

Supplementary materials

Table S1. Full search strategy.

Database	Search terms	Filters/limits	Search date
PubMed	("stroke" [MeSH Terms] OR stroke OR cerebrovascular accident OR cerebral infarction OR intracerebral haemorrhage OR brain haemorrhage) AND (spatial analysis OR spatial clustering OR geographic information systems OR GIS OR spatial regression OR Moran's I OR geographically weighted regression OR GWR)	English, 2005–2025	20 July 2025
MEDLINE	(stroke OR cerebrovascular accident OR cerebral infarction OR intracerebral haemorrhage OR brain haemorrhage) AND (spatial analysis OR spatial clustering OR geographic information systems OR GIS OR spatial regression OR Moran's I OR geographically weighted regression OR GWR)	English, 2005–2025	20 July 2025
ScienceDirect	(stroke OR cerebrovascular accident OR cerebral infarction OR intracerebral haemorrhage OR brain haemorrhage) AND (spatial analysis OR spatial clustering OR geographic information systems OR GIS OR spatial regression OR Moran's I OR geographically weighted regression OR GWR)	English, 2005–2025	20 July 2025
CINAHL	(stroke OR cerebrovascular accident OR cerebral infarction OR intracerebral haemorrhage OR brain haemorrhage) AND (spatial analysis OR spatial clustering OR geographic information systems OR GIS OR spatial regression OR Moran's I OR geographically weighted regression OR GWR)	English, 2005–2025	20 July 2025
ScienceON	(stroke OR cerebral infarction OR intracerebral haemorrhage) AND (spatial analysis OR spatial clustering OR GIS OR spatial regression OR Moran's I OR GWR)	Korean/English, 2005–2025	20 July 2025
DBpia	(stroke OR cerebral infarction OR intracerebral haemorrhage) AND	Korean/English, 2005–2025	20 July 2025

	(spatial analysis OR spatial clustering OR GIS OR spatial regression OR Moran's I OR GWR)		
KoreaMed	(stroke OR cerebral infarction OR intracerebral haemorrhage) AND (spatial analysis OR spatial clustering OR GIS OR spatial regression OR Moran's I OR GWR)	Korean/English, 2005–2025	20 July 2025
RISS	(stroke OR cerebral infarction OR intracerebral haemorrhage) AND (spatial analysis OR spatial clustering OR GIS OR spatial regression OR Moran's I OR GWR)	Korean/English, 2005–2025	20 July 2025
KISS	(stroke OR cerebral infarction OR intracerebral haemorrhage) AND (spatial analysis OR spatial clustering OR GIS OR spatial regression OR Moran's I OR GWR)	Korean/English, 2005–2025	20 July 2025

Table S2. Reviewed studies on spatial associations of stroke incidence, prevalence and mortality.

No.	Authors, year	Country, region	Study design, spatial unit	Sample, age group	Method used for the spatial analysis	Model covariates	Outcome measures	Main findings
1	Adzandeh et al., 2016	Nigeria, Osun State	Retrospective longitudinal study, 30 Osun LGAs ^a	Stroke cases 1990-2012, ≥ 19 -years olds	GIS ^b mapping	Occupation; Gender, Age, Hypertension, Diabetes mellitus	Persistent social inequalities, incidence: urban $\sim 3\times$ more than rural	Better healthcare accessibility in urban vs rural areas
2	van Rheenen et al., 2015	Canada, Alberta	Retrospective longitudinal study, Alberta State	Stroke cases across Alberta (n=3,757), ≥ 19 -year olds	Spatial Scan, Getis-Ord Gi ^{***} (Bayes smoothing)	Age, Gender, Hypertension, Diabetes mellitus, Atrial fibrillation, Stroke centres,	Urban centre hotspots: Intracerebral haemorrhage (RR ^c 1.80, $p<0.05$) Subarachnoid haemorrhage (RR ^c 1.64, $p<0.05$)	Regional spatial distribution disparities with regard to stroke incidence and outcomes
3	Padilla et al., 2021	France, Brest	Ecological study, Census block	People in Brest Stroke Registry, ≥ 60 -year olds	Geographic weighted regression	Deprivation and urban-rural index	Stroke incidence in people with deprivation in urban census tracts	Regional disparities with regard to mortality risk
4	Pedigo et al., 2011	USA, Tennessee	Retrospective longitudinal study, Census	11 counties in east Tennessee, ≥ 19 -year olds	SaTScan, spatial empirical Bayesian	Socioeconomic and demographic neighbourhood	Higher-mortality and stroke high-risk areas associated with low-	Disparities with regard to mortality risk between regions

