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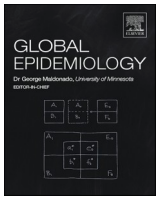

Comprehensive analysis of stroke epidemiology in Vietnam: Insights from GBD 1990–2019 and RES-Q 2017–2023

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ABSTRACT

Background: Stroke is a significant health burden in Vietnam, with substantial impacts on mortality, morbidity, and healthcare resources. An up-to-date report on stroke epidemiology and associated risk factors in Vietnam was missing.

Method: We analyzed the data published in the Global Burden of Disease (GBD) 2019, in combination with the first-time analysis of the Registry of Stroke Care Quality Improvement (RES-Q) initiative in Vietnam from 2017 to 2023.

Findings: Comparative analysis globally revealed that Vietnam had one of the highest stroke incidence and prevalence rates in Southeast Asia and ranked 4th in stroke mortality among 11 neighbouring countries. In the RES-Q dataset, 95,696 patients (77 %) were ischemic stroke, 23,203 (18 %) were intracerebral haemorrhage, and 2816 (2 %) were subarachnoid haemorrhage. In GBD 2019, stroke was the leading cause of death among cardiovascular diseases in Vietnam, accounting for 135,999 fatalities. The incidence of stroke was 222 (95 % UIs 206–242) per 100,000 population, with a prevalence of 1541 (1430-1679) per 100,000. Results align with the report from the RES-Q dataset in two megacities of Vietnam: Hanoi (incidence rate of 168.9, prevalence rate of 1182.2) and Ho Chi Minh City (incidence rate of 207.1, prevalence rate of 1221.8). Key risk factors for stroke mortality are high systolic blood pressure (79,000 deaths), unhealthy dietary (43,000 deaths), high fasting plasma glucose (35,000 deaths), and air pollution (33,000 deaths). Incidence is lower in rural Vietnam, but availability and quality of care are higher in megacities.

Interpretation: The results promote a further understanding of stroke and risk factors for the Vietnamese population and suggest prevention and treatment strategies for the Vietnamese government, including facility and capacity improvement and applications of advanced technologies.

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Introduction

Stroke is a significant global health issue, with a high incidence and mortality rate, particularly in low- and middle-income countries [1,2]. The incidence of stroke globally is expected to increase up to 81 % from 2021 to 2050 [3], making effective prevention and management crucial. The implementation of better surveillance systems and prevention programs is necessary to track and reduce the burden of stroke [2]. The high prevalence of traditional risk factors, including hypertension, diabetes, dyslipidemia, and smoking, are major concerns, according to Wasay et al. [4]. This study also showed the urgent need for interventions to reduce the burden of stroke in Southeast Asia. These studies underscore the urgent need for interventions to reduce the burden of stroke in Southeast Asia. Further research is needed to fully understand the burden of stroke and its risk factors in this population [5]. The Global Burden of Diseases (GBD) was released in 2019, with a whopping 204 countries and territories, including both sovereign nations and regions with distinct epidemiological profiles, 21 regions, and four World Bank income level groups from 1990 to 2019, categorised by age group and gender [6]. This report includes Injuries and Risk Factors Study in an exhaustive analysis that produces comparable estimates of the worldwide, regional, and country-specific burden of various diseases and conditions, including stroke.

A report published in the Lancet South Southeast Asia Region (SEAR) in 2023 pointed out that this SEAR region accounts for 40 % of global stroke mortality [7,8]. However, according to the World Health Organization (WHO), there are 11 countries in SEAR but not Vietnam. Although Vietnam belongs to the Western Pacific Region (WPR), Vietnam shares the most cultural, topographical, and social diversity with SEAR's nations. However, the stroke report in Vietnam has not been covered yet. Distinctive aetiologies less commonly encountered in the developed world, such as tropical diseases, infections, snakebites, and scorpion stings, are specific to this region and contribute substantially to the stroke burden [7]. It is important to consider these unique risk factors when designing prevention and management strategies for stroke in Vietnam and other similar regions [8,9].

As of 2019, the state of stroke care in Vietnam remains complex, with significant gaps in standardized protocols and healthcare infrastructure [10,11]. Despite these challenges, Vietnam has achieved significant improvements in stroke care, including the implementation of stroke units and aligned stroke care management with international guidelines [10–13]. The delay in hospital arrival after the initial symptoms of a stroke could be a significant concern, highlighting the need for greater public awareness and more stroke units across the country [12]. The Registry of Stroke Care Quality (RES-Q) is a global platform that collects data to improve stroke care quality [14,15]. RES-Q has been deployed in Vietnam since 2017 and has been widely adopted across 52 stroke centres, though independent validation studies in the Vietnamese healthcare context remain limited [10].

Therefore, in this study, we aim to provide an overview of the stroke panorama in Vietnam based on the GBD 2019 and the RES-Q dataset. We do so by comparing the GBD 2019 data on incidence, prevalence, mortality, and quality of life metrics (DALYs, DLLs, and DLYs) across the SEAR and Western Pacific with that of Vietnam. We report quantitatively on the characteristics of stroke risk factors and differences between genders by phenotypes of stroke. A further comparison of the incidence and prevalence of the stroke burden in two megacities of Vietnam (Hanoi, the capital city and Ho Chi Minh City (HCMC), the biggest Vietnamese economic centre) using the RES-Q dataset is shown between 2017 and 2023.

