

ORIGINAL RESEARCH ARTICLE

**Risk-factor count and admission stroke severity:
A hospital-based registry study at a tertiary
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Abstract

Admission stroke severity, commonly quantified using the National Institutes of Health Stroke Scale (NIHSS), strongly influences early complications and long-term outcomes. However, evidence from routine clinical practice regarding whether a cumulative burden of vascular risk factors relates to initial severity remains limited. To address this, a cross-sectional analysis of consecutive stroke admissions recorded in a tertiary-care stroke registry between January 2020 and December 2024 was conducted. Exposure was defined as the cumulative count of eight prespecified vascular risk factors—hypertension, diabetes mellitus, dyslipidemia, current smoking, coronary artery disease, heart failure, atrial fibrillation, and prior transient ischemic attack—while the outcome was admission NIHSS score. Among the 1988 screened records, 1676 unique adult index admissions were analyzed. The cumulative risk-factor count demonstrated a weak but statistically significant positive correlation with overall admission NIHSS scores and within both ischemic and hemorrhagic subtypes. In adjusted multivariable analyses, hypertension, diabetes mellitus, heart failure, and smoking were independently associated with higher NIHSS scores, whereas dyslipidemia and coronary artery disease showed inverse associations. These findings indicate that a greater cumulative vascular risk-factor burden is associated with worse admission stroke severity, reflecting a modest dose–response relationship that complements lesion-level determinants in early stroke assessment; thus, aggressive management of these risk factors is crucial not only for prevention but also potentially for mitigating initial stroke severity.

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(dodiktugasworo@lecturer.undip.ac.id)**Citation:** Pramukarso DT, Retnaningsih R, Pranata EC. Risk-factor count and admission stroke severity: A hospital-based registry study at a tertiary referral center. *Adv Neurol.* 2026;5(2):025470118. doi: 10.36922/AN025470118**Received:** November 22, 2025**Revised:** January 5, 2026**Accepted:** January 12, 2026**Published online:** February 12, 2026**Copyright:** © 2026 Author(s). This is an Open-Access article distributed under the terms of the Creative Commons Attribution License, permitting distribution, and reproduction in any medium, provided the original work is properly cited.**Publisher's Note:** AccScience Publishing remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.**Keywords:** Stroke; National Institutes of Health Stroke Scale; Vascular risk factors; Registry; Cross-sectional study; Tertiary center**1. Introduction**

Stroke has been recognized as a leading cause of death and disability worldwide, imposing substantial clinical and economic burdens on patients, caregivers, and health systems.¹⁻³ Under current clinical definitions, stroke is defined as an acute focal neurological deficit of vascular origin and includes ischemic and hemorrhagic subtypes. The initial severity of neurological deficits at presentation has been consistently linked to short-term complications, length of stay, and long-term functional outcomes, underscoring the need

to understand determinants of severity at admission.²⁻⁴ Accordingly, the quantification of stroke severity has been prioritized in both research and practice.

The National Institutes of Health Stroke Scale (NIHSS) has been widely adopted to quantify neurological impairment and has been validated as a prognostic indicator for mortality, disability, and post-stroke complications.^{4,5} Higher NIHSS scores at admission have been associated with poorer functional recovery and increased resource utilization, making this measure an appropriate anchor for severity assessments in hospital-based studies. A range of vascular risk factors has been implicated in the pathogenesis and outcomes of stroke. More severe presentations have been reported among patients with atrial fibrillation, long-standing hypertension, and diabetes mellitus; adverse associations have also been described for active smoking, dyslipidemia, coronary artery disease, and heart failure.⁶⁻⁹ Prior transient ischemic attack has additionally been linked to cerebrovascular events and may influence clinical severity at onset.⁶⁻¹⁰ While these factors are frequently examined individually, their combined influence at the time of presentation has remained less clearly delineated.

An accumulating body of work has suggested that the cumulative burden of coexisting vascular risk factors may be associated with greater stroke severity through additive or synergistic mechanisms.^{11,12} From a clinical perspective, such a burden-based construct is attractive because it can be quickly estimated at admission and may inform triage, monitoring intensity, and early secondary prevention strategies.^{10,11} Nevertheless, evidence regarding the magnitude and pattern of these associations has varied across settings and populations.

In Indonesia, stroke has been documented as a major public health problem with a high prevalence and substantial disability-adjusted life years lost.^{12,13} However, evidence from Indonesian hospital registries quantifying the dose-response association between the cumulative number of vascular risk factors and admission NIHSS scores remains limited. In particular, locally derived estimates that assess both ischemic and hemorrhagic subtypes and account for potential effect modification across key demographic strata have been scarce, leaving uncertainty regarding the magnitude and clinical interpretability of a simple risk-factor burden measure at presentation.^{12,13}

Against this background, a cross-sectional, registry-based analysis was conducted to evaluate whether a simple count of eight routinely documented vascular risk factors is associated with admission stroke severity as measured by the NIHSS among patients recorded in the Dr. Kariadi Central General Hospital, Semarang, stroke

registry between 2020 and 2024. The primary objective is to quantify the association between vascular risk-factor burden (count) and NIHSS at presentation in the overall cohort and stratified by stroke subtype (ischemic vs. hemorrhagic).

Secondary objectives are to examine the independent associations of each prespecified risk factor—including atrial fibrillation, hypertension, diabetes mellitus, current smoking, dyslipidemia, coronary artery disease, prior transient ischemic attack, and heart failure—with NIHSS in multivariable models, and to explore potential effect modification by age and sex. Given that prior evidence has been inconsistent across populations, this study adds data from an Indonesian tertiary referral setting, where locally derived, registry-based estimates of admission NIHSS scores in relation to cumulative vascular risk are limited. The risk-factor count was conceptualized as a rapid, calculation-free metric intended to complement clinical assessment at admission rather than as a standalone predictor of stroke severity, particularly in light of the expected modest magnitude of association.

2. Methods

2.1. Study design and setting

A cross-sectional analysis was performed using consecutive admissions recorded in the Dr. Kariadi Central General Hospital, Semarang, stroke registry between January 01, 2020, and December 31, 2024. Reporting followed the Strengthening the Reporting of Observational Studies in Epidemiology recommendations for observational studies.

