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Multiple Causes of Death Associated With Stroke in Young Adults Aged 20-49 Years in Brazil: A Population-Based Time-Series Analysis From 2015 to 2024

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Abstract

Introduction: Stroke mortality has been rising among young adults, and restricting analysis to the underlying cause of death simplifies the sequence of coexisting conditions that culminate in a fatal outcome. This study aimed to analyze mortality from underlying and multiple causes of death associated with stroke among young adults (20-49 years) in Brazil between 2015 and 2024.

Methods: This retrospective, population-based time-series study analyzed individual-level death certificate data for residents of Brazil of both sexes aged 20 to 49 years, recorded in the National Mortality Information System/Department of Informatics of the Brazilian Unified Health System (SIM/DATASUS) between 2015 and 2024. Stroke deaths were identified using ICD-10 codes I60-I69. Temporal trends were assessed using Prais-Winsten regression.

Results: Of 2,187,873 deaths recorded during the period, 71,349 (3.26%) had stroke as the underlying cause. Hemorrhagic stroke predominated (n = 38,447; 53.9%) over ischemic stroke (n = 4,719; 6.6%). Proportional mortality was higher among females (n = 34,047; 5.20%) than males (n = 37,296; 2.43%). The temporal trend was stationary (annual percent change = −0.85%; p = 0.536), with a transient decline during the coronavirus disease 2019 (COVID-19) pandemic. Hypertension was the main recorded comorbidity (n = 21,926; 30.7%). Alcohol use was nearly four times more frequent among men (prevalence ratio (PR) = 3.83). Most deaths occurred in hospital settings (n = 64,134; 89.9%), frequently associated with complications such as sepsis and cerebral edema.

Conclusions: Hemorrhagic stroke is the leading cause of cerebrovascular death among young Brazilian adults, strongly linked to hypertension. These findings highlight the complexity of multiple causes of death and the need to strengthen primary prevention and control of modifiable risk factors, alongside improved hospital care to reduce premature mortality in this population.

Categories: Neurology, Preventive Medicine, Epidemiology/Public Health
Keywords: brazil, cause of death, death certificates, mortality, stroke, young adult

Introduction

Stroke is a leading cause of death and disability worldwide, responsible for millions of deaths annually and a substantial share of disability-adjusted life-years [1,2]. Declines in stroke mortality driven by improved risk-factor control and acute management have been uneven across age groups. In Brazil, stroke is the second leading cause of death, with more than 100,000 deaths per year [3], and its incidence and mortality have been rising among young adults, challenging established paradigms of prevention and care [2,4].

Stroke in young adults follows a different epidemiological pattern than in older adults, with a comparatively higher proportion of hemorrhagic events [5], frequently linked to underdiagnosed risk factors such as uncontrolled hypertension, alcohol and substance use [6], hormonal contraceptive use, and pregnancy-related conditions including eclampsia [7]. Restricting mortality analysis to the underlying cause of death simplifies the sequence of coexisting conditions and clinical events that culminate in a fatal outcome. Multiple-cause-of-death analysis, drawing on all conditions recorded on the death certificate, reconstructs this trajectory in more detail and has previously revealed clinically relevant associations that a single

underlying cause could not capture [8].

To our knowledge, no population-based study in Brazil has yet integrated multiple-cause-of-death analysis with stroke mortality in this age group. Understanding the causal chain leading to these deaths is essential for developing more effective strategies for prevention, early diagnosis, and clinical management, and for reducing stroke-related mortality and sequelae among young adults.

Because the National Mortality Information System (SIM) captures the complete national census of registered deaths rather than a sample restricted to hospitalized survivors, a population-based time-series design, tracking proportional mortality and its recorded causal chain across consecutive calendar years, is the design suited to this data source. Comparable designs have been used to describe cerebrovascular mortality trends in Brazil using the same national registry [3,9].

This study aimed to analyze mortality from underlying and multiple causes of death associated with stroke among young adults (20-49 years) in Brazil between 2015 and 2024.

