns and inclusion criteria, imaging modality (cross-sectional CT is more sensitive than two-dimensional radiography (Cai et al., 2022)), radiographic technique, and reader thresholds for low-grade calcification; these explanations were not tested in the present study.

The monotonic increase in the crude proportion of ischemic stroke across AAC grades is consistent with studies reporting graded associations of AAC with recurrent stroke (Cai et al., 2022) and cardiovascular events (Tian et al., 2022). However, in a cross-sectional analysis of an ordinal radiographic score that is strongly age-dependent, this gradient is better described as an unadjusted graded association than as a dose–response effect. The comparison group without ischemic stroke provided variation in the outcome, but it was selected from patients undergoing the same imaging pathway; it is neither population-based nor age-matched, and its vascular risk profile may differ from that of the stroke group, so referral, verification, and confounding bias cannot be excluded. Because AAC grade and age increased almost in parallel ($\rho = 0.807$) and no adjusted analysis was performed, the observed gradient may largely reflect confounding by age, and the present data cannot separate the two. Importantly, the independent and incremental

value of AAC grade beyond age remains unknown; conversely, the strong age dependence does not exclude a modest independent contribution of AAC, which should be tested in larger studies with appropriate adjustment.

Studies with larger samples, flexible modeling of age, or participants within a narrower age range are needed to disentangle the contributions of age and AAC. The strong association between AAC grade and age in our data is consistent with previous studies identifying age as a principal determinant of AAC in Japanese (Iijima et al., 2010), American (Iribarren et al., 2000), and Chinese (Tian et al., 2022) cohorts, and is biologically expected, because calcification accumulates with prolonged exposure to vascular risk factors. This correlation, however, does not validate the grading system, which would require reliability assessment and comparison with a reference modality such as CT. We found no association between AAC grade and sex, and the prevalence of ischemic stroke did not differ by sex. A large cohort study reported an association between AAC and ischemic stroke only in women (Iribarren et al., 2000); we did not formally test for interaction by sex, and our finding should be interpreted only as the absence of a detectable difference in this sample. Previous studies have related AAC severity to stroke subtype (Lee et al., 2023) and recanalization outcomes (Jeong et al., 2023); because neither stroke mechanism nor prognosis was assessed here, these observations are not supported by the present data.

Within these limitations, the findings have cautious implications for radiological practice. AAC is frequently visible on chest radiographs obtained for clinical indications in patients evaluated for stroke, and its grade can be recorded without additional cost, time, or radiation when such a radiograph already exists; these data do not justify obtaining chest radiography solely to grade AAC. Because the association was not adjusted for age or other vascular risk factors, and because reader reliability in routine practice, incremental predictive performance (discrimination, calibration, and reclassification beyond age and conventional risk factors), effects on management, and patient outcomes were not assessed, we do not recommend AAC grading as a stroke risk-stratification tool at present. Rather, structured reporting of AAC grade is a candidate feature that warrants evaluation in validation and implementation studies. AAC grading has also been explored in Indonesian patients with ST-elevation myocardial infarction (Assania et al., 2026), which supports its feasibility in local radiology practice, although that study did not address stroke. Finally, whether a high AAC grade in a younger patient indicates accelerated atherosclerosis, and whether AAC relates to infarct distribution (e.g., multiterritory infarcts), are hypotheses for future research; neither was analyzed in the present study.

This study has several important limitations. First, residual confounding is a major concern: hypertension, diabetes mellitus, smoking, dyslipidemia, chronic kidney disease, atrial fibrillation, carotid and coronary disease, prior cardiovascular disease, and medication use are plausible common causes of both AAC and stroke and were not included in the analysis; without adjustment for these factors and for age, an independent AAC–stroke association cannot be established. Second, outcome misclassification is possible because non-contrast CT has limited sensitivity for hyperacute ischemia and may not reliably distinguish acute from chronic infarcts. Third, AAC grading is semiquantitative and reader blinding and inter- and intraobserver agreement were not formally assessed; chest radiography is less sensitive than CT for detecting calcification, cannot characterize plaque morphology, and the grading system has not been validated locally. Fourth, requiring both examinations and a posteroanterior radiograph created a selected diagnostic cohort that may exclude bedbound or severely ill patients who receive anteroposterior portable radiographs, introducing referral and spectrum bias; the 68% proportion with ischemic stroke reflects this selection. Fifth, the cross-sectional design precludes causal or temporal inference, the single-center setting limits generalizability, and no multivariable (age-adjusted) analysis was performed, so the independent contribution of AAC could not be estimated.

Future studies should be designed according to their aim. For etiologic questions, prospective studies should measure and adjust for key vascular confounders, model age flexibly, and, if age matching is used, apply matched analyses. For prediction questions, matching should be avoided, and studies should test whether AAC grade improves discrimination and calibration

beyond age and established risk factors. In both cases, AAC should be scored by blinded readers with documented interobserver reliability and validated against a reference modality such as CT, CT angiography, or transesophageal echocardiography, and acute ischemic stroke should be defined using clinical criteria with MRI or follow-up imaging when needed.

Conclusion

In this selected single-center cohort of adults who underwent both non-contrast head CT and posteroanterior chest radiography, AAC grade showed a graded, unadjusted association with ischemic stroke: the proportion with ischemic stroke rose from 33.3% in grade 0 to 100% in grade 3, and any AAC was associated with a higher crude prevalence (PR 2.49, 95% CI 1.48–4.17). However, AAC grade was strongly correlated with age (Spearman ρ = 0.807), and no age-adjusted analysis was performed. These findings suggest that radiographic AAC is a common marker of atherosclerotic burden whose crude association with ischemic stroke in this sample may be largely explained by age; they do not establish an independent or incremental role for AAC grading in stroke risk assessment. Recording AAC grade on clinically indicated chest radiographs may warrant further evaluation in prospective studies with comprehensive adjustment for vascular confounders, blinded scoring with interobserver reliability assessment, validation against a reference modality such as CT angiography or transesophageal echocardiography, and formal assessment of predictive performance.

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DECLARATION OF INTEREST

There is no conflict of interest in this study.

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