Journal of Stroke and Cerebrovascular Diseases 35 (2026) 108668

Contents lists available at ScienceDirect

Journal of Stroke and Cerebrovascular Diseases

journal homepage: www.elsevier.com/locate/jstroke

Acute ischemic stroke trends in Slovenia, 2015-2022: declining admissions, rising reperfusion, uneven gains

Tjaša Furlan [a,b,*], Borut Jug [a,c], Neža Nograšek [d,e,f], Dalibor Gavrić [g], Janja Pretnar Oblak [a,h], Petra Došenović Bonča [i,1], Senta Frol [a,h,1]

[a] Medical Faculty, University of Ljubljana, Vrazov trg 2, 1000 Ljubljana, Slovenia
[b] General Hospital Trbovlje, Rudarska cesta 9, 1420 Trbovlje, Slovenia
[c] Department of Vascular Diseases, University Medical Centre Ljubljana, Zaloška cesta 7, 1000 Ljubljana, Slovenia
[d] University Medical Centre Ljubljana, Zaloška cesta 7, 1000 Ljubljana, Slovenia
[e] Faculty of Electrical Engineering, University of Ljubljana, Tržaška cesta 25, 1000 Ljubljana, Slovenia
[f] Faculty of Sport, University of Ljubljana, Gortanova 22, 1000 Ljubljana, Slovenia
[g] Department for Development and Analysis, Health Insurance Institute of Slovenia, Miklošičeva cest 24, 1000 Ljubljana, Slovenia
[h] Clinic of Neurology, Clinical Department of Vascular Neurology, University Medical Centre Ljubljana, Zaloška cesta 7, 1000 Ljubljana, Slovenia
[i] School of Economics and Business, University of Ljubljana, Kardeljeva ploščad 17, 1000 Ljubljana, Slovenia

ARTICLE INFO

Keywords:
Ischaemic stroke
Intravenous thrombolysis
Mechanical thrombectomy
Carotid endarterectomy
Thromboendarterectomy

ABSTRACT

Introduction: We assessed nationwide trends in administratively identified ischaemic stroke admissions, procedures, secondary prevention, and outcomes in Slovenia using linked national datasets in the absence of a dedicated stroke registry.

Methods: We conducted a nationwide longitudinal analysis of adult hospital admissions captured in linked administrative databases between 2015 and 2022. We report crude index-admission rates, acute procedures (intravenous thrombolysis [IVT], mechanical thrombectomy [MT], carotid thromboendarterectomy [CEA], carotid artery angioplasty with stenting [CAS]), discharge secondary-prevention prescriptions, and time-to-death analyses with a maximum follow-up of 5 years.

Results: We included 16,839 unique index patients (median age 74 years; 54% male). Admissions peaked in 2017 (2169) and crude rates decreased from 105 to 99 per 100,000 residents by 2022. Revascularisation increased (IVT 6.2% to 15%, MT 5.4% to 9.5%, CEA 9.1% to 14%), length of stay decreased, and discharge prevention therapy improved. Five-year mortality was higher with age and comorbidity and lower among patients receiving IVT and several secondary-prevention therapies. Care pathways differed by stroke aetiology; women were older and men underwent more CAS and CEA, while IVT and MT were similar.

Conclusion: Crude admissions declined modestly while reperfusion and prevention improved, but the magnitude and pattern of improvement differed by care domain and patient subgroup, supporting continued monitoring and the development of a national stroke registry.

Introduction

Stroke remains a leading cause of death and a major contributor to disability and dementia.[1] The Global Burden of Disease (GBD) 2021 analysis indicates that current prevention strategies are insufficient to halt the accelerating global stroke burden.[2] Although age-standardised rates have declined in many regions, population ageing and adverse trends in vascular risk factors continue to increase absolute numbers and sustain inequities in access to prevention, acute treatment, and rehabilitation.[2]

National stroke registries and audits enable performance monitoring, benchmarking, and identification of inequities.[3] In Slovenia, acute stroke care is delivered within publicly financed hospitals, and reimbursement claims from these hospitals are submitted to the Health Insurance Institute of Slovenia (HIIS), which is the main national payer. In the absence of a dedicated national stroke registry, these routinely

* Corresponding author at: General Hospital Trbovlje, Rudarska cesta 9, 1420 Trbovlje, Slovenia.
E-mail address: tjasa.furlan@gmail.com (T. Furlan).
[1] Authors contributed equally to the manuscript.

https://doi.org/10.1016/j.jstrokecerebrovasdis.2026.108668
Received 22 March 2026; Received in revised form 25 April 2026; Accepted 26 May 2026
Available online 27 May 2026

collected datasets provide the best available nationwide overview, but they do not offer the clinical granularity or validation of a purpose-built audit. Accordingly, we aimed to characterise nationwide trends in admissions, acute procedures, discharge secondary prevention, and outcomes, while interpreting crude population rates within the constraints of administrative data.

Methods

Study design and data sources

We conducted a nationwide longitudinal analysis of stroke-related hospital admissions using routinely collected electronic claims data from the HIIS. The source dataset was the national reimbursement claims system, which captures hospital episodes submitted for payment and therefore reflects routine reporting practice across Slovenian hospitals. We linked these data to the National Medicines Reimbursement Claims Database and the Central Population Registry to ascertain discharge pharmacotherapy and vital status.

Study population and case definition

We included all inpatient episodes for individuals aged 18 years or older with a primary discharge diagnosis of ischaemic stroke between 1 January 2015 and 31 December 2022, identified using ICD-10 codes (I63.0–I63.9, I65.0–I65.9, and I66.0–I66.9). Individuals without HIIS coverage (for example, tourists and non-residents) were excluded. Because reimbursement claims are submitted nationally for publicly financed hospital care, this approach likely captured most resident inpatient acute ischaemic stroke admissions, although miscoding and inclusion of some non-acute or follow-up-coded events cannot be excluded. The index admission was the first eligible hospitalisation per individual during the study period and therefore does not distinguish first-ever from recurrent stroke if a patient had a stroke before 2015. All eligible index patients contributed to admission-rate and hospital-process analyses; the 30-day landmark restriction (alive and not rehospitalised within 30 days after discharge from the index admission) was applied only to the time-to-event outcome models.