Methods

Overview and study design

In this study, for GBD data, we analyzed long-term trends from 1990 to 2019 but primarily reported results for 2019 to align with RES-Q data from 2017 to 2023. Stroke definition, stroke types, subtypes, and stroke estimation for mortality of the GBD 2019 were reported elsewhere [6]. We present the incidence, prevalence, deaths, mortality, disability and DALYs with 95 % uncertainty intervals (UIs) due to stroke, including ischaemic stroke, intracerebral haemorrhage and subarachnoid haemorrhage, stratified by sex, and age groups. Also, the risk factors for stroke mortality are reported for Vietnam using the GBD 2019. On the other hand, using the RES-Q dataset, we highlight the stroke incidence and prevalence of two megacities in Vietnam, which are Hanoi and HCMC. While the RES-Q dataset includes nationwide data, detailed incidence and prevalence analyses were conducted for Hanoi and Ho Chi Minh City, as they provide the most comprehensive hospital-level data. In this analysis, we criticise the differences between genders and compare the risk factors related to stroke incidence. We acknowledge the potential biases due to socio-political, healthcare changes, and especially the pandemic (COVID-19).

The GBD 2019 for stroke in Vietnam

The data used for this analysis of the GBD 2019 for Vietnam stroke estimation are available at the following link: http://ghdx.healthdata.org/gbd-2019 and the methodology of GBD 2019 has already been published [6]. Stroke and stroke types (ischemic stroke [IS], intracerebral haemorrhage [ICH], and subarachnoid haemorrhage [SAH]) were defined according to standard WHO criteria [16]. The prevalence and incidence of the disease were estimated using mixed-effects models such as Bayesian meta-regression (DisMod-MR 2.1) and a spatiotemporal Gaussian process regression model (ST-GPR) [6]. In this model, predictors included age, sex, and regional/country-level factors; the response variable was the disease burden metric (e.g., incidence, prevalence, mortality). Random effects accounted for variability across regions, and a log link function was employed to model relative risks. The assumptions underlying the models, including linearity for quantitative predictors were assessed using internal validation methods, and k-fold cross-validation, to evaluate the robustness of the models.

To analyse trends over time from 1990 to 2019, we examined incidence, prevalence, and mortality at three time points: 1990, 2005, and 2019, with a primary focus on GBD for all stroke and subtypes (IS, ICH, and SAH) [17]. The years 1990, 2005, and 2019 were chosen to represent the start, middle, and end of the study period for analysing stroke trends, based on available Global Burden of Disease (GBD) data. The average annual per cent change (AAPC) from 1990 to 2019 and the per cent change between 1990 and 2005 and 2005–2019 were then calculated. Confounders were selected based on a causal framework incorporating prior evidence. We also compared the mortality rate of stroke in Vietnam with that of SEAR and WPR. The ratio of males/females at different age categories and associated risk of stroke is also reported. Furthermore, we adopted a hierarchical approach analysis to confounders and risk factors for stroke, as shown in Appendix Table S10, with stratification by subgroups that include stroke type, age categories, and gender. In a comparison study with nearby counties, we used the definition from the WHO for the SEAR, which consists of 11 member countries, and the WPR, which comprises 27 member countries and areas. These specific countries were included in the Appendix.

RES-Q from 2017 to 2023

The ANGELS program, an alliance officially endorsed by the World Stroke Organization (WSO) was initiated in Vietnam in 2017 [18]. The program established a reporting system on stroke care management by developing the Registry of Stroke Care Quality (RES-Q) [14,15]. The RES-Q dataset includes patient demographics, stroke characteristics, clinical management, and outcome measures (functional recovery and discharge information) from all 52 stroke care units in Vietnam from 2017 to 2023 (126,432 patients were reported on the RES-Q from 2017

to 2023). All patients were treated according to local standards of care [13].

Additionally, two megacities of Vietnam, Hanoi (the capital city of Vietnam) and Ho Chi Minh City (the biggest economic centre- South Vietnam), are considered to calculate the incidence and prevalence rate. Although Vietnam is administratively divided into 63 provinces, 618 districts, and about 11,000 communes, about 42 % of the patients in the RES-Q dataset are recorded from these two cities [19]. Mapping was conducted in two cities for further comparison. Aged group, stroke type and history of medical conditions are presented in gender groups. The mortality rate is not included in the RES-Q data analysis because it is reported at the hospital level and might not represent the whole population.

Data visualisation and standadisation

Power BI (Microsoft) was used to process the data visualisation and R-Studio was applied for calculation. Maps included in this study were acquired by Creative Commons Attribution License CC BY 4.0, which is suitable for journal presentation. The categorised variables were presented as counts with the corresponding percentages. On the analysis of the RES-Q data, the incidence and prevalence were calculated using the age standard for both genders per 100,000 population. The 95 % upper and lower uncertainty intervals were calculated to address the possible heterogeneity from sampling error and variance [20].

Results

Stroke, national burden level in Vietnam

In Vietnam in 2019, stroke was classified in the group of cardiovascular diseases as the number one cause of death, with 135,999 cases, according to the GBD report, Fig. 1A. This figure was equivalent to both the sum of diabetes plus kidney diseases and respiratory infections, tuberculosis and chronic respiratory diseases altogether. In 2019, in the 98 million population of Vietnam, the incidence of stroke per 100,000 people was 222 cases (95 % UI 206–242), the prevalence was 1541 cases (95 % UI: 1431–1679), DALYs were 3400 (95 % UI: 2795–4027), and death from stroke 170 (95 % UI: 139–199) per 100,000 people, (Table 1). The mortality rate for ischemic stroke was 85 % (95 % UI: 69–101), intracerebral haemorrhage was 80 % (64–98), and the lowest was subarachnoid haemorrhage stroke with 4.9 % (3.0–7.8). Overall, the median age group of stroke patients in Vietnam is 60–64 years for men and 65–69 years for women, Fig. 1B. On average, men had about 58 % higher risk of stroke mortality than women.