2.2. Data sources

Data were obtained from a prospectively maintained hospital-based stroke registry that routinely captures demographics, vascular risk factors, comorbidities, stroke subtype, and neurological assessments at presentation, including the NIHSS. Variables used for the present analysis were extracted from the registry and, when applicable, cross-checked against the electronic medical record.

2.3. Eligibility criteria

Eligible encounters were admissions of adults aged ≥ 19 years with a final diagnosis of ischemic or hemorrhagic stroke during the study period and a documented admission NIHSS score. Pediatric patients (age ≤ 18 years) were excluded a priori due to differing vascular risk profiles. Repeat admissions for the same patient were identified, and only the first (index) admission was retained. Records without admission NIHSS scores were excluded.

2.4. Exposure, covariates, and operational definitions

Eight prespecified vascular risk factors were analyzed as binary variables: Hypertension, diabetes mellitus, dyslipidemia, current smoking, coronary artery disease, heart failure, atrial fibrillation, and prior transient ischemic attack. Definitions followed registry standards based on clinician documentation in the medical record and/or active therapy at admission:

- i. Hypertension was defined by a documented diagnosis and/or current use of antihypertensive medication
- ii. Diabetes mellitus was defined by a documented diagnosis and/or current use of glucose-lowering therapy (insulin and/or oral agents)
- iii. Dyslipidemia was defined by a documented diagnosis and/or current use of lipid-lowering therapy
- iv. Current smoking was defined as documented current tobacco use at presentation
- v. Coronary artery disease was defined by a documented history of coronary artery disease (e.g., prior myocardial infarction, angina, or coronary revascularization)
- vi. Heart failure was defined by a documented clinical diagnosis of heart failure
- vii. Atrial fibrillation was defined by a documented history and/or electrocardiographic evidence of atrial fibrillation
- viii. Prior transient ischemic attack was defined by a documented history of transient ischemic attack.

A cumulative risk-factor count (0–8) was calculated by summing the present factors for each patient. Other relevant vascular risk factors (e.g., alcohol consumption, obesity/body mass index, obstructive sleep apnea, prior stroke, socioeconomic status, and medication adherence) were not systematically captured in the registry during the study period and therefore were not included in the present analysis.

2.5. NIHSS assessment

Admission to NIHSS was recorded at the first neurological assessment upon hospital arrival as part of routine stroke care. NIHSS scores were obtained by trained neurology residents using a standardized institutional assessment protocol and subsequently cross-checked by attending neurologists during ward rounds/visits to ensure consistency.

2.6. Data management, quality control, and missing data

Data were de-duplicated, and coding was harmonized with the prespecified analysis plan before statistical analysis.

Internal consistency checks were performed, including range checks and cross-field validation (e.g., plausibility of age and stroke subtype coding). When multiple NIHSS entries were available for the same encounter, the earliest admission score was used. The registry data entry system employs mandatory fields for key variables, including admission NIHSS scores and the prespecified vascular risk factors, which minimizes missingness for the variables used in this study. After applying the eligibility criteria, all variables included in the present analyses were complete; therefore, analyses were performed using a complete-case approach.

2.7. Statistical analysis

Baseline characteristics were summarized using counts (percentages) for categorical variables and means (standard deviations) or medians (interquartile ranges) for continuous variables, as appropriate. The association between vascular risk-factor count and admission NIHSS scores was assessed using Spearman's rank correlation in the overall cohort and stratified by stroke subtype (ischemic vs. hemorrhagic).

Independent associations of individual risk factors with NIHSS scores were estimated using multivariable linear regression (ordinary least squares) with admission NIHSS score as the dependent variable and the eight prespecified risk factors entered simultaneously as predictors; models were fitted in the overall cohort and separately within ischemic and hemorrhagic stroke subgroups. Additional analyses were conducted stratified by sex and age group (19–40, 41–60, and >60 years). Effect modification by sex was evaluated by including centered risk-factor count, sex, and their interaction term (risk-factor count \times sex) in linear regression models, and effect modification by age group was assessed using a general linear model including age group, centered risk-factor count, and their interaction (age group \times risk-factor count). Results are reported as unstandardized coefficients (B) with 95% confidence intervals (CI) and two-sided *p*-values; $\alpha = 0.05$ was used to define statistical significance. Graphical summaries included a scatter plot and box plot of NIHSS across risk-factor count categories (with counts ≥ 6 pooled for visualization) and a forest plot of adjusted regression coefficients with 95% CIs. Analyses were performed using the Statistical Package for the Social Sciences Statistics (version 31.0, IBM, United States).^{14,15}

2.8. Ethical considerations

The study was approved by the Institutional Ethics Committee of Dr. Kariadi Central General Hospital, Semarang (Approval No. 16574/EC/KEPK-RSDK/2025). Given the use of de-identified registry data, individual

informed consent was waived in accordance with institutional policy and local regulations.

3. Results

3.1. Study population

A total of 1988 registry entries recorded between January 1, 2020, and December 31, 2024, were screened (annual accruals: 180 in 2020; 400 in 2021; 508 in 2022; 400 in 2023; 500 in 2024). After removal of 268 duplicate admissions (clerical duplicates and repeat encounters) and 25 entries without admission NIHSS scores, 1695 unique index admissions were identified. An additional 19 entries were excluded because the patients were aged ≤ 18 years, resulting in 1676 adult index admissions included in the analytic cohort (Figure 1). No additional exclusions for miscoded non-stroke conditions were applied.

3.2. Baseline characteristics

3.2.1. Overall cohort ($n = 1,676$)

Admissions were concentrated in 2023 and 2024 (462 [27.6%] and 461 [27.5%], respectively; 55.1% combined). Males comprised 943 (56.3%) and females 733 (43.7%). By age category, 19–40 years accounted for 140 (8.4%), 41–60 years for 721 (43.0%), and >60 years for 815 (48.6%). The baseline characteristics of the study population are summarized in Table 1. The most frequent vascular risk factors were dyslipidemia (1214 [71.6%]), hypertension (1095 [65.3%]), and diabetes mellitus (648 [38.7%]); additional comorbidities included current smoking (422 [25.2%]), heart failure (266 [15.9%]), coronary artery

disease (164 [9.8%]), atrial fibrillation (89 [5.3%]), and prior transient ischemic attack (110 [6.6%]). Admission NIHSS categories were <5 in 416 (24.8%) patients, 5–14 in 844 (50.4%), 15–25 in 260 (15.5%), 25–34 in 101 (6.0%), and ≥ 35 in 55 (3.3%).