			tracts		technique (SEB)	variables	education population	Spatial clustering of stroke
5	Dworkis et al., 2020	USA, Atlanta, Georgia	Retrospective cross-sectional study 174 census blocks	500 cities dataset, ≥ 19 years	GIS ^f mapping, Global Moran's <i>I</i>	Crude prevalence of stroke	Significant (27.3%) regional-level spatial clustering in 136 cases	cases in metropolitan areas Geographic variation in heat-wave-related stroke
6	Chen et al., 2015	China, Nanjing	Cross-sectional study, 13 districts of Nanjing	13 Nanjing districts, ≥ 19-year olds	Point pattern analysis, generalized additive models	Disposable income, ≥ 65 years of age, air conditioning units, hospital beds	Increased stroke mortality risk in rural areas during heat-wave periods	mortality risk Disparities in high-incidence north & west metropolitan regions
7	Freyssen ge et al., 2020	France, Rhone	Cohort study, Rhone department	French 'stroke 69 cohort'(3,442 patients) ≥ 18-year olds	Global auto-correlation, cluster detection	Stroke/transient ischaemic attack (TIA) diagnosis	Regional clustering and outlier patterns, Moran's <i>I</i> = 0.004	
8	Xing et al., 2025	Worldwide (183 countries)	Repeated cross-sectional study over 20 years,183 spatial units (WHO)	183 countries, ≥ 19-year olds	Spatiotemporal variations, Moran's <i>I</i> , Getis-Ord Gi*	Number of stroke deaths, AMSR ^d	Global increase in stroke deaths, accompanied by declining AMSR ^d	Lower stroke mortality in countries with higher economic levels

9	Qian et al., 2025	Worldwide (204 countries)	Cross-sectional cohort study, (GBD ^e) - 204 spatial units	204 countries and regions, ≥ 19 -year olds	Bayesian age-period-cohort (BAPC) model	Stoke DALY ^f , estimated annual % change of the age-standardised incidence rate, ASDR ^g , and ASMR ^d for stroke in countries with five socio-demographic index levels (SDIs)	Global increase in stroke incidence and decrease in mortality; highest rates in Eastern Europe, Central Asia and East Asia	Increase in stroke incidence with decline in age-standardised incidence rate and ASMR ^d , 1990–present
10	Tran et al., 2024	USA, Tennessee	Cross-sectional, 95 Tennessee counties	4,561 census blocks in Tennessee	GIS mapping	Health care access	Mean travel distance, time: rural (22.0 miles, 31.6 min) vs. urban (10.5 miles, 18.4 min)	Higher prevalence in rural Tennessee due to limited facilities and longer travel to care.
11	Leveau et al., 2024	Spain, provinces (n=50)	Cross-sectional ecological study 50 provinces	8,131 municipalities, ≥ 19 -year olds	GIS mapping, Poisson Besag-York-Mollié (BYM) model	Healthcare accessibility index (HAcI), Gross geographic product per capita	Higher ischaemic stroke mortality and case fatality rates in southern Spain in ≥ 60 -year adults	Association of economic development with reduced ischaemic stroke mortality
12	Ha et al.,	Korea nationwide	Ecological study	332 stations, 249 districts	GIS mapping	Air pollution particulate matter ≤ 10	Stroke mortality in relation to air	Strongest association of high air pollutant

	2023					μm (PM ₁₀), NO ₂ , SO ₂ , CO)	pollution levels	concentrations with ischaemic stroke mortality
13	Bando et al., 2024	Brazil, Minas Gerais	Ecological study (41 years), State of Minas Gerais	State micro-regions, 20.5 million inhabitants	GIS mapping, Temporal distribution	Stroke incidence and mortality rates	Clusters with high incidence found in southern regions (1980–1999)	Persistent high-rate clusters despite overall stroke mortality decline
14	Luo et al., 2017	China, nationwide	Repeated cross-sectional study over 20 years	GBD 2015, ≥ 19 -year olds	Spatial autocorrelation, age-period-cohort model (APC)	Stroke mortality rate, PM _{2.5}	Hotspot shift from northeast to midwest and southwest; coldspots mainly in coastal areas	Spatial correlation between stroke incidence and lifetime smoking prevalence
15	Li et al., 2024	China, Shanghai	Retrospective longitudinal study, Class 3 A hospital data	Class 3 A hospital stroke data	Multiscale geographically weighted regression (MGWR)	Stress, Pollution, Habit, Social Indicators	The most influential residential environment factor	Limited impact of environmental factors on stroke incidence
16	Paulina et al., 2025	Colombia nationwide	Retrospective longitudinal study, 33 administrative	National mortality data (1985-2017), ≥ 25 -years olds	GIS mapping	Gender, age, education, level, Relative index of inequality (RII), Standardised mortality	Stroke mortality declined (men: 66.01/100,000; women:	Elevated mortality in economically developed regions, higher SMR and RR by women's