Data linkage and privacy

Records were assembled through deterministic linkage using the HIIS unique patient identifier across the National Hospital Management Database, the National Medicines Reimbursement Claims Database, and the Central Population Registry. Reporting to these databases is administrative rather than research-oriented; accordingly, linkage was robust, but the accuracy and completeness of individual clinical fields depend on routine coding practice. Linked data were de-identified before analysis and were accessed only by authorised investigators.

Variables

Comorbidities were identified from diagnosis codes recorded during the index admission. The Charlson Comorbidity Index (CCI) summarised overall comorbidity burden.[4] Stroke aetiology was derived from the routinely documented TOAST-based subtype field available in the administrative dataset and grouped as cardioembolic, large artery disease, small artery disease (lacunar), and other (not captured by the preceding categories).[5] Because neither comorbidity coding nor TOAST-based subtype assignment was independently validated at a national level for the present study, both were used as pragmatic descriptors and interpreted cautiously.

Binary variables were created for coronary artery disease, peripheral artery disease, aortic aneurysm, diabetes mellitus, arterial hypertension, dyslipidaemia, heart failure, atrial fibrillation, chronic kidney disease, malignancy, chronic obstructive pulmonary disease/asthma, dementia, and depression.

Hospitalisation rates, procedures, treatment, outcomes

Annual hospitalisation rates were calculated as unique index admissions per 100,000 population and are therefore presented as crude population rates and age-adjusted rates. Costs were based on reimbursed claim values per episode and were inflation-adjusted to 2025 values using the Harmonised Index of Consumer Prices; they are summarised as median cost per episode. Procedures performed during hospitalisation (intravenous thrombolysis [IVT], mechanical thrombectomy [MT], carotid endarterectomy [CEA], carotid artery angioplasty with stenting [CAS]) were recorded. Discharge prescriptions for secondary prevention were summarised, including ACE inhibitors (ACEi) or angiotensin receptor blockers (ARB), lipid-lowering therapy (statins, ezetimibe, or PCSK9 inhibitors), and antithrombotic therapy (acetylsalicylic acid, P2Y12 inhibitors, or anticoagulation). For survival analyses, we performed two complementary analyses. First, to address early outcomes, we estimated in-hospital and 30-day all-cause mortality in the full cohort, stratified by stroke aetiology. Second, we estimated longer-term survival from the 30-day landmark to 5 years.

Statistical analysis

Baseline characteristics are presented as medians (IQR) and counts (%). Normality was assessed with the Kolmogorov-Smirnov test. Group comparisons used Pearson's chi-square test for categorical variables and the Wilcoxon rank-sum test for continuous variables. We report effect estimates with 95% confidence intervals and two-sided *p*-values. Survival analyses were performed in two complementary steps. First, early mortality was assessed in the full cohort by estimating in-hospital and 30-day all-cause mortality, overall and by stroke aetiology. Second, longer-term survival after the 30-day landmark was assessed using Kaplan–Meier methods, with survival curves stratified by stroke aetiology and compared using the log-rank test. Kaplan–Meier mortality estimates were reported at 1, 2, and 5 years, together with median survival time, median follow-up duration, and maximum follow-up duration. To evaluate factors associated with longer-term mortality, we fitted a multivariable Cox proportional hazards model using a 30-day landmark approach. For this model, time zero was 30 days after discharge from the index admission; patients were followed until death, 5 years of follow-up, or administrative censoring at the end of available mortality follow-up, whichever came first. The model included clinically prespecified covariates available in the linked dataset: age, sex, stroke etiology, length of stay, recorded comorbidities, in-hospital procedures, and discharge pharmacotherapy. The proportional hazards assumption was assessed using Schoenfeld residuals; variables violating the assumption were handled using stratification: lipid-lowering therapy, CEA, malignancy, CAS, and sex. All analyses were performed in R version 4.4.0.

Ethics

The National Medical Ethics Committee of the Republic of Slovenia, Ministry of Health, approved the study (KME-0120-29/2022/6). The study adhered to the Declaration of Helsinki. The requirement for informed consent was waived by the Committee.

Results

We identified 21,146 stroke admissions between 2015 and 2022, corresponding to 16,839 unique adult index patients (shown in Fig. 1). The full index cohort was used for descriptive epidemiology and hospital-process analyses. The 30-day landmark restriction was applied only to the longer-term survival models.

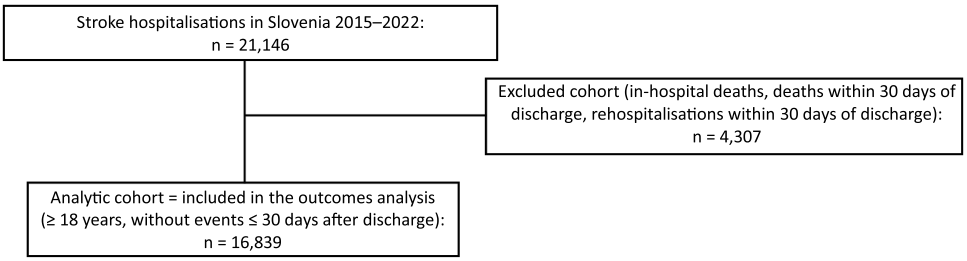

Fig. 1. Flow diagram of study selection, showing total stroke-related admissions, derivation of the unique index cohort, and the 30-day landmark subgroup used for time-to-event analyses.

Baseline characteristics

The analytic cohort had a median age of 74 years (IQR 65–82), and slightly male-predominant (54%) (Supplementary table S1). Lacunar stroke and large artery disease accounted for two-thirds of cases (40% and 24%), while cardioembolic and other aetiologies comprised 22% and 14%. Hypertension was prevalent (68%), with notable burdens of dyslipidaemia (36%), atrial fibrillation (25%), and diabetes mellitus (22%).