3.2.2. Ischemic stroke ($n = 1,142$)

Most ischemic admissions occurred in 2023 and 2024 (346 [30.3%] and 252 [22.1%], respectively; 52.4% combined). Males were 640 (56.0%) and females 502 (44.0%). Age categories were 96 (8.4%) for 19–40 years, 468 (41.0%) for 41–60 years, and 578 (50.6%) for >60 years. Risk factors included dyslipidemia (850 [74.4%]), hypertension (707 [61.9%]), diabetes mellitus (455 [39.8%]), current smoking (268 [23.5%]), heart failure (160 [14.0%]), coronary artery disease (136 [11.9%]), atrial fibrillation (76 [6.7%]), and prior transient ischemic attack (93 [8.1%]). NIHSS score on admission was <5 in 332 (29.1%) patients, 5–14 in 601 (52.6%), 15–25 in 156 (13.7%), 25–34 in 44 (3.9%), and ≥ 35 in 9 (0.8%).

3.2.3. Hemorrhagic stroke ($n = 534$)

Nearly two-fifths of hemorrhagic admissions occurred in 2024 (209 [39.1%]). Males were 303 (56.7%) and females 231 (43.3%). Age categories were 44 (8.2%) for 19–40 years, 253 (47.4%) for 41–60 years, and 237 (44.4%) for >60 years. Risk factors included hypertension (388 [72.7%]), dyslipidemia (358 [67.0%]), diabetes mellitus (193 [36.1%]), current smoking (154 [28.8%]), heart failure (106 [19.9%]), coronary artery disease (28 [5.2%]), atrial fibrillation (13 [2.4%]), and prior transient ischemic attack (17 [3.2%]). NIHSS categories were <5 in 84 (15.7%) patients, 5–14 in 243 (45.5%), 15–25 in 104 (19.5%), 25–34 in 57 (10.7%), and ≥ 35 in 46 (8.6%).

3.3. Correlation between risk-factor count and NIHSS scores

In the overall cohort, most patients had ≥ 2 vascular risk factors (1272 [75.9%]). The distribution of risk-factor counts stratified by stroke subtype is presented in Table 2. When broken down by exact counts, the distribution was 0 risk (85 [5.1%]), 1 risk (319 [19.0%]), 2 risks (522 [31.1%]), 3 risks (458 [27.3%]), 4 risks (218 [13.0%]), 5 risks (53 [3.2%]), 6 risks (19 [1.1%]), and 7 risks (2 [0.1%]), indicating that intermediate burdens (2–3 risk factors) were most common, whereas very high counts were rare. The distribution of admission NIHSS scores across risk-factor categories is further visualized in Figure 2.

Because admission NIHSS scores were non-normally distributed, Spearman's rank correlation was used to assess the monotonic association between risk-factor count and NIHSS score. In the overall cohort, the

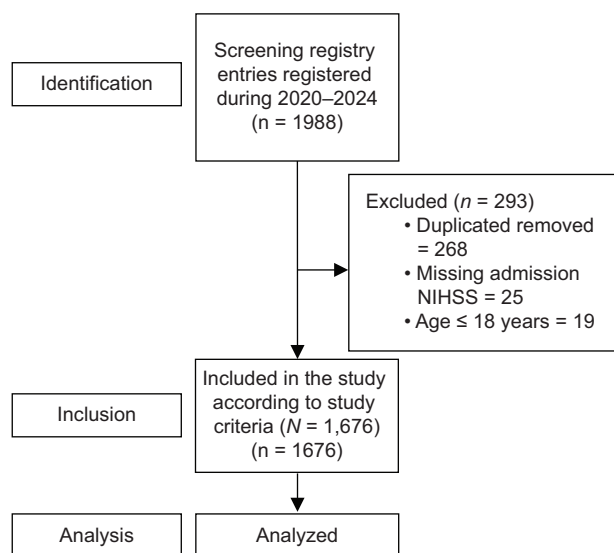


Figure 1. Strengthening the reporting of observational studies in epidemiology flow diagram of study participant selection. Abbreviation: NIHSS: National Institutes of Health Stroke Scale.

Table 1. Baseline characteristics of the study population by stroke subtype

Variables	Ischemic stroke		Hemorrhagic stroke		Overall sample	
	<i>n</i>	Percentage	<i>n</i>	Percentage	<i>n</i>	Percentage
Year						
2020	42	3.7	6	1.1	48	2.9
2021	231	20.2	105	19.7	336	20.0
2022	271	23.7	98	18.4	369	22.0
2023	346	30.3	116	21.7	462	27.6
2024	252	22.1	209	39.1	461	27.5
Sex						
Male	640	56.0	303	56.7	943	56.3
Female	502	44.0	231	43.3	733	43.7
Age						
19–40	96	8.4	44	8.2	140	8.4
41–60	468	41.0	253	47.4	721	43.0
>60	578	50.6	237	44.4	815	48.6
Hypertension						
Yes	707	61.9	388	72.7	1095	65.3
No	435	38.1	146	27.3	581	34.7
Diabetes mellitus						
Yes	455	39.8	193	36.1	648	38.7
No	687	60.2	341	63.9	1028	61.3
Dyslipidemia						
Yes	850	74.4	358	67.0	1214	71.6
No	292	25.6	176	33.0	481	28.4
Current smoking						
Yes	268	23.5	154	28.8	422	25.2
No	874	76.5	380	71.2	1254	74.8
Coronary artery disease						
Yes	136	11.9	28	5.2	164	9.8
No	1,006	88.1	506	94.8	1512	90.2
Heart failure						
Yes	160	14.0	106	19.9	266	15.9
No	982	86.0	428	80.1	1410	84.1
Atrial fibrillation						
Yes	76	6.7	13	2.4	89	5.3
No	1,066	93.3	521	97.6	1587	94.7
Prior transient ischemic attack						
Yes	93	8.1	17	3.2	110	6.6
No	1,049	91.9	517	96.8	1566	93.4
NIHSS scores						
<5	332	29.1	84	15.7	416	24.8
5–14	601	52.6	243	45.5	844	50.4
15–25	156	13.7	104	19.5	260	15.5
25–34	44	3.9	57	10.7	101	6.0
0.35	0	0	0	0	0	0

Notes: Percentages are calculated within each stroke subtype and for the overall sample. Age categories are expressed in years. Stroke severity was classified using the National Institutes of Health Stroke Scale at admission.