Materials And Methods

Study design and reporting

This retrospective, population-based time-series study analyzed nationwide death certificate data from individuals aged 20 to 49 years who died in Brazil between 2015 and 2024, using multiple-cause-of-death records extracted from the SIM [10], maintained by the Department of Informatics of the Brazilian Unified Health System (DATASUS) [11]. Because SIM provides a virtually complete national census of death certificates rather than a sample of survivors or hospitalized patients, a population-based time-series design was chosen to describe the temporal trend in proportional mortality across the study period; this observational design involved no intervention, experimental assignment, or investigational exposure applied to any individual and analyzed exclusively pre-existing, routinely collected registry data.

Reporting followed the STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) guidelines [12] and the RECORD (REporting of studies Conducted using Observational Routinely-collected health Data) extension of STROBE [13], as the data source was a routinely collected administrative registry rather than a study-specific data collection instrument.

Study population and data source

We used all death records registered in SIM for individuals aged 20 to 49 years at the time of death, between January 1, 2015, and December 31, 2024, retrieved as individual-level microdata files organized by federative unit and consolidated into a single national dataset. SIM is a nationwide, mandatory vital registration system that captures virtually all deaths occurring in Brazil, regardless of the place of death or type of health care facility, with each record corresponding to a single, uniquely identified death certificate. Records with missing or internally inconsistent age (for instance, a documented birth-to-death interval incompatible with the stated age at death) were excluded before applying the 20-to-49-year age restriction. Because Brazilian death registration requires a single certificate per decedent and SIM assigns a unique administrative identifier to each certificate, no individual contributed more than one record to this dataset, unlike hospitalization-based or claims-based registries in which the same patient may appear more than once. A total of 71,349 deaths with stroke recorded as the underlying cause, and 93,486 deaths with stroke recorded on any line of the death certificate, were included in the respective analyses. Because this study used the complete national census of eligible deaths rather than a sample, no a priori sample-size calculation was performed.

Data collection and variables

In Brazil, the death certificate is composed of two parts. Part I, comprising four lines (a to d), records the immediate, intermediate, and underlying causes of death, describing the direct causal sequence leading to death; the underlying cause, the disease or injury that initiated this sequence, is the cause conventionally used for routine mortality statistics. Part II records other conditions that contributed to death without being part of this direct causal sequence [14]. Multiple-cause-of-death analysis considers all conditions recorded in both parts of the death certificate, rather than the underlying cause alone. Stroke was defined by the International Classification of Diseases, 10th Revision (ICD-10) [15] codes I60-I69 (cerebrovascular diseases) and classified into the following subtypes: hemorrhagic stroke (I60, subarachnoid hemorrhage; I61, intracerebral hemorrhage; I62, other nontraumatic intracranial hemorrhage), ischemic stroke (I63, cerebral infarction), unspecified stroke (I64), and other cerebrovascular diseases (I65-I69). The proportion of unspecified stroke was examined as an indirect proxy for diagnostic misclassification, since assignment to this subtype typically reflects the absence of neuroimaging at the time of certification rather than a distinct clinical entity. Sex was recorded as male, female, or not informed; among the 71,349 stroke deaths, records with sex not informed (n = 6) were retained in overall and subtype-specific totals but excluded from sex-stratified analyses. Place of death was classified as within a health care facility, outside a health care facility, or not informed; the n = 16 (0.02%) records with place of death not informed were retained in overall totals but excluded from the place-of-death comparison across subtypes.

Outcomes

The primary outcome was proportional mortality from stroke recorded as the underlying cause of death. Secondary outcomes included the proportion of stroke recorded on any line of the death certificate, multiple causes of death associated with stroke, the distribution of stroke subtypes, and place of death. The underlying-cause outcome captures deaths in which stroke was assessed by the certifying physician as the direct, initiating cause of the fatal sequence, whereas the multiple-cause outcome also captures deaths attributed to other underlying causes in which stroke was recorded as a contributing or coexisting condition elsewhere on the death certificate.