The cohort excluded from the landmark survival analysis (Supplementary table S2) was older than the analytic survival cohort (median age 82 years, IQR 74-88) and had a greater comorbidity burden (coronary artery disease 15% vs 9%, heart failure 23% vs 7.2%, atrial fibrillation 42% vs 25%, chronic kidney disease 14% vs 6.3%). These differences indicate that the landmark survival cohort was clinically healthier than the full index cohort and should therefore be interpreted as a conditional post-acute subgroup rather than as the entire stroke population.

Individual hospitalisation rates

Between 2015 and 2022, Slovenia's stroke hospitalisation burden slightly declined. Hospitalisations peaked in 2017 (2169 hospitalisations) and crude rates decreased thereafter from 105 per 100,000 residents per year (hereinafter 100,000/year) (age-adjusted 90 per 100,000/year) to 99 per 100,000/year (age-adjusted 80 per 100,000/year) by 2022 (Supplementary table S3). These values are crude rather than age-standardised population rates and should be interpreted accordingly. The largest year-on-year decline occurred between 2019 and 2020, coinciding with the COVID-19 period.

Table 1
Variables grouped by calendar year.

Variable	2015	2016	2017	2018	2019	2020	2021	2022	*p*-value
age, years	74 (65–81)	74 (65–82)	74 (65–82)	75 (65–82)	74 (65–81)	74 (66–82)	74 (66–82)	74 (65–82)	0.18
sex, male	1126 (53%)	1130 (53%)	1174 (54%)	1187 (55%)	1118 (53%)	1073 (53%)	1122 (55%)	1040 (55%)	0.53
coronary artery disease	212 (10%)	183 (8.6%)	253 (12%)	190 (8.8%)	169 (8%)	160 (7.9%)	170 (8.3%)	175 (8.4%)	**<0.001**
peripheral artery disease	170 (8%)	165 (7.7%)	173 (8%)	228 (11%)	176 (8.3%)	178 (8.3%)	193 (9.4%)	163 (7.8%)	**0.009**
aortic aneurism	22 (1%)	8 (0.4%)	17 (0.8%)	21 (1%)	22 (1%)	19 (0.9%)	16 (0.8%)	19 (0.9%)	0.30
diabetes mellitus	497 (23%)	494 (23%)	512 (24%)	451 (21%)	443 (21%)	441 (22%)	451 (22%)	432 (21%)	0.12
arterial hypertension	1577 (74%)	1565 (73%)	1575 (73%)	1458 (68%)	1362 (64%)	1317 (65%)	1298 (63%)	1277 (61%)	**<0.001**
dyslipidaemia	711 (33%)	651 (30%)	860 (40%)	800 (37%)	761 (36%)	728 (36%)	764 (37%)	816 (39%)	**<0.001**
heart failure	152 (7.1%)	156 (7.3%)	169 (7.8%)	170 (7.9%)	143 (6.8%)	132 (6.5%)	142 (6.9%)	145 (7%)	0.65
atrial fibrillation	515 (24%)	528 (25%)	572 (26%)	547 (25%)	501 (24%)	494 (24%)	531 (26%)	486 (23%)	0.25
artificial valve	11 (0.5%)	16 (0.7%)	18 (0.8%)	13 (0.6%)	9 (0.4%)	10 (0.5%)	7 (0.3%)	18 (0.9%)	0.25
chronic kidney disease	151 (7.1%)	135 (6.3%)	134 (6.2%)	127 (5.9%)	134 (6.3%)	128 (6.3%)	123 (6%)	121 (5.8%)	0.79
malignancy	114 (5.4%)	127 (5.9%)	126 (5.8%)	122 (5.7%)	133 (6.3%)	94 (4.7%)	104 (5.1%)	89 (4.3%)	0.067
chronic obstructive pulmonary disease/ asthma	90 (4.2%)	78 (3.7%)	89 (4.1%)	91 (4.2%)	56 (2.6%)	60 (3%)	59 (2.9%)	57 (2.7%)	**0.003**
dementia	199 (9.3%)	192 (9.0%)	166 (7.7%)	174 (8.1%)	142 (6.7%)	155 (7.7%)	140 (6.8%)	124 (6.0%)	**<0.001**
depression	83 (3.9%)	56 (2.6%)	78 (3.6%)	70 (3.3%)	66 (3.1%)	49 (2.4%)	56 (2.7%)	46 (2.2%)	**0.015**
length-of-stay, days	10 (6–17)	11 (7–18)	10 (6–17)	10 (6–16)	10 (6–17)	9 (5–16)	9 (5–16)	10 (6–17)	**<0.001**
cost per episode, Euro	409,113 (319,538 – 611,741)	334,875 (227,124 – 470,858)	408,170 (320,058 – 599,477)	422,339 (317,046 – 663,402)	449,523 (355,640 – 665,499)	448,251 (312,510 – 647,978)	412,151 (317,279 – 683,110)	412,151 (319,538 – 663,402)	**<0.001**
CAS	215 (10%)	228 (11%)	234 (11%)	174 (8.1%)	152 (7.2%)	141 (7%)	191 (9.3%)	153 (7.4%)	**<0.001**
CEA	193 (9.1%)	177 (8.3%)	227 (10%)	198 (9.2%)	246 (12%)	209 (10%)	239 (12%)	290 (14%)	**<0.001**
IVT	132 (6.2%)	196 (9.2%)	189 (8.7%)	218 (10%)	299 (14%)	305 (15%)	251 (12%)	302 (15%)	**<0.001**
MT	115 (5.4%)	93 (4.4%)	144 (6.6%)	143 (6.7%)	148 (7%)	116 (5.8%)	157 (7.7%)	198 (9.5%)	**<0.001**
anticoagulant therapy	605 (28%)	656 (31%)	706 (33%)	698 (32%)	692 (33%)	683 (34%)	775 (38%)	766 (37%)	**<0.001**
acetylsalicylic acid	1596 (75%)	1603 (75%)	1608 (74%)	1635 (76%)	1604 (76%)	1522 (75%)	1501 (73%)	1511 (73%)	0.14
P2Y12 inhibitors	288 (14%)	304 (14%)	316 (15%)	302 (14%)	315 (15%)	351 (17%)	418 (20%)	482 (23%)	**<0.001**
lipid-lowering therapy	1493 (70%)	1514 (71%)	1671 (77%)	1663 (77%)	1656 (78%)	1634 (81%)	1654 (82%)	1697 (77%)	**<0.001**
ACEi/ARB	1472 (69%)	1493 (70%)	1555 (72%)	1533 (71%)	1477 (70%)	1411 (70%)	1437 (70%)	1484 (71%)	0.53

