Trends in the burden of stroke in Mexico: A national and subnational analysis of the global burden of disease 1990−2019

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Summary

Background Scarce epidemiological information on stroke in Mexico impedes evidence-based decisions and debilitates the design of effective prevention programmes at the local level.

Methods Ecological and secondary analysis of Global Burden of Disease national and subnational data for Mexico, from 1990 to 2019. We analysed the incidence, prevalence, deaths, premature mortality, disability, and DALYs due to cerebrovascular disease included to identify the differences in the burden of stroke in Mexico by type of stroke (ischaemic [IS], intracerebral haemorrhage [ICH] and subarachnoid haemorrhage [SAH]), sex, age groups, and state levels ordered by quartiles of Sociodemographic Index (SDI). Means and 95% uncertainty intervals are reported.

Findings Reductions in all metrics of total stroke occurred during the 1990 to 2005 period; however, this declining trend was followed up by stagnation of progress from 2006 to 2019, except for premature mortality. This pattern of the declining trend was observed also for IS and to a lesser extent for ICH, while SAH showed no major changes during the 1990-2019 period. The magnitude of decline was higher in females for total stroke for incidence, prevalence and YLDs rates. The less developed states by SDI exhibited the lowest improvements during the period, particularly for ICH metrics.

Interpretation The reduction in stroke burden in Mexico did not follow the same pace for all types of stroke, with regional differences by SDI and by sex. Study findings reveal the need for strengthening prevention policies to address health disparities in the burden of stroke by sex and states, within the fragmented Mexican Healthcare System.

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Keywords: Global burden of disease; Haemorrhagic stroke; Ischaemic stroke; Mexico; Stroke

Introduction

Cerebrovascular diseases represent a major global health problem with a 43.3% increase in the absolute number of deaths from 1990 to 2019, mainly due to population growth and ageing along with patterns in risk factors.[1] Among the neurological disorders analysed in the Global Burden of Disease (GBD) study 2016, stroke accounted for the largest proportion of total disability-adjusted life years (DALYs) (42.2%) and deaths (60.4%) worldwide.[2] Moreover, the global lifetime risk of stroke from the age of ≥ 25 years is estimated to be 24.9%.[3]

The burden of stroke differed greatly between low- to middle-income countries (LMICs) and high (HIC).[4] In 2019, the World Bank low-income countries had age-standardised stroke death and DALYs rates 3.5 times higher than those of high-income group of countries.[1] Stroke burden in Latin America prevailed as an important health problem in 2017, with over 5.5 million stroke

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Research in context

Evidence before this study

Even though stroke has been among the first leading causes of death in Mexico for several decades, few epidemiological studies on stroke have been carried out. Available data is out-dated or suffer from low generalisability. In addition, it was until the GBD-2019, that intracerebral haemorrhage and subarachnoid haemorrhage were estimated separately. This provides a unique opportunity to examine the trends for ischaemic and haemorrhagic stroke burden by age groups sex, state level and Socio Demographic Index (SDI) levels in Mexico.

Added value of this study

This is the first study that provides updated trends of the burden of overall stroke in Mexico by type of stroke (ischaemic stroke, intracerebral, and subarachnoid haemorrhage) from 1990 to 2019, at a national level and for 32 states in Mexico. Stroke burden was measured by incidence, prevalence, mortality, and DALYs by age groups and in men and women living in different SDI levels. We identified reductions of total stroke occurred during the 1990 to 2005 period, but this declining trend was followed-up by a stagnation of progress from 2006 to 2019. The elderly population is the most affected, but haemorrhagic stroke mortality is increasing in the young adult population. Improvements are more noticeable in females, although changes vary by type of stroke and states, with the less-developed states of the southern region exhibiting the lowest improvements in stroke mortality and disability. This is the first evidence-based study on stroke burden that provides a clearer understanding of the evolution stroke burden in each state and provides means to improve prevention and medical care of stroke in the country.

Implications of all the available evidence

The declining trend of stroke over the 1990−2005 period and the stagnation of progress from 2006 to 2019 denotes variations in early diagnosis, treatment rehabilitation, and access to stroke management, particularly in the less developed areas of the country, where improvements were minimal. The low mortality of stroke for Mexico also prompts us to recognise that the burden of stroke in GBD 2019 may be underestimated. This study provides new information that policy makers may use to guide evidence-based decisions and strengthen the design of effective prevention programmes at the national and subnational levels.

survivors, 600,000 new first-ever strokes, around 260,000 deaths from stroke, and almost 5.5 million stroke-related DALYs. This region is also known for a lower proportion of ischaemic stroke (57%) compared with high-income countries (80−85%), but a higher proportion of intracerebral haemorrhage (27%) and subarachnoid haemorrhage (15%).[5]

Although cerebrovascular disease ranks among the main causes of death (6th) in Mexico in 2019 (INEGI),[6] it has been scarcely studied. Few epidemiological studies on stroke have been carried out in Mexico;[7] only one at the population level (BASID study)[8,9] and two multicentre hospital registries: the PREMIER registry for IS,[10,11] and a Mexican multicentre registry of all types of acute stroke (the RENAMEVASC registry)[12] including specific analysis of SAH and ICH.[13,14] In BASID, the cumulative incidence among people aged 35 years and older obtained from door-to-door surveillance was 232·3 per 100 000, whereas the prevalence was 8 per 1000 (18 per 1000 among those >60 years old). The in-hospital case fatality rate was about 50% for HS and 29% for IS.[8,9] The main risk factors in all studies were hypertension, obesity, and diabetes mellitus. In addition, a retrospective analysis on a 25-year dataset of a third-level neurological hospital (4,481 patients with a median follow-up of 27 months) was carried out but young stroke patients with uncommon aetiologies were overrepresented.[15] Finally, an analysis of death certificates showed that age-adjusted mortality of HS and IS decreased over the period 1980-2012, with an increase in SAH-associated mortality.[16]

The GBD 2019 study provides new insights into the burden of cerebrovascular disease in Mexico. The demographic and health transition in Mexico requires a detailed analysis of the major contributors of stroke death and disability with special emphasis on those less developed states that demand higher investments in prevention and care.[17,18] The objectives of this study are to describe the age-standardised incidence, prevalence, mortality, and DALYs rates changes for ischaemic stroke (IS), intracerebral haemorrhage (ICH), and subarachnoid haemorrhage (SAH) at the national level and stratified by sex as well the changes by quartiles of SDI at the subnational level, identifying changes in the pace of reduction of stroke burden from 1990 to 2019.