Statistical analysis

Temporal trends in proportional stroke mortality were assessed using Prais-Winsten regression [16,17], which corrects for the first-order serial autocorrelation inherent to annual time-series data. Given the limited number of annual data points (n = 10 years), which constrains the stability of segmented joinpoint regression, Prais-Winsten regression was used as the trend-estimation method for a single linear trend across the study period. The regression coefficient for the base-10 logarithm of proportional mortality as a function of year was used to calculate the annual percent change (APC) and its 95% confidence interval (95% CI), using the formula $APC = (10\beta - 1) \times 100$. The analysis was performed for total deaths and stratified by sex. Data for 2024, the most recent year available at the time of extraction, were treated as complete; no additional sensitivity analysis excluding this year was performed. Variation in the proportion of stroke subtypes and in the frequency of associated comorbidities across age groups was assessed using the Cochran-Armitage trend test [18,19]. Differences in comorbidity frequency between sexes were assessed using the prevalence ratio (PR), calculated as the ratio between prevalence among males and prevalence among females, with 95% confidence intervals obtained by the Katz method [20]. Statistical significance was assessed using Pearson's chi-square test, which was also used to compare the distribution of place of death across stroke subtypes. Because SIM does not capture individual-level clinical severity, comorbid burden at admission, or a non-fatal comparison group, multivariable regression modeling of individual risk was not undertaken; analyses were restricted to descriptive proportions, trend tests, and PRs appropriate to aggregate, registry-based mortality data. A significance level of 5% ($p < 0.05$) was adopted for all analyses. Data were processed and analyzed using R, version 4.5.2 (R Foundation for Statistical Computing, Vienna, Austria).

Ethical considerations

This study was conducted in accordance with the Declaration of Helsinki [21]. It was exempted from review by the Research Ethics Committee because it relied exclusively on publicly available, de-identified national databases, in accordance with Resolution No. 466/2012 of the National Health Council and Resolution No. 510/2016, which governs research using public-domain data [22]. The requirement for individual informed consent was therefore waived.

Results

Between 2015 and 2024, 2,187,873 deaths were recorded among individuals aged 20 to 49 years in Brazil, of whom 1,533,483 (70.1%) were male and 654,150 (29.9%) were female. External causes were the leading underlying cause of death among males across all age groups (n = 724,464; 47.2% of the total), with the greatest impact between 20 and 24 years (n = 169,885; 79.3%). Among females, neoplasms and blood diseases were the leading cause of death (n = 158,862; 24.3%), followed by external causes (n = 96,199; 14.7%) (Figure *1B*). Of the total deaths, 71,349 (3.26%) had cerebrovascular disease (ICD-10: I60-I69) recorded as the underlying cause, and 93,486 (4.27%) had stroke recorded on any line of the death certificate.

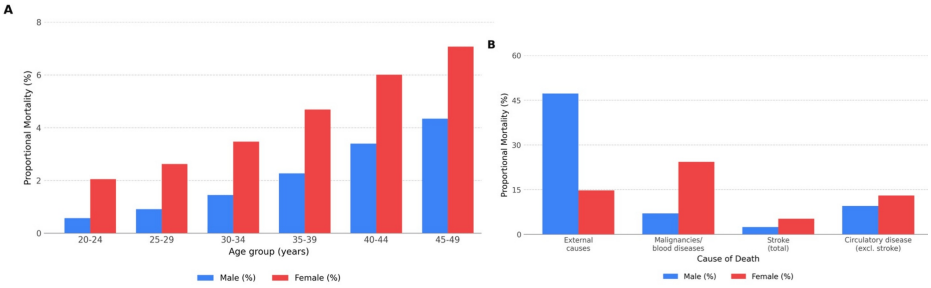


FIGURE 1: Mortality profile among young adults (20–49 years) in Brazil, 2015–2024.

A: proportional mortality from cerebrovascular disease (stroke), stratified by sex and age group; B: proportional mortality from the leading underlying causes of death, by sex.