[1]*n* (%); Median (IQR).
[2]Pearson's Chi-squared test; Wilcoxon rank sum test; Fisher's exact test
CAS, carotid artery angioplasty with stenting; CEA, carotid endarterectomy; IVT, intravenous thrombolysis; MT, mechanical thrombectomy; ACEi, angiotensin converting enzyme inhibitor; ARB, angiotensin receptor blocker.

Hospital procedures, treatment and outcomes

Length of stay declined slightly over time, accompanied by increased uptake of guideline-recommended therapies: IVT more than doubled (6.2% to 15%), MT increased from 5.4% to 9.5%, and CEA increased from 9.1% to 14%; discharge prescriptions for secondary-prevention therapies also improved (Table 1). Because the study relied on routine administrative coding, these changes are best interpreted as system-level trends in recorded care rather than as audited quality indicators.

In the full cohort, early mortality differed substantially by stroke aetiology. In-hospital mortality was highest among patients with cardioembolic stroke and lowest among those with large artery disease. Specifically, in-hospital mortality was 14.9% in cardioembolic stroke, 4.2% in large artery disease, 11.4% in lacunar stroke, and 13.3% in other stroke etiology. Kaplan–Meier estimated 30-day mortality was 22.6%, 8.3%, 16.4%, and 17.6%, respectively. These findings confirm that patients excluded from the 30-day landmark Cox model represented a clinically important, high-risk subgroup and are therefore presented separately as part of the full-cohort outcome description (Supplementary table S4).

Kaplan–Meier analysis from the 30-day landmark to 5 years demonstrated significant differences in survival by stroke aetiology (log-rank $p < 0.0001$; Fig. 2). Cardioembolic stroke had the poorest long-term survival, with estimated mortality of 16.1% at 1 year, 24.3% at 2 years, and 46.3% at 5 years. Large artery disease had the most favourable survival profile, with corresponding mortality estimates of 6.7%, 11.2%, and 27.3%. Lacunar stroke showed intermediate long-term mortality, with 12.1% mortality at 1 year, 18.9% at 2 years, and 38.3% at 5 years, while unspecified stroke showed mortality of 11.7%, 18.3%, and 36.8%, respectively. Median survival was 3.59 years for cardioembolic stroke, 5.53 years for lacunar stroke, and 5.59 years for unspecified stroke; median survival was not reached in the large artery group. Maximum follow-up was approximately 8 years across aetiological groups. In the adjusted Cox model (shown in Fig. 3), age and multimorbidity dominated longer-term mortality risk. Older age was strongly associated with higher mortality, with an estimated 7% increase in risk per additional year. Longer hospital stay and comorbidities including coronary artery disease, diabetes mellitus, chronic kidney disease, dementia, and chronic obstructive pulmonary disease/asthma predicted poorer survival. In contrast, treated arterial hypertension and dyslipidaemia were associated with lower mortality. Protective associations were also observed for the use of ACEi/ARB, calcium-channel blockers, P2Y12 inhibitors, and IVT. Lacunar stroke was associated with modestly higher risk of death (HR 1.10, $p = 0.016$) relative to the model reference category shown in Figure 2, whereas large artery disease and other stroke aetiologies showed no significant difference in mortality.

Stroke etiology differences

Clinical profiles and care pathways differed substantially by stroke etiology (Table 2). Cardioembolic stroke occurred in older patients, and had the highest use of IVT, whereas large artery disease concentrated carotid revascularisation. Antithrombotic prescribing reflected these patterns (acetylsalicylic acid predominated in lacunar stroke and large artery disease, anticoagulation in cardioembolic), and length of stay and costs varied across aetiologies.

Sex differences

Men were younger than women at presentation (Table 3). Women had higher atrial fibrillation and heart failure, while men underwent more carotid procedures; IVT and MT were similar. Differences in discharge pharmacotherapy were consistent with differing comorbidity profiles.

Discussion

In this nationwide analysis of administratively identified ischaemic stroke hospitalisations in Slovenia from 2015 to 2022, we observed a modest decline in crude hospitalisation rates, shorter length of stay, and substantial increases in revascularisation procedures, particularly IVT, MT, and CEA, alongside clinically relevant differences by stroke aetiology and sex. At the same time, the study must be interpreted in light of the strengths and limitations of linked administrative data, including broad case ascertainment, variable coding precision, and the absence of stroke-severity measures.

Our findings align with GBD 2021, which show declining age-standardised stroke rates in many regions, while absolute numbers continue to rise due to population ageing and adverse risk-factor trends.[2] In this context, Slovenia's slightly decreasing crude admission burden and shorter inpatient stays may reflect a combination of factors: more efficient prehospital triage, faster in-hospital workflow, earlier discharge planning and secular shifts in coding or care pathways. Notably, the largest single-year decline in admissions occurred between 2019 and 2020, coinciding with the COVID-19 pandemic, consistent with reduced stroke admissions elsewhere.[6,7] Although pandemic-related care avoidance and service reconfiguration are