Table 2. Distribution of risk-factor count by stroke type

Risk-factor count	Ischemic stroke		Hemorrhagic stroke		Overall sample	
	<i>n</i>	Percentage	<i>n</i>	Percentage	<i>n</i>	Percentage
0 risk factors	62	5.4	23	4.3	85	5.1
1 risk factor	220	19.3	99	18.5	319	19.0
2 risk factors	333	29.2	189	35.4	522	31.1
3 risk factors	320	28.0	138	25.8	458	27.3
4 risk factors	151	13.2	67	12.5	218	13.0
5 risk factors	43	3.8	10	1.9	53	3.2
6 risk factors	11	1.0	8	1.5	19	1.1
7 risk factors	2	0.2	-	-	2	0.1
8 risk factors	-	-	-	-	-	-

Notes: Percentages are calculated within each stroke subtype and for the overall sample. Risk-factor count represents the cumulative number of eight prespecified vascular risk factors recorded at admission, including hypertension, diabetes mellitus, dyslipidemia, current smoking, coronary artery disease, heart failure, atrial fibrillation, and prior transient ischemic attack. Hyphens (-) indicate zero observations.

correlation was statistically significant but weak ($\rho = 0.135$, $p < 0.001$; $n = 1,676$), as illustrated in Figure 3. Similar weak positive correlations were observed within stroke subtypes: Ischemic stroke ($\rho = 0.141$, $p < 0.001$; $n = 1,142$) and hemorrhagic stroke ($\rho = 0.146$, $p = 0.001$; $n = 534$). Collectively, these findings indicate that cumulative vascular risk-factor burden tends to coincide with greater neurological deficit at presentation; however, the effect size is small. Accordingly, the risk-factor count is best interpreted as a complementary admission flag rather than a strong standalone predictor of stroke severity.

3.4. Multivariable linear regression: Individual risk factors versus NIHSS score

In the overall cohort ($n = 1676$), a prespecified multivariable linear regression model including hypertension, diabetes mellitus, dyslipidemia, current smoking, coronary artery disease, heart failure, atrial fibrillation, and prior transient ischemic attack explained a modest proportion of variance in admission NIHSS scores ($R^2 = 0.073$; adjusted $R^2 = 0.069$; $F(8, 1667) = 16.420$; $p < 0.001$). Multicollinearity was negligible (variance inflation factor [VIF] range = 1.005–1.110). Detailed regression results for the overall cohort are shown in Table 3. Hypertension ($B = 1.859$; 95% CI = 0.975–2.743; $p < 0.001$), diabetes mellitus ($B = 1.592$; 95% CI = 0.730–2.454; $p < 0.001$), heart failure ($B = 4.153$; 95% CI = 2.991–5.315; $p < 0.001$), and current smoking ($B = 1.523$; 95% CI = 0.567–2.479; $p = 0.002$) were independently associated with higher NIHSS scores, whereas coronary artery disease ($B = -1.809$; 95% CI = -3.273–-0.344; $p = 0.016$) and dyslipidemia ($B = -2.683$; 95% CI = -3.615–

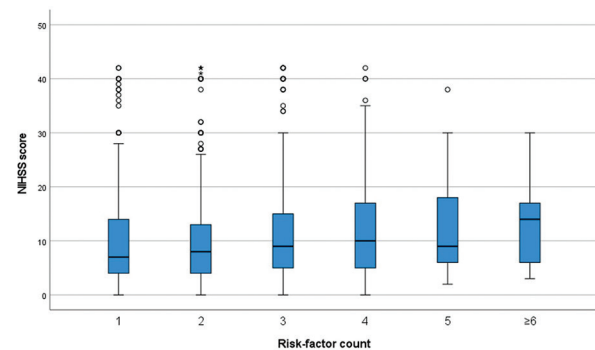


Figure 2. Box plot of admission National Institutes of Health Stroke Scale scores by vascular risk-factor count. Counts ≥ 6 were pooled for visualization because very high-risk-factor counts were uncommon. Notes: Boxes indicate medians and interquartile ranges; whiskers extend to the most extreme values within $1.5 \times$ interquartile range; hollow circles represent outliers; * indicates extreme outliers.

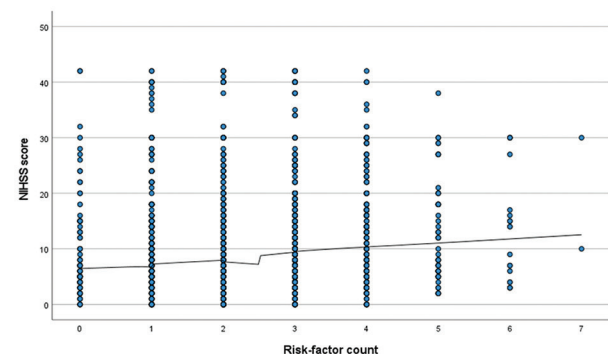


Figure 3. Scatter plot of admission National Institutes of Health Stroke Scale scores by vascular risk-factor count with a fitted smoothing line, illustrating a weak positive trend between cumulative vascular risk-factor burden and stroke severity at presentation

–1.751; $p < 0.001$) were associated with lower NIHSS scores. Atrial fibrillation ($B = 1.278$; 95% CI = -0.662–3.218; $p = 0.197$) and prior transient ischemic attack ($B = -1.452$; 95% CI = -3.123–0.220; $p = 0.089$) were not statistically significant. The adjusted associations for individual risk factors are displayed in Figure 4.