Stroke in Vietnam on a global scale

In comparison with neighbouring countries, Vietnam was in the group with the highest mortality rate, incidence and prevalence of stroke in 2019, Fig. 2. In the Southeast Asian region, the stroke mortality rate in Vietnam ranked 4th highest (170 per 100,000 people), following Myanmar (210), Indonesia (197), and North Korea (186). Thailand had the lowest mortality rate for stroke in 2019 (52). In a comparison with Western Pacific regions, Vietnam was ranked 9th. According to the GBD 2019 model, the highest mortality rate belonged to the Solomon Islands (308), Kiribati (238), and Mongolia (220). On the other hand, the countries that had the lowest rate were Singapore (22), Australia (26), and Japan (30).

Stroke burden in Hanoi and Ho Chi Minh City

Contributing stroke units/departments/hospitals involved in the RES-Q from 2017 to 2023 increased from 2 units to 52, with a total of 126,432 patient records included. The average age was 64, with 58 % male in total (Table 2). There were 95,696 (77 %) ischemic stroke cases

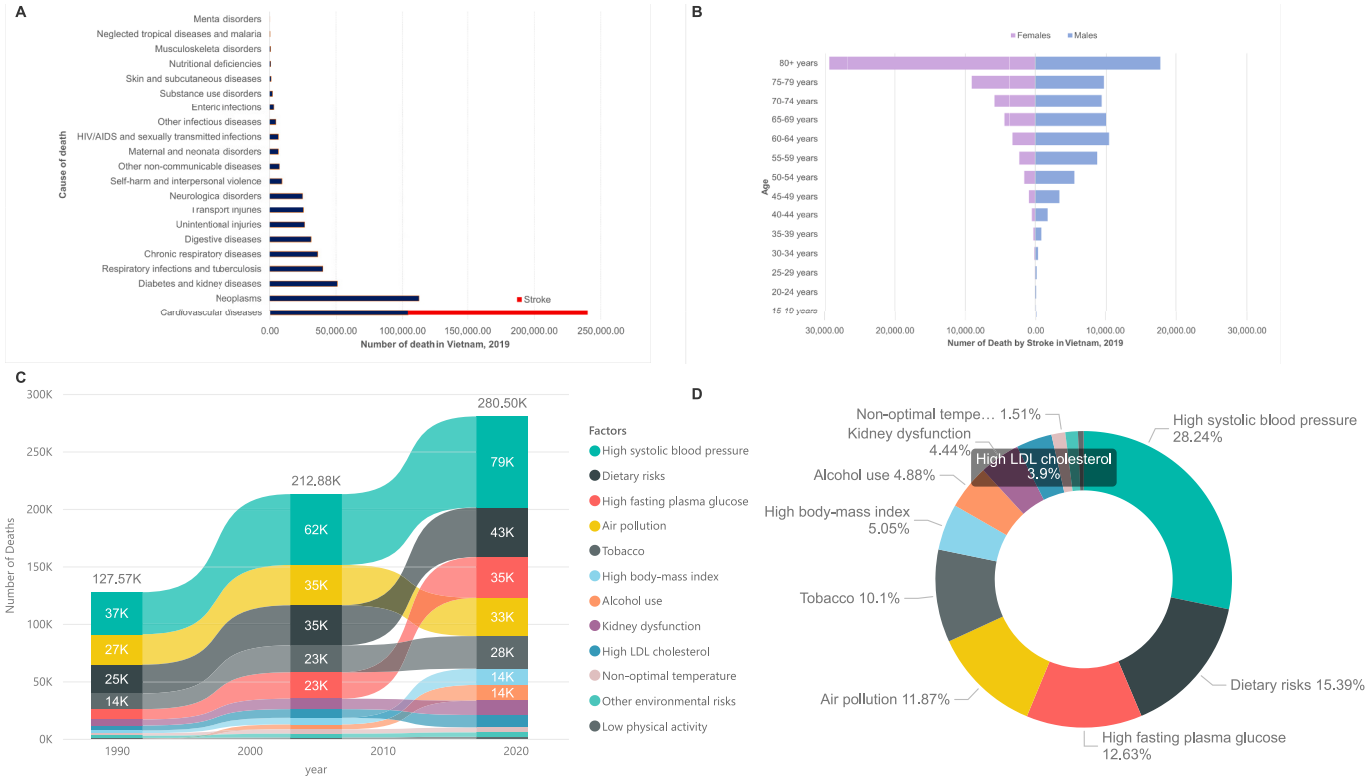

Fig. 1. Global burden of stroke in Vietnam, 2019. Panel A shows the number of deaths in 2019 from different diseases including stroke. Panel B shows the distribution of ages and sex in several deaths by stroke in Vietnam in 2019. Panel C shows the changes in risk factors for deaths from 1990 to 2019 in Vietnam. Panel D shows the percentage of stroke risk factors in Vietnam, in 2019.

Table 1
Age-standardized mortality, disability-adjusted life years (DALYs), years of life lost (YLLs), years lived with disability (YLDs), prevalence, incidence rate (per 100,000 people), and rate change (%) for ischaemic stroke, intracerebral and subarachnoid haemorrhage, by period, in Vietnam.