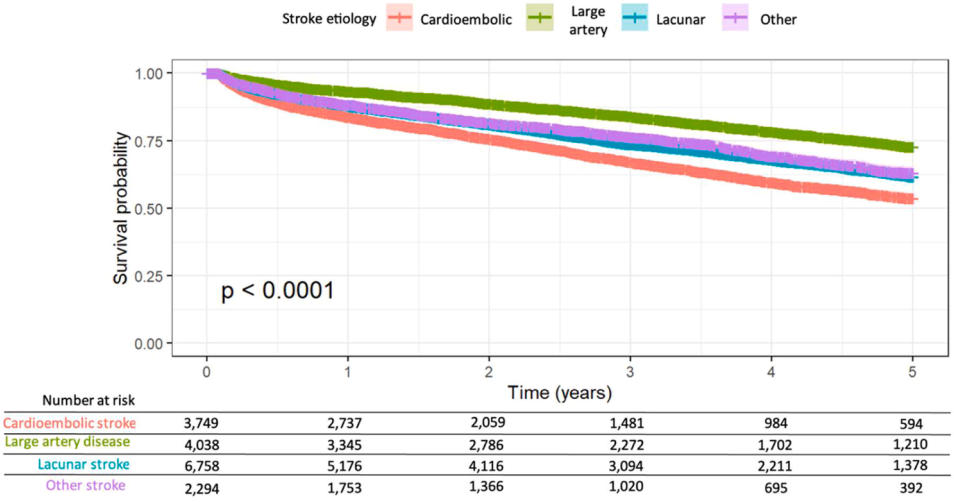

Fig. 2. Kaplan-Meier 5-year survival by stroke etiology.

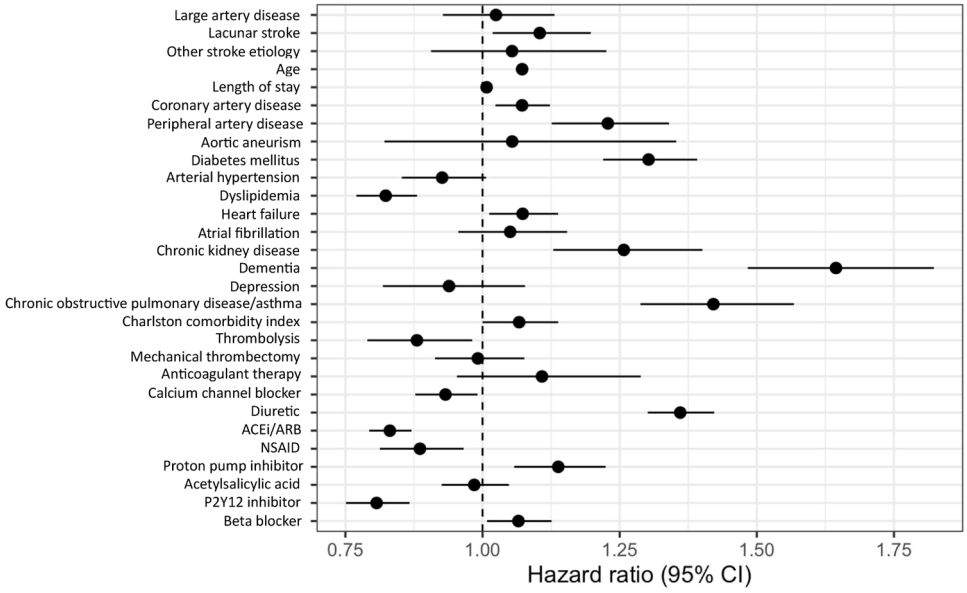

Fig. 3. Adjusted hazard ratios from the multivariable Cox model for long-term all-cause mortality after the 30-day landmark.

Table 2
Pooled variables grouped by stroke aetiologies.

Variable	Cardioembolic stroke[1] *n* = 3749	Large artery disease[1] n = 4038	Lacunar stroke[1] *n* = 6758	Other stroke etiology[1] *n* = 2294	*p*-value[2]
age, years	78 (69–85)	72 (65–78)	73 (65–81)	73 (63–82)	**<0.001**
sex, male	1716 (46%)	2433 (60%)	3721 (55%)	1200 (52%)	**<0.001**
coronary artery disease	422 (11%)	444 (11%)	523 (7.7%)	123 (5.4%)	**<0.001**
peripheral artery disease	301 (8%)	502 (12%)	413 (6.1%)	230 (10%)	**<0.001**
aortic aneurism	39 (1%)	42 (1%)	50 (0.7%)	13 (0.6%)	0.091
diabetes mellitus	769 (21%)	829 (21%)	1646 (24%)	477 (21%)	**<0.001**
arterial hypertension	2625 (70%)	2427 (60%)	4910 (73%)	1467 (64%)	**<0.001**
dyslipidaemia	1292 (34%)	1497 (37%)	2493 (37%)	809 (35%)	**0.037**
heart failure	560 (15%)	201 (5%)	344 (5.1%)	104 (4.5%)	**<0.001**
atrial fibrillation	2558 (68%)	476 (12%)	1140 (17%)	0 (0%)	**<0.001**
chronic kidney disease	343 (9.1%)	246 (6.1%)	336 (5%)	128 (5.6%)	**<0.001**
malignancy	232 (6.2%)	182 (4.5%)	379 (5.6%)	116 (5.1%)	**0.008**
chronic obstructive pulmonary disease/ asthma	126 (3.4%)	162 (4%)	230 (3.4%)	62 (2.7%)	0.05
dementia	373 (9.9%)	177 (4.4%)	566 (8.4%)	176 (7.7%)	**<0.001**
depression	113 (3%)	87 (2.2%)	241 (3.6%)	63 (2.7%)	**<0.001**
length-of-stay, days	11 (7–18)	6 (3–12)	12 (7–19)	10 (6–15)	**<0.001**
cost per episode, Euro	493,817 (333,248–850,767)	371,604 (320,245–600,461)	408,170 (295,144–621,956)	351,420 (251,411–596,373)	**<0.001**
CAS	241 (6.4%)	834 (21%)	351 (5.2%)	562 (2.7%)	**<0.001**
CEA	46 (1.2%)	1437 (36%)	285 (4.2%)	11 (0.5%)	**<0.001**
IVT	562 (12%)	231 (5.7%)	854 (13%)	245 (11%)	**<0.001**
MT	235 (6.3%)	549 (14%)	285 (4.2%)	45 (2%)	**<0.001**
anticoagulant therapy	2470 (66%)	934 (23%)	1780 (26%)	397 (17%)	**<0.001**
acetylsalicylic acid	1910 (51%)	3377 (84%)	5367 (79%)	1926 (84%)	**<0.001**
P2Y12 inhibitors	358 (9.5%)	1259 (31%)	920 (14%)	239 (10%)	**<0.001**
lipid-lowering therapy	2749 (73%)	3462 (86%)	4958 (73%)	1817 (79%)	**<0.001**
ACEi/ARB	2580 (69%)	2910 (72%)	4829 (71%)	1543 (67%)	**<0.001**