			districts			ratio (SMR)	65.74/100,000)	education level and age
17	Odoi & Busingye, 2014	USA, Tennessee	Retrospective longitudinal study, 30 counties	Stroke mortality data (1999-2007) Age-groups:0-34, 35-44, 45-54, 55-64, ≥ 65 years	GIS mapping, BYM model, GWGLM ^h	Sex, race, education level, age-groups	Differences in mortality risk by sex, race, age, and education ($p<0.05$)	Higher stroke mortality risk in rural Census tracts with larger elderly and widowed populations
18	Jung et al., 2024	Korea, Gyeonggi Province	Cross-sectional 12 counties	National cerebrovascular disease data, 4,427 acute stroke patients	GIS mapping	1-year mortality after stroke (%) Intra-regional acute stroke treatment (%)	Intra-regional treatment rates (57.8 % vs. 51.0 %), marginally lower one-year mortality	Regional disparities in stroke treatment and mortality within hospital service areas
19	Halada et al., 2024	USA, Wisconsin	Retrospective longitudinal study	Stroke Centers , n=119	GIS mapping, spatial regression model	Age, sex, education, Driving distance to ASC(advanced-care-capable stroke center) location	Areas with higher stroke SMR are urban centers and rural region	Longer driving distance to ASC and higher stroke mortality in small towns

20	Roth et al., 2016	USA , Ohio	Cross-sectional census tract	≥65-year old women (n=222)	GIS mapping	Cardiovascular health (CVH) score, Body mass index(BMI) score, Blood pressure score	Community-level attributes (income, household size), CVH-linked unemployment	Integration of community and electronic health records (EHR) data in patient care
21	Felix et al., 2021	India / Ludhiana city	Cross-sectional study, 75 wards of the Municipal Corporation	Transient ischaemic attack) patients (TIA) (n=138)	GIS mapping Global Moran's <i>I</i> , Getis-Ord <i>Gi</i> *	Transient ischaemic attack) patients (TIA) incidence rate	Hypertension (87.4%) as the leading risk factor for TIA	Lower-than-expected TIA incidence in low- and middle-income countries (LMICs)
22	Jewett et al., 2017	Canada, Ontario	Cross-sectional Stroke centers	All stroke centers (district, regional, and Telestroke) (39 sites)	GIS mapping	Stroke thrombolysis	Majority of Ontario residents have access to stroke thrombolysis	Geoinformatics for coordinating provincial EVT (Endovascular thrombectomy) access
23	Khan et al., 2011	USA, North and South Carolina, Georgia	Cross-sectional tri-state region from the US Census (16)	88 JCPSCs ^s -accredited hospitals ≥ 25 years	GIS mapping	Drive time to JCPSC ⁱ Age-adjusted stroke death rates, Sex, Race/ethnicity, Education, Income	Largest urban–rural gap in 30-min drive access (70% vs 26%)	Rural coastal plains concentrated with high stroke mortality counties; fewest JCPSCs ⁱ

24	Soljak et al., 2011	England nationwide	Cross-sectional	Local authorities (351) and general practices (8,372) 9,682,176 patients	GIS mapping, Local Moran's I, GWR	Stroke Prevalence rate, Hypertension, CHD (coronary heart disease)	Significant spatial variation in stroke O:E ratio (observed vs. expected prevalence) identified by GWR	Geographic variation and priority healthcare identified
25	Schieb et al., 2025	USA, nationwide	Cross-sectional 72,517 US Census Tracts	Stroke care (n=1,825) or advanced (endovascular-capable) stroke care (n=426) ≥18 years	GIS mapping	Stroke Prevalence rate, Hypertension, CHD	Median drive time: 11.8 min (certified), 23.0 min (advanced)	Increased stroke, hypertension, and CHD prevalence in areas >60 min from stroke care
26	Wu et al., 2024	Taiwan, nationwide	Case-crossover design study, 368 townships	Stroke-related emergency department visit cases	GIS mapping, Distributed Lag Nonlinear Model (DLNM)	Stroke Incidence, Daily temperature	Increased emergency room visits for stroke, >34 °C max daily temperature	Ischaemic stroke incidence increase from 7.8 to 36.1% at global warming level change