	1990			2005			2019			Changes by period (%)		
	rate	upper	lower	rate	upper	lower	rate	upper	lower	1990–2019	1990–2005	2005–2019
Total Stroke												
Deaths	190.5	236.9	155.3	200.4	230.9	178.7	170.3	199.4	138.8	−10.6	5.2	−15.0
Prevalence	1432.3	1536.2	1336.9	1425.0	1501.9	1349.9	1541.4	1679.1	1430.8	7.6	−0.5	8.2
Incidence	218.2	235.6	202.1	221.0	239.6	204.0	222.4	242.2	205.5	2.0	1.3	0.6
DALYs (Disability-Adjusted Life Years)	3909.3	4813.3	3196.5	3936.1	4532.1	3542.0	3400.7	4027.5	2795.0	−13.0	0.7	−13.6
YLDs (Years Lived with Disability)	294.4	374.3	210.4	294.5	371.9	212.2	316.2	402.3	228.7	7.4	0.1	7.4
YLLs (Years of Life Lost)	3614.9	4532.0	2920.5	3641.5	4238.7	3254.0	3084.5	3682.5	2478.3	−14.7	0.7	−15.3
Ischemic Stroke												
Deaths	77.1	97.5	61.1	91.1	105.6	77.1	85.5	100.5	68.5	10.9	18.1	−6.1
Prevalence	918.8	1011.8	831.8	954.4	1026.3	884.6	1068.5	1192.5	960.0	16.3	3.9	12.0
Incidence	104.2	120.5	89.1	111.7	128.0	96.7	122.4	140.9	107.2	17.4	7.2	9.5
DALYs (Disability-Adjusted Life Years)	1301.6	1617.8	1054.3	1479.1	1709.4	1264.6	1433.7	1675.2	1172.7	10.1	13.6	−3.1
YLDs (Years Lived with Disability)	184.3	236.8	130.8	192.0	243.6	138.0	213.1	274.6	154.3	15.6	4.2	11.0
YLLs (Years of Life Lost)	1117.3	1431.8	873.7	1287.1	1513.8	1081.6	1220.5	1459.4	960.0	9.2	15.2	−5.2
Intracerebral Haemorrhage												
Deaths	104.4	129.1	83.3	102.5	121.8	89.4	79.9	98.0	63.8	−23.5	−1.8	−22.1
Prevalence	461.5	507.4	419.9	435.8	466.3	407.2	443.6	494.6	399.5	−3.9	−5.6	1.8
Incidence	98.2	106.8	90.7	96.6	104.0	90.3	87.7	95.2	81.1	−10.7	−1.6	−9.3
DALYs (Disability-Adjusted Life Years)	2348.9	2932.4	1877.6	2258.1	2677.0	1978.3	1817.2	2251.8	1460.5	−22.6	−3.9	−19.5
YLDs (Years Lived with Disability)	86.8	111.8	60.4	82.2	104.8	58.1	83.1	106.6	58.4	−4.3	−5.4	1.1
YLLs (Years of Life Lost)	2262.0	2837.9	1791.7	2175.9	2585.5	1892.4	1734.1	2163.3	1377.2	−23.3	−3.8	−20.3
Subarachnoid Haemorrhage												
Deaths	9.0	16.0	5.7	6.9	11.3	5.0	4.8	7.8	3.0	−46.3	−24.1	−29.3
Prevalence	119.9	137.4	104.4	104.7	116.6	94.3	103.6	119.5	90.1	−13.6	−12.7	−1.1
Incidence	15.8	18.5	13.5	12.7	14.6	11.0	12.4	14.5	10.7	−21.5	−19.7	−2.2
DALYs (Disability-Adjusted Life Years)	258.8	439.9	169.6	198.9	312.4	147.1	149.9	231.2	99.9	−42.1	−23.1	−24.7
YLDs (Years Lived with Disability)	23.2	30.8	16.6	20.4	26.6	14.4	20.0	26.5	14.2	−13.7	−12.3	−1.7
YLLs (Years of Life Lost)	235.6	418.2	147.9	178.5	289.3	126.6	129.9	209.0	80.3	−44.9	−24.2	−27.3

and 23,203 (18 %) intracerebral haemorrhage cases registered. The remaining 5 % of cases encompassed transient ischemic attack (2 %), subarachnoid haemorrhage (2 %), and cerebral venous thrombosis. Overall, 85 % of discharged patients were reported to be discharged back home, and 7 % of discharged patients to social care. The overall average hospital length of stay was 5 days. In Fig. 3A, South East and Red River Delta were shown to account for the highest number of stroke cases in total, with more than 17,100 stroke cases. This is likely because of two megacities, Hanoi and Ho Chi Minh City. Up to 42 % of patients and stroke units were hosted in these two megacities (Fig. 3B). Interestingly, there is no stroke unit in the Central Highlands. Incidence is lower in rural Vietnam, but availability and quality of care are higher in megacities (Appendix RESQ_7 and RESQ_8).

Further estimation of the stroke burden in two megacities, Hanoi and Ho Chi Minh City were detailed in (Appendix Table RESQ_1). HCMC had a higher age-standard incidence rate of stroke (207.1 cases per 100,000 people, UIs 79.8–236.2) compared to Hanoi (168.9, UIs 144.4–195.2), however, the prevalence was quite similar (1182.2 for Hanoi and 1221.8 for HCMC). The majority of stroke incidences in HCMC belonged to ischemic stroke (158.4 cases) and quite infrequently subarachnoid haemorrhage (2.1 cases). The median age range for both males and females reported in the two cities was the same at 64–69 years (Fig. 3D).

Risk factors for stroke in Vietnam

The highest risk for stroke was associated with high systolic blood pressure with 79,000 deaths in 2019, followed by dietary risk (including low in fruits, vegetables, whole grains, and fiber; and high in sodium and red meat), about 43,000 deaths. High fasting plasma glucose and air pollution followed (35,000 and 33,000, respectively) (Fig. 1C and D). Cardiovascular risk factor (high systolic blood pressure) had the highest relationship to the mortality rate of stroke in both genders.

Fig. 3E reports the patient's previous medical history before the stroke in the two megacities in Vietnam. The highest percentage of patients of both sexes had a history of hypertension (71 %), followed by diabetes (39 % in females and 35 % in males). Active smoking (and active smoking in the last 10 years) comes in third place with 19 % in males and 13 % in females.