[1] *n* (%); Median (IQR).
[2] Pearson's Chi-squared test; Wilcoxon rank sum test; Fisher's exact test
CAS, carotid artery angioplasty and stenting; CEA, carotid endarterectomy; IVT, intravenous thrombolysis; MT, mechanical thrombectomy; ACEi, angiotensin converting enzyme inhibitor; ARB, angiotensin receptor blocker.

plausible explanations, alternative mechanisms, including temporary changes in exposure to infectious triggers and shifts in competing risks during social restrictions, should also be considered.

Telestroke has been central to Slovenia's service transformation. Launched in 2014, TeleKap was designed to extend specialist decision-making and IVT access to non-tertiary hospitals. In practice, the most likely mechanisms linking telestroke to the observed trends are earlier stroke recognition, faster remote neurologist consultation, reduced decision-to-needle delay, and more consistent selection for transfer to thrombectomy-capable centres. Our observation of increasing IVT use aligns with Slovenian and international evidence demonstrating that telestroke improves IVT rates without compromising safety.[8–11]

Despite progress, IVT use in Slovenia (15% in 2022) remains slightly below European averages (approximately 17%), whereas MT uptake (9.5% in 2022) appears comparable to or higher than European estimates (approximately 7%).[12] These comparisons should be interpreted

Table 3
Pooled variables grouped by sex.

Variable	Male[1]	Female[1]	*p*-value[2]
stroke type			**<0.001**
cardioembolic	1716 (19%)	2033 (26%)	
large artery disease	2433 (27%)	1605 (21%)	
lacunar	3721 (41%)	3037 (39%)	
other	1200 (13%)	1094 (14%)	
age, years	70 (63–78)	78 (70–84)	**<0.001**
coronary artery disease	898 (9.9%)	614 (7.9%)	**<0.001**
peripheral artery disease	906 (10%)	540 (7%)	**<0.001**
aortic aneurism	105 (1.2%)	39 (0.5%)	**<0.001**
diabetes mellitus	2165 (24%)	1556 (20%)	**<0.001**
arterial hypertension	6060 (67%)	5369 (69%)	**0.002**
dyslipidaemia	3481 (38%)	2610 (34%)	**<0.001**
heart failure	513 (5.7%)	689 (8.9%)	**<0.001**
atrial fibrillation	1816 (20%)	2350 (30%)	**<0.001**
chronic kidney disease	606 (6.7%)	447 (5.8%)	**0.013**
malignancy	482 (4.9%)	396 (5.1%)	0.11
chronic obstructive pulmonary disease/asthma	356 (3.9%)	224 (2.9%)	**<0.001**
dementia	524 (5.8%)	768 (9.9%)	**<0.001**
depression	209 (2.3%)	295 (3.8%)	**<0.001**
length-of-stay, days	10 (5–16)	11 (6–17)	**<0.001**
cost per episode, Euro	379,643 (298,024–613,756)	425,811 (320,245–665,499)	**<0.001**
CAS	1002 (11%)	486 (6.3%)	**<0.001**
CEA	1044 (12%)	735 (9.5%)	**<0.001**
IVT	1005 (11%)	887 (11%)	0.49
MT	608 (6.7%)	506 (6.5%)	0.62
anticoagulant therapy	2624 (29%)	2957 (38%)	**<0.001**
acetylsalicylic acid	7041 (78%)	5538 (71%)	**<0.001**
P2Y12 inhibitors	1823 (20%)	953 (12%)	**<0.001**
lipid-lowering therapy	7311 (81%)	5671 (73%)	**<0.001**
ACEi/ARB	6329 (70%)	5533 (71%)	**0.041**

[1] *n* (%); Median (IQR).
[2] Pearson's Chi-squared test; Wilcoxon rank sum test; Fisher's exact test
CAS, carotid artery angioplasty and stenting; CEA, carotid endarterectomy; IVT, intravenous thrombolysis; MT, mechanical thrombectomy; ACEi, angiotensin converting enzyme inhibitor; ARB, angiotensin receptor blocker.

cautiously because our study reports crude administrative measures rather than age-standardised registry metrics. Even so, the pattern suggests that MT access expanded rapidly, while further IVT improvement may depend more on reducing onset-to-door and door-to-needle delays than on in-hospital capacity alone. Closing the IVT gap will likely require optimised prehospital recognition and triage, including validated stroke scales, bypass and direct-to-imaging protocols, and standardised in-hospital workflows. Transfer protocols should also minimise secondary delays, consistent with European Stroke Organisation guidance.[13]

Secondary prevention at discharge was relatively high in our cohort: acetylsalicylic acid remained 73-76% throughout the years, anticoagulants increased to 37% in 2022 (66% in cardioembolic stroke), lipid-lowering therapy peaked at 82% in 2021, and ACEi/ARB remained 70-71%, consistent with prior reports from large registries and European health systems.[14,15] These findings suggest broadly guideline-concordant prescribing, but several caveats remain: discharge prescription claims do not confirm medication dispensing, adherence, dose intensity, or persistence after discharge. The decline in lipid-lowering therapy in 2022 therefore warrants audit to distinguish a real practice change from an administrative artefact.