3.5. Subgroup analysis by stroke subtype

3.5.1. Ischemic stroke

The results of the subgroup analysis by stroke type are presented in Table 4. In the ischemic subgroup ($n = 1,142$), the same prespecified model showed modest fit ($R^2 = 0.041$; adjusted $R^2 = 0.034$; $F(8, 1133) = 6.049$; $p < 0.001$) with minimal multicollinearity (VIF up to 1.154). Diabetes mellitus ($B = 1.356$; 95% CI = 0.503–2.209; $p = 0.002$), atrial fibrillation ($B = 1.906$; 95% CI = 0.148–3.665; $p = 0.034$), heart failure ($B = 2.257$; 95% CI = 1.043–3.472; $p < 0.001$),

Table 3. Multivariable linear regression (overall) of risk factors for admission NIHSS score

Risk factor	B (unstandardized)	95% CI	p-value
Hypertension	1.86	0.98–2.74	<0.001*
Diabetes mellitus	1.59	0.73–2.45	<0.001*
Atrial fibrillation	1.28	–0.66–3.22	0.197
Coronary artery disease	–1.81	–3.27––0.34	0.016*
Heart failure	4.15	2.99–5.31	<0.001*
Current smoking	1.52	0.57–2.48	0.002*
Prior transient ischemic attack	–1.45	–3.12–0.22	0.089
Dyslipidemia	–2.68	–3.62––1.75	<0.001*

Notes: B represents the unstandardized regression coefficient. 95% confidence interval indicates the range within which the true B value is expected to fall with 95% confidence. * $p < 0.05$.

Abbreviation: NIHSS: National Institutes of Health Stroke Scale.

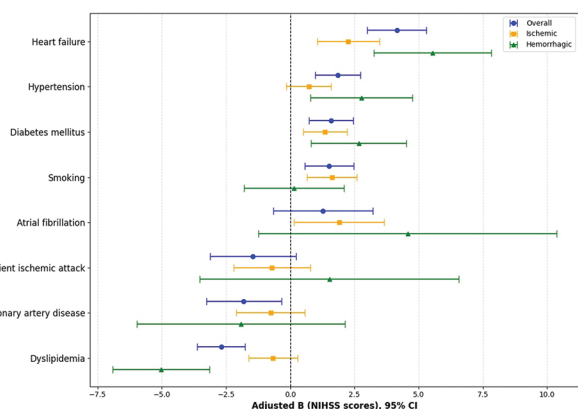


Figure 4. Forest plot of adjusted beta coefficients (B) and 95% confidence intervals for admission NIHSS score. The plot shows the association between risk factors and stroke severity in overall, ischemic, and hemorrhagic stroke patients. Positive values indicate higher admission NIHSS scores. Models were mutually adjusted for all eight risk factors. Abbreviation: NIHSS: National Institutes of Health Stroke Scale.

and current smoking ($B = 1.624$; 95% CI = 0.654–2.595; $p = 0.001$) were associated with higher NIHSS scores, whereas hypertension, dyslipidemia, coronary artery disease, and prior transient ischemic attack were not significantly associated with NIHSS score.

3.5.2. Hemorrhagic stroke

In the hemorrhagic subgroup ($n = 534$), model performance was higher than in ischemic stroke ($R^2 = 0.118$; adjusted $R^2 = 0.105$; $F(8,525) = 8.782$; $p < 0.001$), with low multicollinearity (VIF up to 1.079). Hypertension ($B = 2.773$; 95% CI = 0.784–4.762; $p = 0.006$), diabetes mellitus ($B = 2.675$; 95% CI = 0.820–4.530; $p = 0.005$), and heart failure ($B = 5.545$; 95% CI = 3.259–7.831; $p < 0.001$) were associated with higher NIHSS scores, whereas

dyslipidemia was associated with lower NIHSS scores ($B = -5.029$; 95% CI = -6.921––3.138; $p < 0.001$). Atrial fibrillation, coronary artery disease, current smoking, and prior transient ischemic attack were not significantly associated with NIHSS score. Complete results for the subgroup analyses by stroke subtype, including CIs and p -values for all risk factors, are detailed in Table A1.

3.6. Subgroup analysis by sex and age

When stratified by sex, the association between risk-factor count and admission NIHSS score remained weak in both men ($\rho = 0.111$, $p = 0.001$; $n = 943$) and women ($\rho = 0.161$, $p < 0.001$; $n = 733$). In an interaction model including centered risk-factor count, sex, and their product term, no evidence of effect modification by sex was observed (Risk-factor count \times sex: $B = 0.027$; 95% CI = -0.684–0.738; $p = 0.941$).

Across age groups, correlations were weakest in ages 19–40 ($\rho = 0.081$, $p = 0.343$; $n = 140$) and strongest in ages >60 ($\rho = 0.157$, $p < 0.001$; $n = 815$). In a model incorporating age group, centered risk-factor count, and their interaction, the age group \times risk-factor count interaction was statistically significant ($F = 3.126$; $p = 0.044$), suggesting that the association between cumulative vascular risk and admission NIHSS score may vary by age group. However, the explained variance was small ($R^2 = 0.023$).

4. Discussion

In this registry-based study from an Indonesian tertiary referral center, a simple count of eight routinely documented vascular risk factors showed a statistically significant but weak positive correlation with admission stroke severity (NIHSS score) in the overall cohort ($\rho = 0.135$). This small effect size indicates that cumulative vascular risk-factor burden may relate to initial neurological deficit. However, it explains only a limited portion of clinical variability at presentation, consistent with prior work suggesting that multimorbidity or risk-factor burden is not a strong standalone determinant of acute stroke severity.^{10,16–18} Clinically, the risk-factor count may therefore serve as a complementary flag at admission rather than a substitute for established triage based on neurological examination, imaging findings, and acute stroke workflows.^{5,19}

In multivariable models, several individual risk factors showed independent associations with higher NIHSS scores, including hypertension, diabetes mellitus, heart failure, and current smoking in the overall cohort. These findings are biologically plausible. Long-standing hypertension and diabetes can contribute to vascular remodeling, endothelial dysfunction, and impaired collateral circulation, all of which may predispose to

Table 4. Subgroup analysis of multivariable linear regression for NIHSS score by stroke type