Methods

The Global Burden of Diseases, Injuries and Risk Factors Study is a comprehensive study that produces comparable estimates of the global, regional, and country-specific burden of different diseases and conditions, including stroke. GBD 2019 includes data for 204 countries and territories, 21 regions and four World Bank income level groups from 1990 to 2019, by age group and sex. In countries such as Mexico, data at the subnational level is generated. The GBD study protocol is available online.[19] Methods on data source preparation, modelling, and processing of results have been published previously.[20]

We conducted an ecological and secondary analysis of GBD national and subnational data for stroke and its types in Mexico, from 1990 to 2019. Stroke was defined according to WHO criteria as a rapidly developing syndrome of mainly focal disturbance of cerebral function lasting more than 24 hours or leading to death with no apparent cause other than a vascular origin.[21] IS includes all vascular events leading to limited blood flow to the brain tissue, with resulting infarction, including atherosclerotic and thromboembolic strokes (ICD10 codes: G45-G46.8, I63-I63.9, I65-I66.9, I67.2, I67.3, I67.5, I67.6, I69.3-I69.398). Haemorrhagic stroke (HS) includes all spontaneous strokes due to vascular rupture leading to subarachnoid haemorrhage (SAH) or intracerebral haemorrhage (ICH) (ICD10 codes: I60-I61.9, I62.0-I62.03, I67.0, I67.1, I67.7, I69.0-I69.198, I69.20-I69.298).[22] Non-specific codes were redistributed to IS, SAH or ICH using a regression model, based on the Ahern approach, for each location, year, sex, and age.[22]

Data sources

GBD 2019 used all available information of fatal and nonfatal cases related to cerebrovascular disease. For mortality modelling, vital registration data and verbal autopsy reports were collected. For nonfatal outcomes, data on stroke incidence, prevalence, and mortality risk were estimated from a systematic review of scientific literature, population surveys, and stroke registers.[23] For Mexico, all population-based data sources including state-level inpatient hospital data and one population-based study from the federal state of Durango were included.[8,24] The data and code for the GBD 2019 stroke estimation process are available at http://ghdx.healthdata.org/gbd-2019

Model strategy

Metrics. According to GBD methodology, mortality due to stroke was modelled separately by pathologic subtypes (IS, ICH, SAH) and for all strokes together. Causes of Death Ensemble Models (CODEm) models were used to estimate a continuous time series for mortality by age, sex, year, and location (ie, 33 locations for Mexico, one national and 32 state-level estimations).[25] For stroke estimations, GBD 2019 covariates included health system access, prevalence of smoking and alcohol consumption, metabolic and dietary risk factors, income, education, sociodemographic index (SDI), and summary exposure value for IS, ICH and SAH.[22] Deaths coded as unspecified stroke (ICD-10 codes I62 and I64) were redistributed to IS, ICH and SAH using statistical procedures.

Disease prevalence and incidence were estimated based on mixed-effects models such as Bayesian meta-regression (DisMod-MR 2.1) and a spatiotemporal Gaussian process regression model (ST-GPR), to pool data from different sources, control and adjust for bias in data, and incorporate country-level covariates.[26] IS, ICH and SAH were modelled separately, and adjustments were made in the model to account for incidence estimates of specifying first-ever or any stroke. Disability due to acute stroke was considered to last for up to 28 −30 days while chronic stroke lasted from 30 days until death.[27] YLLs were the product of the estimated count of deaths and the GBD standard life expectancy at the age of death. YLDs were calculated as the product of a disability weight[28] and prevalent cases of stroke. DALYs were calculated as the sum of years of life lost prematurely (YLLs) and YLDs, based on maximum observed global longevity.[29] All these procedures done using multiple regressions models, allow comparability of data between time, regions and countries.

We reported results of the GBD 2019 study for IS, ICH, and SAH related mortality, prevalence, incidence, YLDs, YLLs, and DALYs with corresponding 95% uncertainty intervals (UI) to describe the burden of stroke age-standardised rates and changes during the periods 1990−2005 and 2005−2019, and by sex for national and subnational levels in Mexico. UI represents the variance generated by all the stages of the estimation process and is calculated by obtaining 1,000 draws from the posterior distribution for each age-sex-location group. The interval taken as the 2.5 and 97.5 percentiles of the resulting distribution was reported for each estimation.[29] The division of the study period was performed after examining temporal trends both visually and statistically using Joinpoint analysis.[30] Due to the heterogeneous behaviour observed, different inflexion points were found to be statistically significant at the 95% level. The most frequently inflexion points were again found in the period 2005-2007. Taking this into account, it was determined to stay with the middle of the period, which coincides in the year 2005.

Heterogeneity and comparative assessment of results

To explore any heterogenous trend due to social variables and health system characteristics, state-level age-standardised mortality and disability rate change for each period (1990-2005 and 2005 to 2019) for total stroke and subtypes were grouped and paired using quartiles of GBD's Sociodemographic Index (SDI) estimated for 2019.

SDI is a summary measure that estimates a location's position on a spectrum of development, taking values from 0 (least developed) to 1 (most developed).[22] Quartiles were constructed for 1990, 2005 and 2019, and states were grouped by quartile for each year. *Supplementary figure* A1 shows the quartiles of SDI of the 32 states of Mexico in 2019.