Discussion

In some countries of the SEAR, monitoring and tracking strokes can be a challenge due to a lack of prioritization of stroke surveillance in the health system [8]. This leads to a shortage of primary data. In this study, we presented the results of Vietnam RES-Q, which has been recording stroke care patients for 7 years using a digital patient record. However, there are still several areas that require more attention in Vietnam, including the ratio of stroke centres per local population and the public awareness of stroke. These problems have not yet been solved due to a lack of funding support for stroke surveillance, care, and management. According to [8], the WHO has a collaborating centre for stroke surveillance at the regional level for SEAR, but Vietnam shares the same burden yet has not been included, thus this work represents a previously unreported, much-needed contribution to the existing literature.

Stroke was the leading cause of mortality in Vietnam, according to the GBD in 2019. Ischaemic stroke had the highest increase in prevalence (16.3) and incidence (17.4) from 1990 to 2005, and 2019. Men and women between 60 and 64 and 65–69 years of age, respectively, are

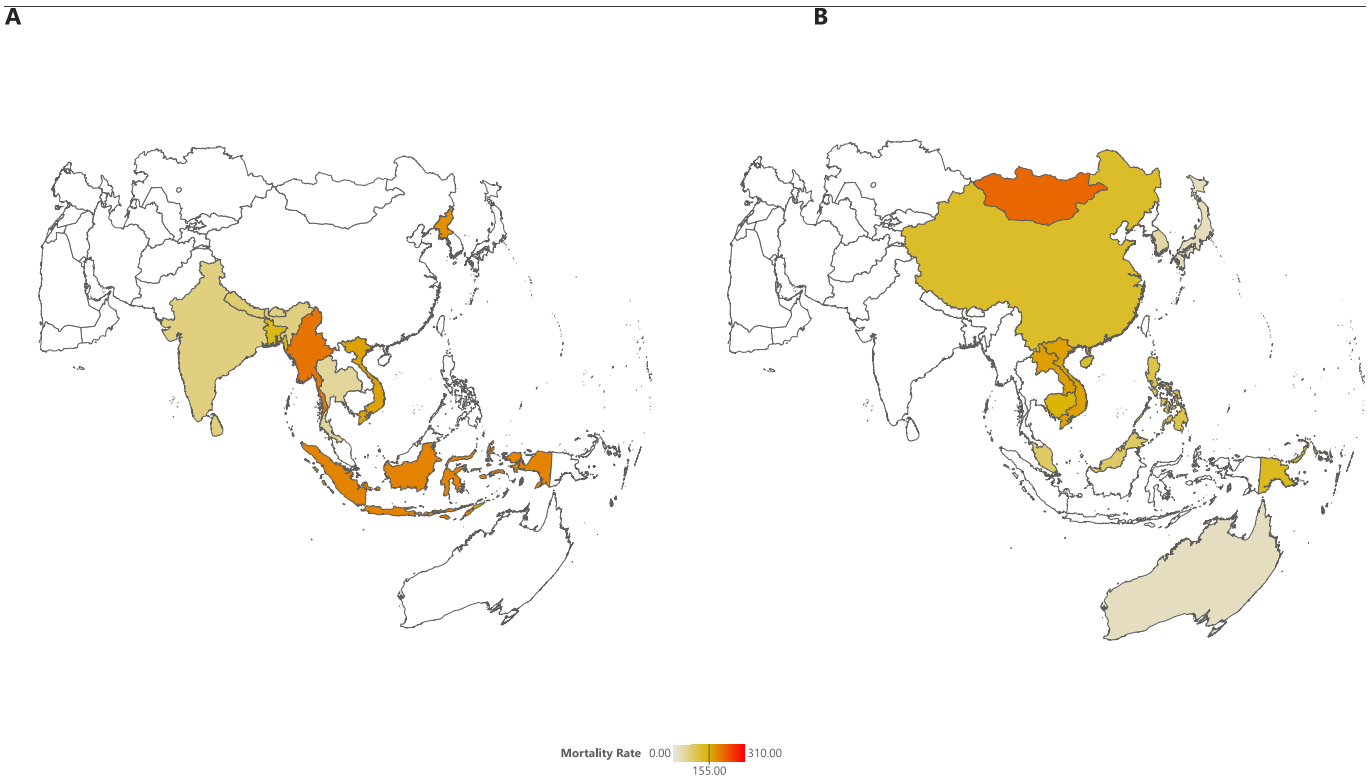

Fig. 2. The mortality rate map of stroke in 2019. Panel A shows the comparison of Vietnam vs Southeast Asia Countries, according to WHO. Panel B shows the comparison of Vietnam vs Western Pacific Countries.

Table 2
A summary report of stroke care management in Vietnam from 2017 to 2023. The numbers, percentages, and median (IQRs) are shown.

	2017		2018		2019		2020		2021		2022		2023		Total	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Site number	2		11		18		25		35		45		52		52	
Number of Patients	2357		11,754		15,575		19,130		24,178		22,067		31,371		126,432	
Median (IQRs) patient age (years)	62 (53–73)		62 (54–72)		64 (55–74)		64 (55–73)		64 (56–74)		65 (57–74)		66 (59–77)		64 (56–75)	
Patients male	1312	56	6410	55	8650	56	11,510	60	14,912	62	13,292	60	18,412	59	74,498	58
Stroke type																
• ischemic stroke	1898	80.5	9457	80	12,446	80	14,488	76	17,783	74	16,455	75	23,169	74	95,696	77
• intracerebral haemorrhage	429	18.2	2221	19	2881	19	3673	19	4835	20	3804	17	5360	17	23,203	18
• transient ischemic attack	0	0	0	0	132	1	515	3	696	3	794	4	1226	4	3363	2
• subarachnoid haemorrhage	30	1.3	74	1	96	1	350	2	731	3	706	3	829	3	2816	2
• cerebral venous thrombosis	0	0	2	0	14	0	42	0	104	0	91	0	129		382	0
• undetermined stroke	0	0	0	0	6	0	62	0	29	0	51	0	55	0	203	0
Median (IQRs) hospital stay (days)	–	–	4 (3–5)		5 (4–6)		5 (4–6)		6 (6–7)		6 (6–7)		6 (6–7)		5 (4–6)	
Discharge destination																
• Home	1742	74	10,709	91	14,409	93	17,725	93	20,664	85	17,540	79	25,783	82	108,572	85
• Transferred within the same centre	315	13	74	1	77	0	110	1	504	2	502	2	613	2	2195	3
• Transferred to another centre	149	6	313	3	448	3	891	5	80	0	27	0	14	0	1922	2
• Social care facility	40	2	259	2	239	2	46	0	2315	10	3616	16	4375	14	10,890	7
• Dead	111	5	399	3	399	3	302	2	615	3	382	2	585	2	2793	3