Risk factor	Ischemic: <i>B</i> (95% CI)	<i>p</i>	Hemorrhagic: <i>B</i> (95% CI)	<i>p</i>
Hypertension	0.722 (−0.143–1.586)	0.102	2.773 (0.784–4.762)	0.006*
Diabetes mellitus	1.356 (0.503–2.209)	0.002*	2.675 (0.820–4.530)	0.005*
Atrial fibrillation	1.906 (0.148–3.665)	0.034*	4.574 (−1.228–10.376)	0.122
Coronary artery disease	−0.764 (−2.104–0.577)	0.264	−1.920 (−5.979–2.138)	0.353
Heart failure	2.257 (1.043–3.472)	<0.001*	5.545 (3.259–7.831)	<0.001*
Current smoking	1.624 (0.654–2.595)	0.001*	0.147 (−1.801–2.095)	0.882
Prior transient ischemic attack	−0.708 (−2.207–0.791)	0.354	1.524 (−3.529–6.577)	0.554
Dyslipidemia	−0.667 (−1.620–0.287)	0.170	−5.029 (−6.921–−3.138)	<0.001*

Notes: *B* represents the unstandardized regression coefficient. 95% confidence interval indicates the range within which the true *B* value is expected to fall with 95% confidence. **p*<0.05.

Abbreviation: NIHSS: National Institutes of Health Stroke Scale.

larger infarct volumes or more severe presentations.^{8,20–26} Heart failure may exacerbate cerebral hypoperfusion and is frequently accompanied by systemic inflammation and cardio-cerebral interactions that worsen early neurological deficits.^{27,28} Smoking is associated with prothrombotic and inflammatory pathways and has been linked to worse outcomes in reperfusion-treated populations, although effect estimates vary across cohorts.^{29–31}

When stratified by stroke subtype, the pattern of associations differed. The correlation between risk-factor count and NIHSS score remained weak in both ischemic (*p*=0.141) and hemorrhagic stroke (*p*=0.146), with modest overall model fit. In ischemic stroke, diabetes mellitus, atrial fibrillation, heart failure, and smoking remained associated with higher NIHSS scores, aligning with evidence that cardioembolic mechanisms and impaired hemodynamics can increase initial deficit severity.^{32,33} In hemorrhagic stroke, hypertension, diabetes mellitus, and heart failure showed stronger associations with NIHSS scores, consistent with the central role of blood pressure and vascular integrity in intracerebral hemorrhage pathophysiology and early neurological deterioration.^{34,35}

Counterintuitively, dyslipidemia and coronary artery disease were associated with lower admission NIHSS scores in the overall model, and dyslipidemia showed an inverse association in the hemorrhagic subgroup. This pattern has been reported in some prior studies and may reflect confounding by pre-stroke preventive care—particularly statin exposure—or differences in baseline risk management among patients labeled as dyslipidemic.^{36–40} Importantly, pre-stroke statin use was not systematically documented in the registry and could not be adjusted for; this limitation may contribute to the observed inverse association and should be considered a key source of residual confounding.^{36–40}

Exploratory analyses assessed whether the association between risk-factor count and NIHSS score differed by sex and age. The sex interaction term was not statistically significant, suggesting no clear evidence of effect modification by sex in linear models. In contrast, an age-group interaction was statistically significant, indicating that the relationship between risk-factor burden and admission NIHSS score may vary across age strata.^{16,41} Given the modest explanatory power of the models and multiple-testing considerations, these findings should be interpreted as hypothesis-generating and warrant confirmation in external datasets.

Several limitations should be acknowledged. First, the cross-sectional design limits causal inference, and residual confounding is likely, including factors not captured systematically (e.g., onset-to-admission time, pre-stroke modified Rankin Scale, socioeconomic factors, medication adherence, and pre-stroke statin use).^{10,16} Second, this was a single-center tertiary referral registry, so generalizability to other hospitals or community settings may be limited. Third, the NIHSS score was analyzed primarily as a total score; individual NIHSS domains/items were not evaluated, which may obscure more granular associations between specific risk factors and distinct neurological deficits.^{5,19,42} Finally, although risk-factor burden may help contextualize early severity, vascular risk factors are better established as predictors of stroke occurrence and initial presentation rather than deterministic predictors of functional recovery, which is influenced by acute management, complications, and rehabilitation.^{5,19} Future research could test whether combining simple admission flags (risk-factor count) with neurological signs can improve prognostic stratification across the recovery pathway, including rehabilitation outcomes.⁴³

In summary, a higher count of routinely documented vascular risk factors was associated with higher admission

NIHSS scores, but the association was weak, supporting the use of risk-factor burden as a complementary admission flag. Individual risk factors—particularly hypertension, diabetes mellitus, heart failure, and smoking—showed consistent associations with greater initial neurological deficit, while inverse associations for dyslipidemia and coronary artery disease potentially reflect unmeasured preventive treatment and residual confounding.^{36–40}

5. Conclusion

This registry-based analysis provides empirical evidence that the cumulative burden of vascular comorbidities exerts a measurable influence on admission stroke severity. While the overall correlation is weak, the independent detrimental effects of hypertension, diabetes mellitus, heart failure, and smoking underscore the critical role of vascular fragility in determining the extent of initial neurological injury. Conversely, the observed inverse associations with dyslipidemia and coronary artery disease highlight the complexity of pre-stroke metabolic profiles and potential medication effects, warranting further investigation. Ultimately, our findings reinforce the concept that stroke severity is not solely a function of the acute lesion but is also modulated by the patient's underlying vascular health. These insights emphasize the necessity of rigorous risk factor management as a strategy to essentially “downstage” potential future stroke events.

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Conflict of interest

The authors declare they have no competing interests.

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Ethics approval and consent to participate

The study was approved by the Institutional Ethics Committee of Dr. Kariadi Central General Hospital, Semarang (Approval No. 16574/EC/KEPK-RSDK/2025). Given the use of de-identified registry data, individual informed consent was waived in accordance with institutional policy and local regulations.

Consent for publication

Not applicable.

Availability of data

The datasets generated and/or analyzed during the current study are not publicly available due to institutional regulations regarding patient privacy, but are available from the corresponding author (D. T. P.) upon reasonable request.