We identified if changes over time were significant by comparing means and UI. According to Roth et al (2018),[3] differences in estimates were considered significant if the 95% UI did not overlap.

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Role of the funding source

The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

Results

The absolute number of stroke new cases and deaths increased 70.7% and 75.3% respectively in the last 29 years from 63,101 [95%UI 56545–70817] new cases and 21,839 [95%UI 20,603–22,577] deaths in 1990, compared to 107,719 [95%UI 96,523–120,512] new cases and 37,897 [95%UI 32,829–42,992] deaths in 2019. Conversely, the age-standardised mortality and DALYs rates were reduced -41.6% and -38.1%, respectively in the same period. The reduction observed in stroke deaths and DALYs for the period 1990–2005 (-29.8% and -27.4%) was almost two-fold higher than that of the period 2005–2019 (-16.7% and -14.7%, respectively) (Table 1).

National burden by type of stroke

The age-standardised mortality rates for IS and ICH showed a decreasing trend from 1990 to 2019 (-46.2% and -42.5%, respectively) that occurred mainly from 1990 to 2005 (-35.5% and -26.3%, respectively) and slowed down during the 2005–2019 period (-16.6% and -21.9%, respectively). Declines in DALYs rates for IS in 1990–2005 (-33.6%) and for ICH (-26.6%) were higher compared to those that occurred in the 2005 –2019 period (-14.7 and -19.9%, respectively) and both types of stroke presented declines in incidence rates. Impact on premature mortality (YLLs) more than disability (YLDs) accounted for the changes in DALYs rates for IS and ICH. On the other hand, SAH showed no changes in mortality, disability, prevalence, or incidence during the whole period (Table 1 and *Supplementary figures* A2 and A3).

National burden of stroke subtypes by age and sex

In 2019, age-specific incidence rates in the 20 to 50 years olds were similar by type of stroke. IS incidence begins to rise by age 50 up to age group 70 to 74 when IS and ICH present an important increase, whereas SAH maintains a lower incidence rate (Figure 1). Prevalence rates for IS showed a higher and growing trend with age in younger populations under 50 years old, while prevalence rates are slightly higher for ICH than SAH in all age groups. On the other hand, age-specific mortality rates due to ICH and SAH were higher than IS in people under 50 years old. By age 70 years and above, IS mortality rate greatly overtakes both haemorrhagic stroke types (Figure 1). An increasing trend was also observed on age-specific SAH mortality from 6.1 deaths per 100,000 [95%UI 4.8-7.4] in age 50 to 53.8 deaths per 100,000 at age 90 [95%UI 38.5-54.4].

Changes in the burden of stroke by sex showed differences for the whole period (Table 2). YLD and prevalence rates and the magnitude of change in YLD, prevalence and incidence rates were higher for females than males in any type of stroke. For IS, similar rates were observed by sex in all metrics, except for a higher prevalence rate in females in 1990. For HS, prevalence and YLD rates were higher for females than males in 1990 and 2019. For SAH, differences in DALYs, YLD, and prevalence rates in 1990 were higher in females as well. In 2019, only the prevalence rate was higher in females. While the magnitude of decrease in the YLD and prevalence rates was higher for females, the incidence rate change increased more in males over the period 1990-2019 (Table 2).

Subnational burden of stroke

Ischaemic stroke. Age-standardised mortality and DALYs rates for all states showed the highest declines during the 1990–2005 period (from -25.8% in Guerrero to -48.1% in Guanajuato). However, during the 2005–2019 period, the declining trend was kept only in Guerrero, Baja California and Sonora, the last 2 states from the highest quartile of SDI (Figure 2 and *Supplementary figure* A4).

As previously stated, at the national level the major contributor to change in DALYs for IS was the reduction of premature mortality (YLLs) rather than any change related to disability (YLDs), particularly during the period 1990-2005. Conversely, in the period 2005-2019 only four states presented changes in premature mortality, 3 of them from the highest quartile of SDI. For the same period, the magnitude of the average decrease in YLDs rates was marginal in all states (*Supplementary figures* A5 and A6).

Intracerebral haemorrhage. Declines in the mortality rates of ICH occurred in all states during the 1990 –2005 period except in Guerrero, but changes during the 2005–2019 period occurred in 10 states, half of them belonging to the highest quartile of SDI. None of the states in the southern region (less developed) except Tabasco achieved decreases in their mortality rates during the 2005–2019 period (Figure 2).

The age-standardised DALYs rate in all states showed changes during the 1990–2005 period but the