the most vulnerable to stroke. This subtle gender difference does not apply in the two megacities where the age range was about the same, 65–69 for both sexes. In another study observed in 10 centres, 2300 prospective cohort of hospitalised Vietnamese stroke patients, males accounted for 61.3 % (1410) of participants with a lower age mean of 63.7 ± 13.3 years compared to females 67.7 ± 13.9 years [21]. The incidence rate of 222.4 per 100,000 in 2019 from the GBD 2019 report was correlated and slightly higher with the rate calculated for Hanoi (168.9, UIs: 144.4–195.2) and HCMC (207.1, UIs: 179.8–236.2) from the RES-Q report. The previous incidence was also reported at the incidence rate of 161 per 100,000 [10,11].

The noticeable risk factors for stroke are high systolic blood pressure and dietary risks such as high body mass index (BMI) owing to the Vietnamese eating culture. Males are 58 % more likely to die of stroke due to these risk factors than females. This study aligns with a previous study on the risk factors and sex distribution of stroke in Vietnam [10,21]. This also relates to smoking and alcohol consumption in different sexes. In comparison with local regions, both SEAR and WPR,

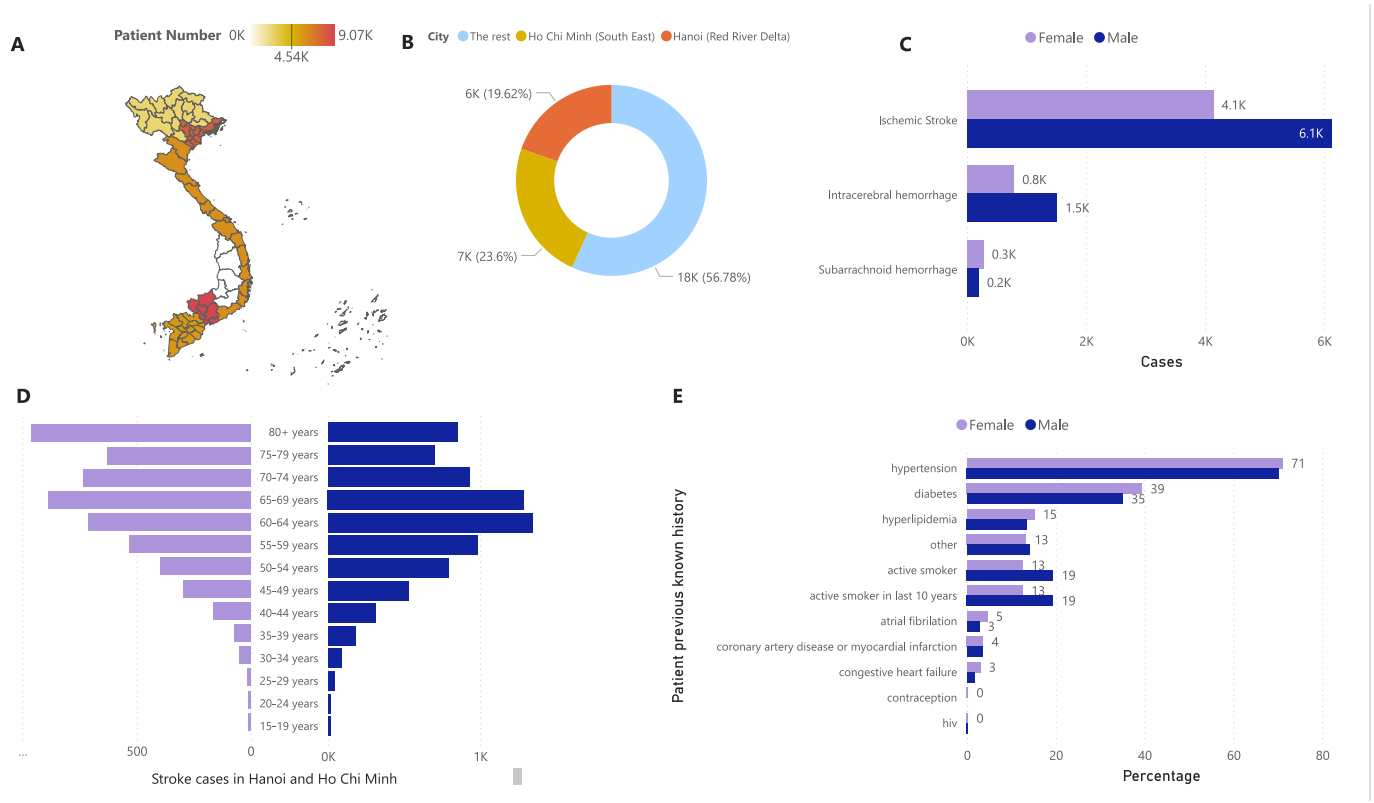

Fig. 3. RES-Q report of stroke in Vietnam, 2023. Panel A shows the geodemographics of Vietnam and the number of patients reported in different regions of Vietnam in 2023. Panel B shows the number of patients and stroke units involved in the RES-Q in two megacities of Vietnam (Hanoi and Ho Chi Minh City) and the rest in 2023. Panel C shows the number of stroke cases divided into stroke types in both genders in two megacities. Panel D shows the distribution of ages and sex in stroke cases reported, and panel E shows the history of medical conditions of stroke patients in Ho Chi Minh and Hanoi.

the Vietnamese population is at the top high risk and most vulnerable to stroke.