Kaplan–Meier analyses showed clear differences in long-term survival by stroke aetiology, with the poorest survival among patients with cardioembolic stroke and the most favourable survival among those with large artery disease. In the adjusted Cox model, longer-term mortality was driven mainly by age and multimorbidity, with adverse associations for diabetes, chronic kidney disease, dementia, chronic pulmonary disease/asthma, and coronary artery disease, consistent with evidence linking these conditions to higher post-stroke mortality and disability.[16–18] The apparently protective associations of hypertension and dyslipidaemia likely reflect treatment effects and index-event/collider bias, consistent with the so-called lipid paradox.[19] Medication-related associations were directionally consistent with secondary-prevention evidence,[20,21] and IVT was associated with improved survival.[22] Because not all patients accrued a full 5 years of observation, the Kaplan–Meier estimates should be interpreted as censored time-to-event estimates rather than complete observed 5-year mortality proportions. The finding that lacunar stroke was associated with higher adjusted long-term mortality requires cautious interpretation. In unadjusted Kaplan–Meier analyses, cardioembolic stroke had substantially poorer survival, while lacunar stroke did not show the worst outcomes. The modestly increased adjusted hazard for lacunar stroke may therefore reflect the 30-day landmark design and residual confounding rather than a direct causal effect. Exclusion of early deaths may have disproportionately affected high-risk groups such as cardioembolic stroke, while administrative subtype classification may have misclassified patients with mixed mechanisms or substantial comorbidity. In addition, lacunar stroke survivors may live long enough for deaths related to age, vascular risk factors, dementia, chronic kidney disease, and other comorbidities to accrue. Thus, this finding should be viewed as an adjusted association in a selected post-acute survivor cohort, not evidence that lacunar stroke has a worse acute prognosis than cardioembolic stroke.

Stroke aetiology shaped care pathways and resource use, supporting the use of aetiology-aware performance indicators. Cardioembolic stroke occurred in older patients and was characterised by high anticoagulant use and higher IVT uptake, whereas large artery disease concentrated carotid revascularisation and showed the highest MT use. The decline in CAS (10% to 7.4%) alongside rising CEA may reflect evolving practice patterns, capacity, or selection and merits further investigation.

Sex differences were present but nuanced. Women presented at older ages and had higher atrial fibrillation and heart failure burdens, whereas men underwent more carotid procedures; IVT and MT were similar. These findings are compatible with sex differences in risk profiles and stroke mechanisms rather than clear disparities in access to hyperacute therapy, but they underscore the need for equitable pathways for anticoagulation initiation, carotid work-up, and follow-up.

Strengths and limitations

Our findings should be interpreted within the Slovenian context of a small population and a publicly financed, nationally coordinated healthcare system that includes telestroke support. National demographic and lifestyle patterns may also influence stroke burden in Slovenia; however, factors such as smoking, obesity, dietary patterns, and other population-level risk characteristics were not directly measured in our administrative dataset and therefore could not be analysed in this study. Comparisons with more heterogeneous settings and non-universal healthcare systems, such as the United States, should therefore be made cautiously, as differences in case mix, access to care, financing, and service organisation may influence both treatment patterns and outcomes. This study also reflects both the strengths and the limitations of linked administrative data. Its strengths include nationwide scope, deterministic linkage across payer, hospital, and population registries, and coverage through 2022. However, several limitations should frame interpretation. First, the analysis was based on administrative datasets rather than a validated stroke registry; although capture of resident inpatient claims is likely near-complete, this was not formally

validated against an external stroke audit. Second, coding of comorbidities and TOAST-based stroke aetiology was not independently validated. Third, first-ever and recurrent stroke could not be reliably distinguished for patients with events before 2015. In addition, important clinical variables, including National Institutes of Health Stroke Scale (NIHSS), modified Rankin Scale (mRS), imaging findings, exact onset-to-treatment times, and mean follow-up duration by subgroup, were unavailable. The analysis was also restricted to hospitalised events and therefore did not capture out-of-hospital strokes or deaths, while the landmark survival approach excluded early post-discharge events from the Cox model. Taken together, these limitations underscore the need for a national stroke registry with core clinical data elements and linkage to emergency medical services and mortality records.

Conclusion

Using nationwide claims data, we observed a modest decline in crude administratively identified ischaemic stroke admissions in Slovenia from 2015 to 2022, alongside shorter length of stay and substantial increases in recorded reperfusion therapies and discharge secondary-prevention prescribing. However, these findings are derived from routine administrative data and should be interpreted cautiously because case specificity, comorbidity coding, and stroke subtype classification are imperfect, and age-standardised rates were not calculated. Within those constraints, care pathways and outcomes varied by stroke aetiology and sex, indicating that improvements were not uniform across patient groups. These findings support continued system-level performance monitoring and the development of a national stroke registry to enable benchmarking and equity-focused quality improvement.

Source of funding

The research underlying this manuscript was funded by the Slovenian Research Agency (ARIS)/Ministry of Health research grant No V3-24038. The contribution of Petra Došenović Bonča was supported by the Slovenian Research and Innovation Agency (ARIS) in the framework of the research grant No P5-0117.

Data availability

Research data supporting the findings of this study are archived in the Repository of the University of Ljubljana under accession number 180146.

Generative AI and AI-assisted technologies were not used in the preparation of this work.

CRediT authorship contribution statement

Tjaša Furlan: Writing – review & editing, Writing – original draft, Formal analysis, Data curation. **Borut Jug:** Writing – review & editing, Validation, Supervision, Resources, Project administration, Methodology, Data curation, Conceptualization. **Neža Nagrašek:** Formal analysis, Data curation. **Dalibor Gavrić:** Project administration. **Janja Pretnar Oblak:** Writing – review & editing. **Petra Došenović Bonča:** Writing – review & editing, Resources, Project administration, Methodology, Funding acquisition, Conceptualization. **Senta Frol:** Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgment

The authors thank The Health Insurance Institute of Slovenia for their assistance and considerable support.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.jstrokecerebrovasdis.2026.108668.