	1990		2005		2019		% change by period		
	Rate	(UI)	Rate	(UI)	Rate	(UI)	Δ(%) 1990-2019	Δ(%) 1990-2005	Δ(%) 2005-2019
Total Stroke									
Deaths	60.2	(55.6, 62.6)	42.2	(38.8, 44.2)	35.2	(30.4, 39.9)	-41.6*	-29.8*	-16.7
DALYs	1191.0	(1134.1, 1236)	864.4	(817.8, 903.1)	737.6	(646.5, 834.4)	-38.1*	-27.4*	-14.7
YLLs	1066.4	(1018.8, 1096.3)	762.2	(725.3, 786.3)	637.3	(552.9, 721.8)	-40.2*	-28.5*	-16.4*
YLDs	124.6	(91.8, 156.5)	102.2	(74.1, 128.7)	100.3	(72.5, 126.9)	-19.5	-18	-1.8
Prevalence	1297.4	(1167.1, 1431.2)	1053.9	(968.1, 1143.6)	1044.3	(943.1, 1152.9)	-19.5*	-18.8*	-0.9
Incidence	127.7	(113.9, 143.5)	96.1	(86.7, 107.2)	91.6	(82.3, 102.6)	-28.3*	-24.7*	-4.7
Ischaemic Stroke									
Deaths	36.4	(33.2, 38.2)	23.5	(21.1, 24.9)	19.6	(16.5, 22.4)	-46.2*	-35.5*	-16.6
DALYs	605.6	(563.4, 639)	402.3	(369.8, 429.3)	343.2	(301.8, 390.3)	-43.3*	-33.6*	-14.7
YLLs	510.4	(478.2, 529.5)	325.4	(301.5, 339.6)	268.4	(228.4, 307.9)	-47.4*	-36.2*	-17.5
YLDs	95.3	(69.1, 121.7)	76.8	(55.6, 97.8)	74.7	(53.9, 95.6)	-21.6	-19.3	-2.8
Prevalence	1023.0	(893.4, 1160.2)	820.0	(731.5, 912.2)	804.6	(703.4, 910.1)	-21.4	-19.8	-1.9
Incidence	86.4	(73.3, 102.4)	61.9	(53.0, 72.4)	58.6	(49.4, 69.2)	-32.2*	-28.3*	-5.4
Intracerebral haemorrhage									
Deaths	20.4	(19.2, 21.1)	15.0	(14.1, 15.6)	11.7	(10.1, 13.5)	-42.5*	-26.3*	-21.9*
DALYs	470.8	(451.3, 485.1)	345.6	(331.4, 357.7)	276.9	(239, 318.6)	-41.2*	-26.6*	-19.9*
YLLs	449.8	(432.6, 462.9)	328.1	(315.1, 338.8)	259.7	(221.1, 299.6)	-42.3*	-27.1*	-20.9*
YLDs	21.0	(15, 27.1)	17.4	(12.7, 22.1)	17.2	(12.3, 22)	-18.1	-16.9	-1.5
Prevalence	235.1	(204.4, 269.4)	193.7	(170.9, 217.2)	191.7	(166.7, 218.9)	-18.4	-17.6	-1.0
Incidence	28.8	(24.5, 33.9)	22.0	(18.8, 25.5)	19.6	(16.6, 23.1)	-32.0*	-23.8	-10.7
Subarachnoid haemorrhage									
Deaths	3.4	(3.2, 4.2)	3.7	(3.5, 3.9)	3.8	(3.2, 4.5)	12.8	9.6	2.9
DALYs	114.6	(108.3, 131.9)	116.5	(110.2, 121.4)	117.6	(98.9, 135.1)	2.7	1.7	0.9
YLLs	106.2	(100.4, 123.2)	108.6	(102.8, 112.9)	109.2	(90.8, 126.2)	2.8	2.3	0.5
YLDs	8.4	(6.0, 11.2)	7.9	(5.7, 10.4)	8.4	(6.0, 11.3)	0.4	-5.7	6.5
Prevalence	94.1	(78.6, 112.9)	87.6	(74.9, 103)	93.8	(78.3, 112.4)	-0.3	-6.8	7.0
Incidence	12.5	(10.5, 14.9)	12.2	(10.4, 14.5)	13.5	(11.4, 16.2)	7.7	-2.2	10.2

***Table 1*: Age-standardised 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 Mexico.**

* Significant change in the period at 95%.

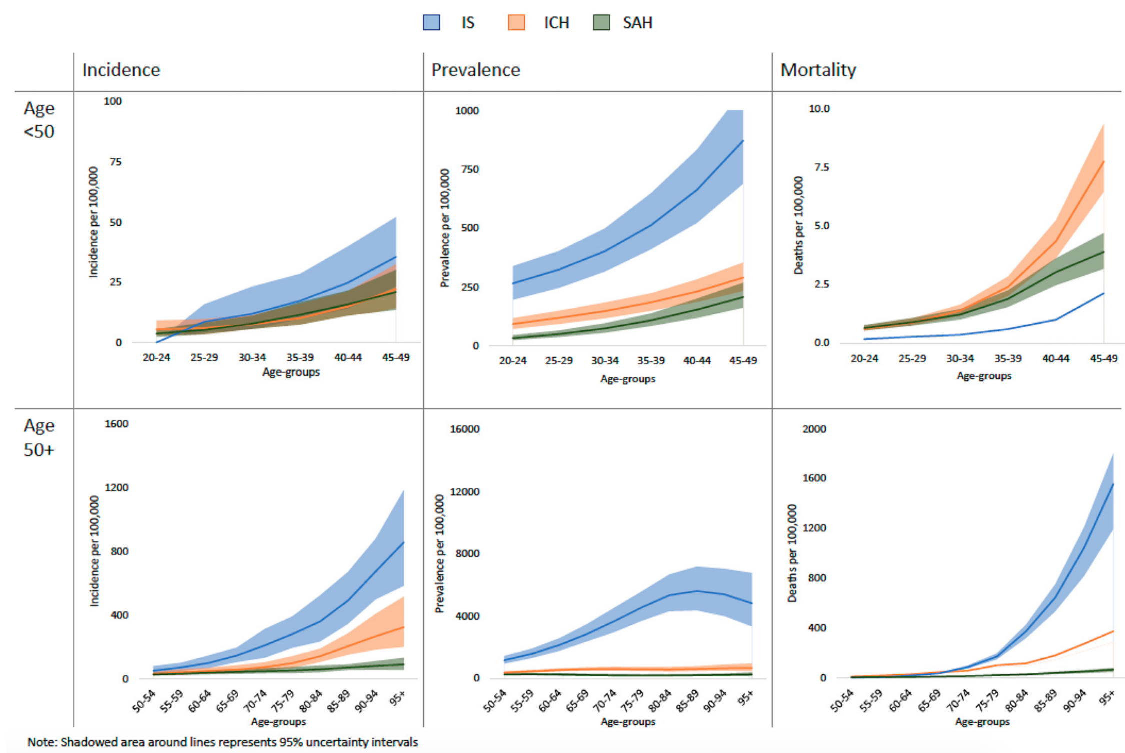

Figure 1. Age-specific incidence, prevalence, and mortality rates of ischaemic stroke (IS), intracerebral haemorrhage (ICH), and subarachnoid haemorrhage (SAC) per 100,000 people per year for Mexico in 2019, by age groups under and over 50 years old. Stoke burden shows different trends by age groups. In younger groups (<50 yrs) incidence rates show no difference by type of stroke while the prevalence for ischemic stroke (IS) is increasingly higher in all age groups. Mortality rates are low, but intracerebral (ICH) and subarachnoid haemorrhage (SAH) rates are higher than for IS. In older age groups (50 +) IS presents higher incidence, prevalence, and mortality rates as age increases. SAH burden shows no difference by age.