Similarities across the SEAR, the principal risk factor associated with stroke in Vietnam is high systolic blood pressure, followed by dietary risk. Similarly, worldwide high body mass index and high fasting plasma glucose were the numbers, followed by high blood pressure [16]. Risk factors evolved in Vietnam, and air pollution was the second most relevant risk factor from 1990 to 2005, but shifted to 4th place by 2019. Vietnam's economic growth has likely led to overweight and obesity over recent decades, and the Vietnamese eating culture has certainly contributed to the dietary risk factors associated with stroke. One study on eating habits in Vietnamese children and adolescents has shown that prevalences of overweight and obesity are 17.8 % and 3.2 %, respectively [22]. This can lead to problems and an increased risk of diabetes and metabolic diseases as they grow up. Achieving the daily sodium intake targets of 8 g/day, 7 g/day, and 5 g/day can lead to a reduction in the prevalence of hypertension by 1.2 %, 2.0 %, and 3.5 %, respectively. This reduction could result in preventing more than 80,000, 180,000, and 257,000 stroke cases and over 18,000, 55,000, and 73,000 stroke-related deaths, respectively, in Vietnam [23]. A voluntary salt substitution strategy was recommended to reduce the burden of stroke in Vietnam with no direct intervention from the government and cost-effective results [24]. Poor awareness leading to inadequate blood pressure control may contribute to the stroke burden in Vietnam, SEAR, and Asia [25]. Other risks of stroke mentioned in the SEAR stroke burden report, such as tuberculosis, dengue, snakebite, and squatting, were also observed in Vietnam [7]. Furthermore, in Northern Vietnam during extreme heat in 2020, research found that daily cardiovascular admissions were associated with ambient air pollutants [26].

In comparison with other countries in the Western Pacific Ocean, Singapore, Australia, and Japan had the lowest mortality rate of stroke, according to the GBD 2019. In Singapore, the prevalence of stroke is high among adults aged 60 and above (7.6 %), which has led to serious consideration of post-stroke quality of life [27]. In Australia, on the other hand, the economic burden of stroke has been the focus of attention, particularly among younger adults. It was estimated that the economic burden of stroke among younger adults amounted to AUD 2.0 billion over 5 years, which is equivalent to a mean of AUD149,180 per stroke patient [28]. In one of the biggest studies in the United Kingdom, between 2010 and 2018, in 94,567 subjects in Oxfordshire, stroke incidence significantly increased by 67 % in young people, those under 55 years [29]. In China, According to the GBD 2019, due to the child policy for a long time and the ageing population, stroke is a heavy burden, with 3·94 million (95 %UI 3.43–4·58) new stroke cases per year [30].

In the European region, neurological disorders, including stroke, epilepsy, Alzheimer's disease, and Parkinson's disease, impose a substantial economic and societal burden in terms of healthcare costs, loss of productivity, and diminished quality of life [31]. The number of people with stroke is expected to rise by 27 % (2.58 million prevalent cases) in the European Union between 2017 and 2047 [32]. In the USA, according to the GBD 2019, there were 7.09 million prevalent strokes [33]. Despite this burden, the allocation of funding for research, prevention, and treatment of neurological conditions remains disproportionately low compared to other disease areas. This situation is worst in low and low-middle-income countries, including Vietnam.

Stroke prevention and care: the state of the art in Vietnam

Advancements, including treatment and access to stroke care, have been made in stroke care management in Vietnam. Vietnamese Minister of Health collaborated with the National Institute for Health and Care

Excellence (NICE), United Kingdom, to initiate standard treatment for stroke patients in 2013, followed by the Guideline for Stroke establishment units in 2016 and the ANGELS program initiated in 2017 [10,11,21]. However, suburban and low-income areas still require further funding and support from the government. The Ministry of Health issued Circular 47 in 2016, mandating the establishment of stroke units in the country [10]. Efforts to enhance stroke care in Vietnam have also involved international partnerships. For example, Stroke International Services (SIS) and Siemens Healthineers established a Value Partnership in 2021 to expand the stroke management network in the country [34]. The Vietnam Association of Stroke was established in 2009 as a leading society for stroke care in Vietnam [35]. In terms of treatment options, intravenous thrombolysis with alteplase and thrombectomy were first introduced in Vietnamese hospitals in 2006 and 2012, respectively [10]. The rate of recanalisation treatment, including intravenous thrombolysis and endovascular therapy, has increased in specialised stroke hospitals, indicating progress in acute stroke care. Programs like ANGELS have been instrumental in promoting quality care management for stroke patients, emphasising the importance of adherence to treatment guidelines and access to recanalisation therapy [36]. According to the survey for acute stroke care in 66 units and hospitals in Vietnam, ongoing efforts to enhance stroke care in the country are essential for addressing the needs of stroke patients and caregivers and ensuring the delivery of high-quality, evidence-based care [37].