References

1. Feigin VL, Owolabi MO, World Stroke Organization–Lancet Neurology Commission Stroke Collaboration Group. Pragmatic solutions to reduce the global burden of stroke: a World Stroke Organization-Lancet Neurology Commission. *Lancet Neurol.* 2023;22(12):1160–1206. https://doi.org/10.1016/S1474-4422(23)00277-6.
2. 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. https://doi.org/10.1016/S1474-4422(24)00369-7.
3. Cadilhac DA, Kim J, Lannin NA, et al. National stroke registries for monitoring and improving the quality of hospital care: a systematic review. *Int J Stroke.* 2016;11(1):28–40. https://doi.org/10.1177/1747493015607523.
4. Quan H, Li B, Couris CM, et al. Updating and validating the Charlson comorbidity index and score for risk adjustment in hospital discharge abstracts using data from 6 countries. *Am J Epidemiol.* 2011;173(6):676–682. https://doi.org/10.1093/aje/kwq433.
5. Adams HP, Bendixen BH, Kappelle LJ, et al. Classification of subtype of acute ischemic stroke. Definitions for use in a multicenter clinical trial. TOAST. Trial of Org 10172 in acute stroke treatment. *Stroke.* 1993;24(1):35–41. https://doi.org/10.1161/01.str.24.1.35.
6. Gunnarsson K, Tofiq A, Mathew A, Cao Y, von Euler M, Ström JO. Changes in stroke and TIA admissions during the COVID-19 pandemic: a meta-analysis. *Eur Stroke J.* 2024;9(1):78–87. https://doi.org/10.1177/23969873231204127.
7. Yang Q, Tong X, Coleman King S, Olivari BS, Merritt RK. Stroke hospitalizations before and during COVID-19 pandemic among Medicare beneficiaries in the United States. *Stroke.* 2021;52(11):3586–3601. https://doi.org/10.1161/STROKEAHA.121.034562.
8. Zupan M, Zaletel M, Žvan B. Enhancement of intravenous thrombolysis by Nationwide Telestroke Care in Slovenia: a model of Care for middle-income countries. *Telemed J E Health.* 2020;26(4):462–467. https://doi.org/10.1089/tmj.2019.0046.
9. Velnar T, Zele T, Bosnjak R. Importance of the telemedicine network for neurosurgery in Slovenia. *World J Methodol.* 2019;9(1):20–25. https://doi.org/10.5662/wjm.v9.i1.20.
10. McDermott M, Skolarus LE, Burke JF. A systematic review and meta-analysis of interventions to increase stroke thrombolysis. *BMC Neurol.* 2019;19(1):86. https://doi.org/10.1186/s12883-019-1298-2.
11. Janßen A, Pardey N, Zeidler J, et al. Support by telestroke networks is associated with increased intravenous thrombolysis and reduced hospital transfers: a german claims data analysis. *Health Econ Rev.* 2024;14(1):100. https://doi.org/10.1186/s13561-024-00577-5.
12. Aguiar de Sousa D, Wilkie A, Norrving B, et al. Delivery of acute ischaemic stroke treatments in the European region in 2019 and 2020. *Eur Stroke J.* 2023;8(3):618–628. https://doi.org/10.1177/23969873231186042.
13. Berge E, Whiteley W, Audebert H, et al. European Stroke Organisation (ESO) guidelines on intravenous thrombolysis for acute ischaemic stroke. *Eur Stroke J.* 2021;6(1):I–LXII. https://doi.org/10.1177/2396987321989865. I-LXII.
14. Ovbiagele B, Schwamm LH, Smith EE, et al. Recent nationwide trends in discharge statin treatment of hospitalized patients with stroke. *Stroke.* 2010;41(7):1508–1513. https://doi.org/10.1161/STROKEAHA.109.573618.
15. Skajaa N, Laugesen K, Lauffenburger JC, Schwamm LH, Sørensen HT, Patorno E. Trends in the use of medications for secondary ischemic stroke prevention in Denmark, 2005-2021. *Neurology.* 2024;102(9), e209309. https://doi.org/10.1212/WNL.0000000000209309.
16. Sennfält S, Pihlsgård M, Petersson J, Norrving B, Ullberg T. Long-term outcome after ischemic stroke in relation to comorbidity - an observational study from the Swedish Stroke Register (Riksstroke). *Eur Stroke J.* 2020;5(1):36–46. https://doi.org/10.1177/2396987319883154.
17. Lau LH, Lew J, Borschmann K, Thijs V, Ekinci EI. Prevalence of diabetes and its effects on stroke outcomes: a meta-analysis and literature review. *J Diabetes Investig.* 2019;10(3):780–792. https://doi.org/10.1111/jdi.12932.
18. Bruce SS, Parikh NS. Chronic kidney disease and stroke outcomes: beyond serum creatinine. *Stroke.* 2023;54(5):1278–1279. https://doi.org/10.1161/STROKEAHA.123.042965.
19. Patel U, Malik P, Dave M, et al. The lipid paradox among acute ischemic stroke patients-a retrospective study of outcomes and complications. *Medicina.* 2019;55(8):475. https://doi.org/10.3390/medicina55080475.
20. Samuel S, Craver K, Miller C, et al. Reviving decades-old wisdom: longitudinal analysis of renin-Angiotensin system inhibitors and its effects on acute ischemic

stroke to improve outcomes. *Am J Hypertens*. 2024;37(7):531–539. https://doi.org/10.1093/ajh/hpae033.
21. CAPRIE Steering Committee. A randomised, blinded, trial of clopidogrel versus aspirin in patients at risk of ischaemic events (CAPRIE). CAPRIE Steering Committee. *Lancet*. 1996;348(9038):1329–1339. https://doi.org/10.1016/s0140-6736(96)09457-3.
22. Muruet W, Rudd A, Wolfe CDA, Douiri A. Long-term survival after intravenous thrombolysis for ischemic stroke: a propensity score-matched cohort with up to 10-year follow-up. *Stroke*. 2018;49(3):607–613. https://doi.org/10.1161/STROKEAHA.117.019889.