trend slowed down in the 2005–2019 period with only 8 states presenting significant reductions, where half of those states were from the highest quartile of SDI (*Supplementary figure* A4). YLLs rates had important declines in all states during the 1990–2005 period ranging from -16.4% reduction in Puebla to -42.6% in Colima in the northern region. During the 2005–2019 period declines in YLLs were significant in only nine states, 5 of them from the highest quartile of SDI (*Supplementary figure* A5). None of the states showed significant reductions in YLDs during the 1990–2019 period (*Supplementary figure* A6).

Subarachnoid haemorrhage. SAH showed no differences in mortality, DALYs, premature mortality, and disability, between states over the whole period (Figure 2 and *Supplementary figures* A4 to A6).

Discussion

Several major findings emerge from our subnational and temporal analyses on the burden of stroke in Mexico during the 1990–2019 period in addition to the panorama provided by the GBD 2019 stroke study.[1] First, due to the growth and population ageing,[31] the absolute number of deaths increased two-fold while the age-standardised mortality rates of stroke showed a major decline during the 1990 to 2005 period that slowed down during the 2005–2019 period. Second, IS and ICH presented reductions in DALYs from 1990 to 2019, but the major contribution for this change was the reduction in premature mortality rather than disability. Third, age and sex differences were noticeable; ICH mortality in the young population appeared as an emergent public health problem, while the magnitude of the decline in incidence, prevalence and YLDs in any type of stroke was more pronounced in women than men. Finally, the less developed states presented the lowest decreases in all metrics in contrast to the improvements observed in the highest developed states. Since population-based studies are scarce in Mexico, these data provide some insights and reveal the disparities in the burden of stroke within a fragmented health care system.[32]

The lack of improvement of all SAH metrics was noticeable, particularly since the incidence of SAH in Mexico (13.5 per 100 000) is much higher than the

Sex	1990		2019		Δ(%) 1990-2019			
	Males	Female	Male	Female	Male		Female	
Total Stroke								
Deaths	59.1 (55.0, 61.4)	61.6 (56.7, 64.9)	37.2 (30.5, 44.4)	33.4 (27.8, 39.8)	-37.1	(-47.7, -25.1)*	-45.8	(-54.8, -35.6) *
DALYs	1161.7 (1112.3, 1203.0)	1221.4 (1153.4, 1278.8)	792.0 (659.7, 941.5)	688.3 (585.7, 801.9)	-31.8	(-43.2, -18.8)*	-43.6	(-51.8, -34.0) *
YLLs	1071.9 (1027.9, 1105.1)	1064.1 (1011.8, 1105.3)	714.8 (582.9, 865.9)	567.5 (467.1, 684.0)	-33.3	(-45.7, -19.3)*	-46.7	(-55.9, -35.7) *
YLDs	89.8 (66.3, 113.7)	157.3 (115.4, 197.4) †	77.2 (56.6, 97.3)	120.9 (86.9, 153.4)	-14.1	(-16.8, -11.4)	-23.1	(-26.0, -20.7) †
Prevalence	1031.8 (923.5, 1145.4)	1546.9 (1395.3, 1703.3) †	889.5 (799.6, 984.3)	1183.4 (1067.5, 1305.1) †	-13.8	(-16.3, -11.4)	-23.5	(-26.2, -21.4) * †
Incidence	114.9 (102.2, 129.9)	(125.2, 156.8)	87.7 (78.4, 98.4)	95.2 (85.3, 106.3)	-23.7	(-25.3, -22.1)*	-32.0	(-33.6, -30.4) * †
Ischaemic Stroke								
Deaths	36.1 (33.2, 37.9)	37.0 (33.4, 39.4)	20.3 (16.6, 24.3)	19.0 (15.6, 22.7)	-43.8	(-53.3, -32.9)*	-48.7	(-57.7, -38.7) *
DALYs	598.6 (562.1, 629.8)	614.9 (567.4, 657.9)	356.3 (297.3, 421.4)	331.6 (283.3, 386.2)	-40.5	(-49.9, -29.9)*	-46.1	(-53.6, -37.9) *
YLLs	527.9 (497.3, 549.8)	496.5 (460.0, 523.9)	297.1 (241.1, 361.1)	243.1 (200.5, 292.7)	-43.7	(-54.5, -31.7)*	-51.0	(-60.2, -40.7) *
YLDs	70.6 (51.0, 90.5)	118.4 (85.5, 151.2)	59.2 (42.7, 75.6)	88.4 (63.7, 113.6)	-16.2	(-19.5, -13.0)	-25.3	(-28.6, -22.4) †
Prevalence	841.0 (733.4, 958.5)	1194.0 (1042.6, 1353.4) †	708.7 (619.4, 798.3)	890.2 (779.1, 1010.6)	-15.7	(-18.6, -12.8)	-25.4	(-28.6, -23.0) * †
Incidence	78.6 (66.7, 94.2)	94.0 (79.8, 110.7)	56.5 (47.9, 67.4)	60.4 (51.1, 70.8)	-28.1	(-29.9, -26.1)	-35.8	(-37.7, -33.9) * †
Intracerebral haemorrhage								
Deaths	20.0 (18.9, 20.9)	20.7 (19.4, 21.8)	13.3 (10.8, 16.1)	10.3 (8.5, 12.4)	-33.5	(-46.0, -18.0)*	-50.4	(-58.7, -40.2) *
DALYs	465.7 (441.3, 483.4)	475.8 (453.6, 493.2)	323.6 (260.7, 396.1)	234.8 (196.4, 280.0)	-30.5	(-44.0, -14.5)*	-50.7	(-59.0, -40.7) *
YLLs	452.1 (427.3, 470)	447.9 (426.7, 464.2)	311.6 (250.5, 385.7)	212.9 (173.9, 258.9)	-31.1	(-44.8, -14.5)*	-52.5	(-61.1, -41.9)
YLDs	13.6 (9.8, 17.7)	27.9 (19.9, 35.9) †	12.0 (8.6, 15.4)	21.8 (15.7, 28.2) †	-11.6	(-15.4, -7.6)	-21.8	(-25.3, -18.2) †
Prevalence	170.8 (146.7, 196)	295.5 (257.4, 338.2) †	151.1 (131, 172.6)	228.7 (198.3, 260.5) †	-11.5	(-13.6, -9.3)	-22.6	(-25.2, -20.3) †
Incidence	26.1 (22.1, 30.9)	31.4 (26.9, 36.7)	19.5 (16.4, 23.1)	19.8 (16.7, 23.3)	-25.5	(-27.2, -23.8)	-37.1	(-38.9, -35.0) * †
Subarachnoid haemorrhage								
Deaths	2.9 (2.7, 4.0)	3.8 (3.6, 4.7)	3.5 (2.6, 4.4)	4.1 (3.2, 5)	19.8	(-32.6, 59.9)	6.9	(-28.9, 32.0)
DALYs	97.4 (90.1, 122.9)	130.7 (124.1, 150.4) †	112.0 (87.1, 139.2)	122.0 (99.6, 147.7)	15.0	(-26.1, 48.4)	-6.6	(-28.0, 13.8)
YLLs	91.8 (85, 117.1)	119.7 (114.2, 140.2)	106.1 (80.7, 132.5)	111.4 (89.4, 136.6)	15.6	(-27.9, 50.7)	-6.9	(-30.1, 15.6)
YLDs	5.6 (4.0, 7.6)	11.0 (7.9, 14.7) †	6.0 (4.2, 8.0)	10.6 (7.5, 14.2)	6.1	(1.8, 10.1)	-3.3	(-7.5, 1.0) †
Prevalence	69.7 (58.2, 84.0)	117.0 (97.7, 141.2) †	73.7 (61.4, 88.7)	111.8 (93.5, 133.9) †	5.8	(4.0, 7.9)	-4.5	(-6.7, -2.5) †
Incidence	10.2 (8.5, 12.3)	14.6 (12.3, 17.5)	11.7 (9.8, 14.1)	15.1 (12.7, 18.0)	13.9	(11.7, 16.3)	3.0	(0.2, 5.7) †