References

- GBD 2019 Stroke Collaborators. Global, regional, and national burden of stroke and its risk factors, 1990–2019: A systematic analysis for the global burden of disease study 2019. *Lancet Neurol.* 2021;20(10):1–26.
doi: 10.1016/S1474-4422(21)00252-0
- GBD 2021 Stroke Risk Factor Collaborators. Global, regional, and national burden of stroke and its risk factors, 1990–2021: A systematic analysis for the global burden of disease study 2021. *Lancet Neurol.* 2024;23(10):973–1003.
doi: 10.1016/S1474-4422(24)00369-7
- Feigin VL, Brainin M, Norrving B, *et al.* World Stroke Organization: Global Stroke Fact Sheet 2025. *Int J Stroke.* 2025;20(2):132–144.
doi: 10.1177/17474930241308142
- Adams HP Jr., Davis PH, Leira EC, *et al.* Baseline NIH stroke scale score strongly predicts outcome after stroke: A report of the trial of org 10172 in acute stroke treatment (TOAST). *Neurology.* 1999;53(1):126–131.
doi: 10.1212/wnl.53.1.126
- Lyden P. Using the National institutes of health stroke scale: A cautionary tale. *Stroke.* 2017;48(2):513–519.
doi: 10.1161/strokeaha.116.015434
- Watanabe K, Okazaki S, Kitano T, *et al.* Stroke severity and outcomes in patients with newly diagnosed atrial fibrillation. *Front Neurol.* 2021;12:666491.
doi: 10.3389/fneur.2021.666491
- Liu CH, Wei YC, Lin JR, *et al.* Initial blood pressure is associated with stroke severity and is predictive of admission cost and one-year outcome in different stroke subtypes: A SRICHs registry study. *BMC Neurol.* 2016;16:27.

- doi: 10.1186/s12883-016-0546-y
8. Lau LH, Lew J, Borschmann K, Thijs V, Ekinici EI. Prevalence of diabetes and its effects on stroke outcomes: A meta-analysis and literature review. *J Diabetes Investig*. 2019;10(3):780-792.
doi: 10.1111/jdi.12932
 9. Edjoc RK, Reid RD, Sharma M, Fang J. The prognostic effect of cigarette smoking on stroke severity, disability, length of stay in hospital, and mortality in a cohort with cerebrovascular disease. *J Stroke Cerebrovasc Dis*. 2013;22(8):e446-e454.
doi: 10.1016/j.jstrokecerebrovasdis.2013.05.001
 10. Downer MB, Li L, Carter S, Beebe S, Rothwell PM. Associations of multimorbidity with stroke severity, subtype, premorbid disability, and early mortality: Oxford vascular study. *Neurology*. 2023;101(6):e645-e652.
doi: 10.1212/wnl.0000000000207479
 11. Reddin C, Canavan M, Hankey GJ, et al. Association of vascular risk with severe vs non-severe stroke: An analysis of the INTERSTROKE study. *Neurology*. 2024;103(11):e210087.
doi: 10.1212/wnl.0000000000210087
 12. Badan Penelitian Dan Pengembangan Kesehatan. *Laporan Nasional Riskesdas 2018 [2018 National Report of Riskesdas (Basic Health Research)]*. Jakarta: Lembaga Penerbit Badan Penelitian Dan Pengembangan Kesehatan; 2019.
 13. Venketasubramanian N, Yudiarto FL, Tugaworo D. Stroke burden and stroke services in Indonesia. *Cerebrovasc Dis Extra*. 2022;12(1):53-57.
doi: 10.1159/000524161
 14. Field AP. *Discovering Statistics Using IBM SPSS Statistics*. 5th ed. United Kingdom: Sage; 2018.
 15. Sugiyono S. *Metode Penelitian Kuantitatif, Kualitatif, Dan R&D [Quantitative, Qualitative, and R&D Research Methods]*. Bandung: Alfabeta; 2018.
 16. Karatepe AG, Gunaydin R, Kaya T, Turkmen G. Comorbidity in patients after stroke: Impact on functional outcome. *J Rehabil Med*. 2008;40(10):831-835.
doi: 10.2340/16501977-0269
 17. Joundi RA, Patten SB, Williams JV, Smith EE. Vascular risk factors and stroke risk across the life span: A population-representative study of half a million people. *Int J Stroke*. 2022;17(9):1021-1029.
doi: 10.1177/17474930211070682
 18. Kimura K, Minematsu K, Yamaguchi T, Japan Multicenter Stroke Investigators' Collaboration (J-MUSIC). Atrial fibrillation as a predictive factor for severe stroke and early death in 15,831 patients with acute ischaemic stroke. *J Neurol Neurosurg Psychiatry*. 2005;76(5):679-683.
doi: 10.1136/jnnp.2004.048827
 19. Brott T, Adams HP Jr, Olinger CP, et al. Measurements of acute cerebral infarction: A clinical examination scale. *Stroke*. 1989;20(7):864-870.
doi: 10.1161/01.str.20.7.864
 20. Mohammad A, Yadav I, Lashari UG, et al. Hypertension and risk of stroke: A systematic review and meta-analysis. *Cureus*. 2025;17(12):e43932.
doi: 10.7759/cureus.99863
 21. Jalan C, Patel RK, Lakra D. Impact of diabetes mellitus on stroke severity and clinical profile: A cross-sectional study at a tertiary care centre. *CME J Geriatr Med*. 2026;18:23-30.
doi: 10.61336/cmejgm/2026-01-14
 22. Mubarak AS, Kurniawan HD, Verasita P, Azmiardi A, Puspitasary K. Influence of diabetes mellitus on the incident of stroke: Meta-analysis. *Indones J Glob Health Res*. 2023;5(4):787-794.
doi: 10.37287/ijghr.v5i4.2461
 23. Reddin C, Murphy R, Hankey GJ, et al. Blood pressure variability in acute stroke: Risk factors and association with functional outcomes at 1 month. *Eur J Neurol*. 2024;31(8):e16314.
doi: 10.1111/ene.16314
 24. Qureshi AI, Palesch YY, Barsan WG, et al. Intensive blood-pressure lowering in patients with acute cerebral hemorrhage. *N Engl J Med*. 2016;375(11):1033-1043.
doi: 10.1056/nejmoa1603460
 25. Anderson CS, Heeley E, Huang Y, et al. Rapid blood-pressure lowering in patients with acute intracerebral hemorrhage. *N Engl J Med*. 2013;368(25):2355-2365.
doi: 10.1056/nejmoa1214609
 26. Khadka T, Giri GK, Sherpa P, et al. Dyslipidemia among patients with ischemic stroke admitted to the department of medicine of a tertiary care centre. *J Nepal Med Assoc*. 2023;61(265):718-721.
doi: 10.31729/jnma.8261
 27. Doehner W, Böhm M, Boriani G, et al. Interaction of heart failure and stroke: A clinical consensus statement of the ESC council on stroke, the heart failure association (HFA) and the ESC working group on thrombosis. *Eur J Heart Fail*. 2023;25(12):2107-2129.
doi: 10.1002/ehf.3071
 28. Cumbler E. In-hospital ischemic stroke. *Neurohospitalist*. 2015;5(3):173-181.
doi: 10.1177/1941874415588319
 29. Zhao Z, Zhao Z, Zheng X, et al. The association between smoking and unfavorable outcomes in acute ischemic stroke patients with mechanical thrombectomy. *Tob Induc Dis*. 2020;18:31.