								from 2 °C to 4 °C
27	Han et al., 2015	Korea, nationwide	Cross-sectional study, 232 municipal administrative districts	208,800 people $\geq$ 19-year olds	GIS mapping conditional autoregressive model (CAR)	Physician-diagnosed stroke cases per 100,000 population, Prevalence of lifetime smokers per 100,000 population	Physician-diagnosed stroke cases per 100,000 population - Moran's $I = 0.33$. Prevalence of lifetime smokers (per 100,000 population - Moran's $I = 0.17$	Spatial correlation between stroke incidence and lifetime smoking prevalence
28	Ju et al., 2017	Korea, nationwide	Cross-sectional study, 230 municipal administrative districts	207,000 people $\geq$ 19 years	GIS mapping Moran's I , Local indicators of spatial association (LISA)	Stroke, Hypertension, Diabetes	Global Moran's $I = 0.386$ Unique local clustering patterns, spatial outliers	Spatial correlation between stroke and hypertension/diabetes; low-prevalence clusters in urbanized areas, high-prevalence clusters in inland regions
29	Park et al., 2016	Korea, nationwide	Cross-sectional study, 251 municipal administrative	225,900 people $\geq$ 19 years	Geographically weighted regression (GWR)	Metropolitan concentration, Aged population rate, health service	Moran's $I = 0.222$	Concentration of rural patients in Seoul metropolitan area linked to medical resources,

			districts			satisfaction		elderly proportion, diagnosis rate, and satisfaction
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^alocal government area; ^bgeographic information systems; ^crelative risk; ^dage-standardised stroke mortality rate; ^eGlobal Burden of Disease;

^fdisability-adjusted life-years; ^gage-standardized disability-adjusted life-year rate; ^hPoisson geographically-weighted generalized linear models; ⁱJoint Commission–Certified Primary Stroke Center.

Table S3. Methodological Quality Assessment of Included Spatial Epidemiological Studies

Study	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Total score	Overall Quality
Adzandeh et al., 2016	Yes	Yes	Yes	Unclear	No	No	No	Yes	Yes	Yes	6.5/10	Moderate
Rheenen et al., 2015	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	9/10	High
Padilla et al., 2021	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	9/10	High
Pedigo et al., 2011	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	10/10	High
Dworkis et al., 2020	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	10/10	High
Chen et al., 2015	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	9/10	High
Freyssenge et al., 2020	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	9/10	High
Xing et al., 2025	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	9/10	High
Qian et al., 2025	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	9/10	High

Tran et al., 2024	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	9/10	High
Leveau et al., 2024	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	10/10	High
Ha et al., 2023	Yes	Yes	Yes	No	No	No	No	Yes	Yes	Yes	6/10	Moderate
Bando et al., 2024	Yes	Yes	Yes	No	No	No	No	Yes	Yes	Yes	6/10	Moderate
Luo et al., 2017	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	10/10	High
Li et al., 2024	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	9/10	High
Paulina et al., 2025	Yes	Yes	Yes	No	No	Yes	No	Yes	Yes	Yes	7/10	Moderate
Odoi et al., 2014	Yes	Yes	Yes	Yes	Yes	Yes	Unclear	Yes	Yes	Yes	9.5/10	High
Jung et al., 2024	Yes	Yes	Yes	No	No o	No	No	Yes	Yes	Yes	6/10	Moderate
Halada et al., 2024	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	9/10	High
Roth et al., 2016	Yes	Yes	Yes	No	No	No	No	Yes	Yes	Yes	6/10	Moderate
Felix et al., 2021	Yes	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	8/10	High
Jewett et al., 2017	Yes	Yes	Yes	No	No	No	No	Yes	Yes	Yes	6/10	Moderate
Khan et al., 2011	Yes	Yes	Yes	No	No	Yes	No	Yes	Yes	Yes	7/10	Moderate
Soljak et al., 2011	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	9/10	High
Schieb et al., 2025	Yes	Yes	Yes	No	No	No	No	Yes	Yes	Yes	6/10	Moderate
Wu et al., 2024	Yes	Yes	Yes	No	No	No	Unclear	Yes	Yes	Yes	6.5/10	Moderate
Han et al., 2015	Yes	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	8/10	High
Ju et al., 2017	Yes	Yes	Yes	Yes	No	No	No	Yes	Yes	Yes	7/10	Moderate
Park, 2016	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	7/10	Moderate

Each item was rated as Yes (1), No (0), or Unclear (0.5). Overall methodological quality was classified as High (≥ 8), Moderate (5–7.5), or Low (< 5). No highlighted for contrast only. Assessment was based on the Joanna Briggs Institute (JBI) Critical Appraisal Checklist for Analytical Cross-Sectional Studies, with additional spatial epidemiology-specific items: Q1=clarity of objectives; Q2=validity of data sources and spatial units; Q3=definition and measurement of variables; Q4=assessment of spatial autocorrelation; Q5=appropriateness of spatial analytical methods; Q6=control of confounding; Q7=consideration of MAUP and boundary effects; Q8=interpretation and external validity; Q9=visualisation quality and reproducibility; Q10=ethical considerations and data reliability.