***Table 2*: Age-standardised 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 sex, in the period 1990-2019, in Mexico.**

* Significant change over the period.

† Significant difference between male and female, at 95%.

SDI 2019 quartile	Location	Ischaemic stroke Δ 1990-2019	Ischaemic stroke Δ 1990-2005	Ischaemic stroke Δ 2005-2019	Intracerebral haemorrhage Δ 1990-2019	Intracerebral haemorrhage Δ 1990-2005	Intracerebral haemorrhage Δ 2005-2019	Subarachnoid haemorrhage Δ 1990-2019	Subarachnoid haemorrhage Δ 1990-2005	Subarachnoid haemorrhage Δ 2005-2019
	National	-46.2% *	-35.5% *	-16.6%	**-42.5%** *	**-26.3%** *	**-21.9%** *	**12.8%**	**9.6%**	**2.9%**
Q1	Chiapas	-42.1% *	-38.0% *	-6.6%	-37.4% *	-22.7% *	-19.0%	15.4%	6.9%	7.9%
Q1	Guerrero	-48.6% *	-25.8% *	-30.7% *	-39.4% *	-16.7%	-27.3% *	-2.8%	8.6%	-10.5%
Q1	Oaxaca	-44.8% *	-37.6% *	-11.6%	-39.5% *	-22.2% *	-22.3%	2.8%	2.3%	0.5%
Q1	Michoacan	-50.1% *	-39.5% *	-17.4%	-40.8% *	-26.8% *	-19.1%	5.7%	4.1%	1.6%
Q1	Veracruz	-38.2% *	-26.7% *	-15.7%	-36.2% *	-19.3% *	-20.9%	16.8%	18.9%	-1.8%
Q1	Hidalgo	-45.9% *	-36.9% *	-14.3%	-39.0% *	-24.6% *	-19.0%	3.2%	1.2%	2.0%
Q1	Puebla	-40.5% *	-31.0% *	-13.8%	-30.0% *	-16.2% *	-16.4%	14.9%	4.8%	9.6%
Q1	Durango	-50.5% *	-36.9% *	-21.5%	-38.7% *	-18.3% *	-25.0% *	5.2%	0.8%	4.4%
Q2	Zacatecas	-43.5% *	-39.2% *	-7.1%	-30.9% *	-19.2% *	-14.4%	12.7%	6.9%	5.4%
Q2	Guanajuato	-55.5% *	-48.1% *	-14.3%	-43.4% *	-30.2% *	-18.9%	4.8%	1.5%	3.3%
Q2	San Luis Potosi	-46.8% *	-39.7% *	-11.7%	-40.7% *	-30.7% *	-14.4%	9.4%	0.0%	9.4%
Q2	Tabasco	-45.5% *	-30.8% *	-21.2%	-42.8% *	-20.5% *	-28.0% *	8.3%	8.2%	0.1%
Q2	Tlaxcala	-49.6% *	-40.4% *	-15.4%	-40.5% *	-27.4% *	-18.1%	7.2%	1.5%	5.6%
Q2	Yucatan	-54.7% *	-44.7% *	-18.1%	-45.4% *	-30.0% *	-22.0%	14.8%	2.8%	11.7%
Q2	Nayarit	-49.8% *	-39.4% *	-17.2%	-44.1% *	-31.5% *	-18.4%	2.5%	-0.6%	3.1%
Q2	Campeche	-51.2% *	-39.9% *	-18.8%	-43.7% *	-27.8% *	-22.0%	10.1%	2.8%	7.1%
Q3	Morelos	-49.2% *	-43.6% *	-9.9%	-47.3% *	-35.0% *	-18.9%	7.1%	0.4%	6.6%
Q3	Chihuahua	-45.2% *	-41.0% *	-7.2%	-38.2% *	-32.7% *	-8.3%	17.9%	3.5%	13.9%
Q3	State of Mexico	-51.2% *	-39.3% *	-19.7%	-49.5% *	-29.7% *	-28.2% *	18.9%	13.1%	5.1%
Q3	Coahuila	-52.2% *	-44.0% *	-14.5%	-40.4% *	-27.8% *	-17.5%	13.2%	5.6%	7.2%
Q3	Jalisco	-55.7% *	-42.4% *	-23.2%	-48.7% *	-29.6% *	-27.1% *	6.5%	9.8%	-3.0%
Q3	Tamaulipas	-49.2% *	-43.1% *	-10.8%	-46.0% *	-36.0% *	-15.6%	7.2%	1.1%	6.0%
Q3	Sinaloa	-42.7% *	-34.6% *	-12.4%	-39.2% *	-28.4% *	-15.1%	7.5%	-0.7%	8.2%
Q3	Quintana Roo	-23.5%	-30.7% *	10.3%	-24.5%	-19.4% *	-6.4%	35.4%	20.5%	12.4%
Q4	Queretaro	-44.6% *	-41.2% *	-5.8%	-38.5% *	-26.3% *	-16.6%	10.2%	4.6%	5.4%
Q4	Aguascalientes	-57.2% *	-42.3% *	-25.7%	-46.7% *	-27.2% *	-26.8% *	8.2%	13.5%	-4.7%
Q4	Colima	-52.5% *	-47.5% *	-9.6%	-46.6% *	-40.4% *	-10.4%	1.6%	-5.0%	7.0%
Q4	Sonora	-50.9% *	-34.7% *	-24.8% *	-44.6% *	-25.7% *	-25.5% *	7.9%	10.0%	-1.9%
Q4	Baja California	-49.2% *	-32.5% *	-24.7% *	-46.4% *	-25.3% *	-28.2% *	7.5%	14.8%	-6.4%
Q4	Baja California Sur	-43.7% *	-39.1% *	-7.7%	-35.2% *	-26.3% *	-12.0%	21.1%	12.7%	7.5%
Q4	Nuevo Leon	-49.2% *	-34.2% *	-22.8%	-47.9% *	-31.6% *	-23.9% *	10.9%	10.7%	0.2%
Q4	Mexico City	-42.1% *	-26.5% *	-21.1%	-50.5% *	-29.4% *	-29.9% *	34.8%	26.0%	7.0%