- doi: 10.18332/tid/119229
30. Pan B, Jin X, Jun L, Qiu S, Zheng Q, Pan M. The relationship between smoking and stroke: A meta-analysis. *Medicine (Baltimore)*. 2019;98(12):e14872.
doi: 10.1097/md.00000000000014872
31. Sakinah S, Nugroho SD. Relationship between smoking and ischemic stroke: meta analysis. *J Epidemiol Public Health*. 2022;7(1):120-129.
doi: 10.26911/jepublichealth.2022.07.01.10
32. Thygesen SK, Frost L, Eagle KA, Johnsen SP. Atrial fibrillation in patients with ischemic stroke: A population-based study. *Clin Epidemiol*. 2009;1:55-65.
doi: 10.2147/dep.s4794
33. Venketasubramanian N. Ischemic stroke: New insights from risk factors, mechanisms and outcomes. *J Cardiovasc Dev Dis*. 2023;10(12):472.
doi: 10.3390/jcdd10120472
34. Rossaint R, Afshari A, Bouillon B, *et al*. The European guideline on management of major bleeding and coagulopathy following trauma: Sixth edition. *Crit Care*. 2023;27(1):80.
doi: 10.1186/s13054-023-04327-7
35. Mutimer CA, Yassi N, Wu TY. Blood pressure management in intracerebral haemorrhage: When, how much, and for how long? *Curr Neurol Neurosci Rep*. 2024;24(7):181-189.
doi: 10.1007/s11910-024-01341-2
36. Westover MB, Bianchi MT, Eckman MH, Greenberg SM. Statin use following intracerebral hemorrhage: A decision analysis. *Arch Neurol*. 2011;68(5):573-579.
doi: 10.1001/archneurol.2010.356
37. Tapia-Pérez JH, Rupa R, Zilke R, Gehring S, Voellger B, Schneider T. Continued statin therapy could improve the outcome after spontaneous intracerebral hemorrhage. *Neurosurg Rev*. 2013;36(2):279-287.
doi: 10.1007/s10143-012-0431-0
38. Tsigoulis G, Kadlecová P, Kobayashi A, *et al*. Safety of statin pretreatment in intravenous thrombolysis for acute ischemic stroke. *Stroke*. 2015;46(9):2681-2684.
doi: 10.1161/strokeaha.115.010244
39. Amarenco P, Labreuche J. Lipid management in the prevention of stroke: Review and updated meta-analysis of statins for stroke prevention. *Lancet Neurol*. 2009;8(5):453-463.
doi: 10.1016/S1474-4422(09)70058-4
40. Heart Protection Study Collaborative Group. MRC/BHF Heart Protection Study of cholesterol lowering with simvastatin in 20,536 high-risk individuals: A randomised placebo-controlled trial. *Lancet*. 2002;360(9326):7-22.
doi: 10.1016/S0140-6736(02)09327-3
41. Reverté-Villarroya S, Suñer-Soler R, Sauras-Colón E, Zaragoza-Brunet J, Fernández-Sáez J, Lopez-Espuela F. Ischemic stroke and vascular risk factors in young and older adults. Community-based retrospective study (2011-2020). *Aten Primaria*. 2023;55(6):102636.
doi: 10.1016/j.aprim.2023.102623
42. De Havenon A, Ayodele I, Alhanti B, *et al*. Prediction of large vessel occlusion stroke using clinical registries for research. *Neurology*. 2024;102(11):e209424.
doi: 10.1212/wnl.00000000000209424
43. Laufer Y. The use of walking aids in the rehabilitation of stroke patients. *Rev Clin Gerontol*. 2004;14(2):137-144.
doi: 10.1017/S0959259805001449

Appendix

Table A1. Subgroup regression analysis of vascular risk factors and admission NIHSS score by stroke subtype

Risk factor	Ischemic			Hemorrhagic		
	<i>B</i>	95% CI	<i>p</i>	<i>B</i>	95% CI	<i>p</i>
Hypertension	0.72	−0.14–1.59	0.102	2.77	0.78–4.76	0.006*
Diabetes mellitus	1.36	0.50–2.21	0.002*	2.68	0.82–4.53	0.005*
Atrial fibrillation	1.91	0.15–3.67	0.034*	4.57	−1.23–10.38	0.122
Coronary artery disease	−0.76	−2.10–0.58	0.264	−1.92	−5.98–2.14	0.353
Heart failure	2.26	1.04–3.47	<0.001*	5.55	3.26–7.83	<0.001*
Smoking	1.62	0.65–2.60	0.001*	0.15	−1.80–2.10	0.882
Transient ischemic attack	−0.71	−2.21–0.79	0.354	1.52	−3.53–6.58	0.554
Dyslipidemia	−0.67	−1.62–0.29	0.170	−5.03	−6.92–−3.14	<0.001*

Notes: Models were mutually adjusted for all eight prespecified vascular risk factors recorded at admission. *B* represents the change in National Institutes of Health Stroke Scale scores associated with the presence of the risk factor. **p*<0.05.

Abbreviation: CI: Confidence interval.