Implications: how epidemiological data can inform strategic decisions

This study demonstrates that incidence and prevalence are lower in rural Vietnam, but availability and quality of care are higher in megacities; thus, once those notions are coupled with the information above, we can propose two working theories. One of the challenges of providing care for stroke patients in Vietnam relates to the inner characteristics of the country, which has a heterogeneous population density (1/5 of the population living in or around the two megacities in the North and South valleys) and very narrow and long geography (Vietnam is 1025 miles or 1650 km long from north to south, by comparison this is much longer than the distance between Rome and London, 890.48 miles or 1433.09 km). Transportation relies mostly on country roads, with only 1276 km or 793 miles of expressway available at present versus over 7000 km or 4300 mi required, and hopefully planned for construction by 2030, according to the Vietnam Ministry of Transport [38]. Another challenge is that the healthcare system is fragmented, with 15–20 % of care provided by private institutions. According to WHO [39], public hospitals in Vietnam are divided into three tiers: central level I, 47 hospitals; provincial level II, 419 hospitals; and district level III, 684 hospitals, which is inversely proportional to the level categories proposed by the American College of Surgeons for the complexity of trauma centres). Although the country can also count on 182 private hospitals, mostly located in urban areas, to boost the quality and efficiency of care, those centres cannot be considered as a valuable alternative to public offers. The ratio of public/private hospitals suggests that the vast majority of the over 100 million population, with a GDP per capita of $4623 country [40], will not have any access to required care if the public offer is exhausted.

For this, two working theories can be proposed: the first refers to the projected development of infrastructures, and the second refers to the contribution of technological advancement to catch up with the gaps outlined above. While Vietnam has progressed over the past 10 years, and those positive economic and social trends are projected to continue in the future, the data from this study suggests an estimation of investment to build 150 new stroke care units across Vietnam, double the current number. Furthermore, the provision of care for stroke patients is likely to be impacted by the use of new technologies, including those aimed at expediting diagnosis and enhancing the quality of care. For instance, digital development in healthcare with artificial intelligence, stroke prediction and monitoring are challenging but promising to be potentially effective tools. Stroke was shown to orchestrate distinct characteristics in different biosignals, which can be converted to digital signals in a device. Studies with explainable AI tools, such as Eli5 and LIME [41,42], also consolidated the findings from previous signal-based analyses. These distinct characteristics lay the foundation for automated stroke prediction and rehabilitation using machine learning methods, enabling stroke care and monitoring at home. A few attempts have explored more conventional methods like [43,44] stroke prediction using biosignals. Some other studies have employed deep learning for stroke prediction using convolutional neural networks (CNN) [43], Long-Short Term Memory (LSTM) [45], or the combination of CNN and LSTM. Apart from stroke prediction (i.e., stroke/non-stroke), predicting more fine-grained stroke types [43], stroke severity [46], and after-stroke functional outcomes [47] have also been investigated.

Limitation of the data source

The Global Burden of Disease Study 2019 model has emphasised the overview importance of implementing health, social, and economic development strategies to tackle global health trends and emerging challenges. This study provides a thorough examination of health outcomes, risk factors, and healthcare system responses. However, it is worth noting that the findings are limited by the constraints outlined in the component GBD capstone papers, this model might not work in some countries and specific cases [48]. The uncertainty intervals reported in this study did not take into account measurement bias including selection bias, and model misspecification bias. The RES-Q dataset had been utilised to harmonise with the GBD 2019 to provide sophisticated views of the stroke burden in Vietnam. Nevertheless, RES-Q data in Vietnam contains limitations. The whole RES-Q validation studies in the Vietnamese healthcare context remain limited. This is an important consideration when interpreting our findings. From 2 units in 2017, the number of units increased to 52 in 2023. However, this number does not cover all stroke units in Vietnam. The majority of the unit was included in this report, but the Center Highlands regions did not have data in the RES-Q. Some of the data of new participants in the RES-Q was missing and were excluded from the analysis. RES-Q might not be possible to report the epidemiology data, but in combination with GBD, we can understand the stroke burden in Vietnam. We recognize that comparing GBD data from 1990 to 2019 with RES-Q data from 2017 to 2023 introduces potential biases due to socio-political and healthcare changes, including the impact of the COVID-19 pandemic. This is acknowledged as a study limitation. Based on the results of this study, in the future, we will explore further understanding of stroke care to highlight the relationship between patient transfer to mortality and complications, as well as the time from arrival to therapy across Vietnam.

Data sharing statement

Corresponding authors are willing to share the dataset upon request.

Ethical statement

We adhere to established guidelines for processing patient data and access data from the GBD 2019. All data in the RES-Q database are anonymised to ensure patient confidentiality. Patient information is uploaded using a pseudonymised ID, which contains no identifiable details.

CRediT authorship contribution statement

Minh Cong Tran: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Lara Prisco:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Funding acquisition, Data curation, Conceptualization. **Phuong Minh Pham:** Writing – review & editing, Writing – original draft, Conceptualization. **Huy Quoc Phan:** Writing – review & editing, Writing –

original draft, Conceptualization. **Mario Ganau:** Writing – review & editing, Writing – original draft, Methodology, Investigation, Conceptualization. **Nhat Pham:** Writing – review & editing, Writing – original draft, Conceptualization. **Linh Huyen Truong:** Writing – review & editing, Writing – original draft. **Proochista Ariana:** Writing – review & editing, Writing – original draft. **Phuong Viet Dao:** Writing – review & editing, Writing – original draft. **Dung Tien Nguyen:** Writing – review & editing, Writing – original draft. **Chi Van Nguyen:** Writing – review & editing, Writing – original draft. **Hoa Thi Truong:** Writing – review & editing, Writing – original draft. **Thang Huy Nguyen:** Writing – review & editing, Writing – original draft, Formal analysis, Data curation, Conceptualization. **Jeyaraj Pandian:** Writing – review & editing, Writing – original draft. **Ton Duy Mai:** Writing – review & editing, Writing – original draft, Visualization, Validation, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Andrew Farmery:** Writing – review & editing, Writing – original draft.

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Declaration of competing interest

The authors declare that we don't have any conflict of interest in this study.

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Appendix A. Supplementary data

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