Figure 2. Age-standardised death rate change (per cent) for ischaemic stroke, intracerebral and subarachnoid haemorrhage, by period, for Mexico at national and subnational level ordered by quartiles of SDI. * Significant change over the period, at 95%.

SAH global incidence (7.9 per 100 000 person-years).[33] Moreover, while global SAH incidence declined by 40.6% in Europe, 46.2% in Asia, and 14.0% in North America between 1980 and 2010, in Mexico, the incidence has not changed from 1990 to 2019.

Total stroke incidence and prevalence rates showed an important decline over the period mostly explained by changes from 1990-2005. Compared with the continuous declining pattern of IS incidence rates observed in the USA, Canada, and Asian populations,[34,35] incidence rates in Mexico had not changed over the second period, possibly due to the lack of clinical data for modelling nonfatal trends in Mexico compared to other countries. Nevertheless, stroke incidence trends could be modified if prevention and control of major risk factors are improved. In Mexico, the prevalence of overweight and obesity (75.2%),[36] hypertension (30.9% when JNC-7 criteria are considered and 49.9% according to the AHA criteria),[37] and diabetes (16.8%)[38] in the adult population has increased from 2006 to 2018, which contributed to the small changes in stroke incidence rates and coincided with the period when stroke showed fewer improvements. Food policies (taxes to unhealthy foods, front of pack nutrition labelling, among others)[39] and massive campaigns[40] implemented by the Federal Government and the Mexican health care system to control obesity, diabetes and hypertension in at-risk populations have generated irregular effects. Estimates on the taxation in the energy-dense foods and SSB targeted to reduce the consumption could prevent 189,000 cases of diabetes, 20,000 myocardial infarctions and strokes, and 20,000 cardiovascular disease deaths in a decade.[41] Further impact evaluation of these strategies is needed to discern the real impact of these risk factors on stroke incidence.

Hypertension is the main risk factor for both IS and HS. According to GBD 2019 stroke study,[1] high systolic blood pressure is the leading risk factor contributing to stroke death and disability with 79·6 million attributable DALYs, which represents more than half of all stroke DALYs.[1] This is also revealed in the Mexico City Prospective Study, a cohort of 133,613 Mexican adults aged 35 to 74 years with high levels of adiposity and uncontrolled diabetes. In this large study with a median follow-up of 15.5 years, 2508 participants died from vascular causes including 22.9% from acute stroke (either IS or HS). Each 20 mmHg lower SBP was associated with a 48% lower stroke mortality rate and was higher in younger populations.[42]

No focalised strategies have been implemented to opportunely prevent, detect, and control hypertension, particularly in the population under 50 years. The emergence of higher ICH mortality in the young population appears to be associated with poor recognition (51%)[37] and inadequate control of hypertension (45.1%);[37] while in diabetes, it represents 38% and 58% respectively.[38] Early diagnosis of hypertension and diabetes, as well as adequate control, need to be properly addressed by non-pharmacological treatment (diet, exercise and loss weight). Early pharmacological treatment as well should be also indicated among those with incipient elevated blood pressure[42] and prediabetes.

Health care coverage faces important challenges to meet the evolving health needs of the Mexican population. Even when universal health care access has increased in recent years, stroke coverage in the country is non-existent and access to acute and long-term care is not granted for around 50% of the population.[43] Access to health care coverage is not necessarily followed by improvements in organised acute stroke care. Mexico is still lacking standardised management in the different phases of stroke care, such as neuroimaging availability, stroke codes, implementation of stroke units, thrombolysis administration, stroke mechanism study assignment, physical and language rehabilitation, as well as programmes to promote the reintegration into the labour market. Indeed, thrombolysis was administrated to only 0.5% of patients in the PREMIER study.[10] Worryingly, a recent economic analysis on actions to reduce the burden of non-communicable diseases in Mexico stated that only post-acute stroke interventions are highly cost-effective, while interventions in the acute period (including thrombolysis) came at significantly high costs with relatively low health gains.[44] All the issues mentioned above may partially explain the stagnation of the progress attained during the second period.

Despite that our results show that the burden of stroke is similar in both sexes, reductions in stroke incidence, prevalence and YDLs over the whole period were more pronounced in women than in men (without differences in the magnitude of reduction on mortality and DALYs change by sex). These differences could be gender associated with searching health and self-care of women.[45]

All these findings differed from the worldwide picture of cerebrovascular diseases that show a sustained decline in stroke burden during the last three decades,[2] with major advances in high-income countries that have been able to contain the rising burden by implementing opportune treatments in acute stroke patients, improving medical care and rehabilitation services, and promoting better home care for stroke survivors.[46] These uncovered needs may explain the lack of improvement in the reduction of disability burden during this period.

It is interesting to note that increases in stroke risk and mortality in developing countries are associated with better socioeconomic status (SES), while decreases in stroke risk and mortality in developed countries are associated with increasing SES.[47] According to the analysis of GBD 2019, Mexico presents an epidemiological pattern that contrasts with the findings of both HIC and LMIC.[1] By exploring other countries, Mexico's data resemble that of HIC regarding low mortality rate and LMIC with low prevalence and incidence. Hence, these results highly contrast with other Latin American countries (i.e., Brazil) as well as the only population-based study done in Mexico,[8] and with the Mexican-American population[48] were incidence, prevalence, and mortality rates are higher than those reported here. Although it is desirable to think that Mexico is going through a health transition like HIC concerning a low mortality rate, we should consider the possibility of limitations on information sources such as diagnosis, death certification and coding and predominance of hospital discharge data as well as over report of risk factors.

According to Coyoacan-Iztapalapa's study, the cerebrovascular mortality rate among patients older than 35 years with diabetes history would be several-fold higher than the rate assumed with the GBD model.[49] This suggests that the current model can be updated based on recent information and that new population-based studies are urgently needed to clarify possible discrepancies. Similarly, it was previously recognised that the coding system of diabetes deaths should be standardised to assure comparability at the individual and community level and that these measures will be important to public health policy planning.[50]

In Mexico, conventions for certifying the cause of death tend to assign the underlying cause to diabetes when it is mentioned anywhere in the sequence of events leading to death. This coding system would result in the underestimation of vascular deaths.[49] Preliminary multiple-cause analysis of stroke (upcoming) shows that the magnitude of the use of unspecified codes and particularly the use of the code I64 for stroke, represents almost 56.2% and 20%, respectively, of all deaths registered as stroke in the National Vital Statistics database, which may influence the magnitude of each subtype of stroke but not the trends observed. Further studies exploring multiple causes of death data could reveal the real magnitude of mortality for each subtype of stroke. Improvements in the reduction of misclassification and miscoding of those comorbidities associated with stroke would improve the estimation herein observed.

Among the opportunities in Mexico to improve the quality of acute stroke care; we should mention the Acute Networks Striving for Excellence in Stroke (ANGELS) initiative. The ANGELS initiative is an international collaborative strategy endorsed by the World Stroke Organization, that aims to improve the treatment of patients with acute stroke by providing stroke teams with the academic tools, educational resources, and support, based on evidence-based guidelines, needed to set up or improve stroke networks and to optimise the quality of treatment in all existing stroke centres. The ANGELS initiative was launched in Mexico in June 2017 and hope to help train more than 300 hospitals through all Mexican states by 2022. This program will probably facilitate identifying specific gaps and needs in stroke care delivered at the national, regional, and hospital-level.[51] In addition, the extension of the population coverage of hypertension care programs (including detection, treatment, and control) should be a priority in Mexico for reducing vascular deaths and stroke.

Despite data source limitations, GBD databases give us a more comprehensive view to characterise the shifts in stroke patterns at national and subnational levels in

Mexico, allowing us to assess the changing patterns over time with a homogeneous methodology, highlighting disparities of cerebrovascular disease burden by states.

In conclusion, the reduction in stroke burden in Mexico did not follow the same pace for all types of strokes, with regional differences by SDI and by sex. The declining trend of stroke over the 1990–2005 period and the stagnation of progress from 2006 to 2019 denotes variations in early diagnosis, treatment rehabilitation, and access to stroke management, particularly in the less developed areas of the country, where improvements were minimal. This study provides new information that policymakers may use to guide evidence-based decisions and strengthen the design of effective prevention programmes at the national and sub-national levels.

Contributors

VDG: literature search, figures, study design, data collection, data analysis, data interpretation, writing. ECH: literature search, figures, data analysis and interpretation, writing. HGD: study design, data collection, data analysis and interpretation, writing. LCH: literature search, figures, study design, data collection, data analysis, data interpretation, writing. CCB: study design, data analysis and interpretation, writing. All authors have read and agreed to the published version of the manuscript.

Data sharing statement

The data used in this study can be retrieved from: http://ghdx.healthdata.org/

Editorial note

The Lancet Group takes a neutral position with respect to territorial claims in published maps and institutional affiliations.

Declaration of interests

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Supplementary materials

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