Proportional mortality from stroke as the underlying cause was higher among females (n = 34,047; 5.20%) than males (n = 37,296; 2.43%), a pattern that persisted across all age groups. In both sexes, proportional stroke mortality increased progressively with age, with n = 29,680 (41.6%) of deaths concentrated in the 45-49-year age group (Figure *1A*).

Regarding subtype distribution, hemorrhagic stroke (I60-I62) predominated in both sexes, accounting for n = 38,447 (53.9%) of stroke deaths as the underlying cause, followed by unspecified stroke (I64) at n = 15,131 (21.2%), other cerebrovascular diseases (I65-I69) at n = 13,052 (18.3%), and ischemic stroke (I63) at n = 4,719 (6.6%). Subtype distribution was similar between sexes (Figure *2*).

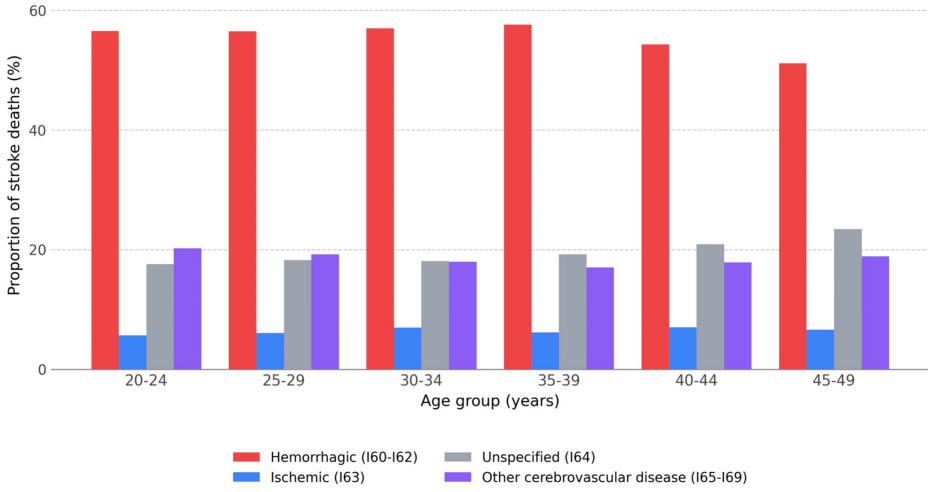


FIGURE 2: Proportional distribution of cerebrovascular disease (stroke) deaths by subtype and age group in Brazil, 2015–2024.

The variation in the proportion of hemorrhagic stroke across age groups was statistically significant (Cochran-Armitage trend test, $\chi^2 = 138.37$; $p < 0.001$).

The Cochran-Armitage trend test revealed significant variation in the proportion of hemorrhagic stroke across age groups ($\chi^2 = 138.37$; $p < 0.001$), which decreased from n = 1,251 (56.6%) at 20-24 years to n = 15,175 (51.1%) at 45-49 years, suggesting that ischemic stroke and other cerebrovascular diseases gain relative importance with aging, although hemorrhagic stroke remained predominant across all age groups. The proportion of ischemic stroke remained stable, between 5.7% and 7.0% across age groups, without a significant trend ($\chi^2 = 2.72$; $p = 0.099$).

Temporal trend analysis showed a stationary pattern in proportional stroke mortality overall (annual percent change = −0.85%; $p = 0.536$), with no significant change across the study period in either sex (Figure *3*). However, there was a marked decline in proportional mortality in 2020 (n = 6,654; 2.92%) and 2021 (n = 7,306; 2.55%), attributable to the substantial increase in total COVID-19-related mortality, which raised the denominator without a proportional increase in stroke deaths. The comparison between the pre-COVID (2015-2019: n = 35,599; 3.45%) and COVID (2020-2021: n = 13,960; 2.72%) periods revealed a statistically

significant difference ($\chi^2 = 427.91$; $p < 0.001$). In the post-pandemic years (2022-2024), proportional mortality returned to levels similar to the pre-COVID period (n = 21,790; 3.39%), confirming that the reduction observed in 2020-2021 was artifactual (Figure 3).

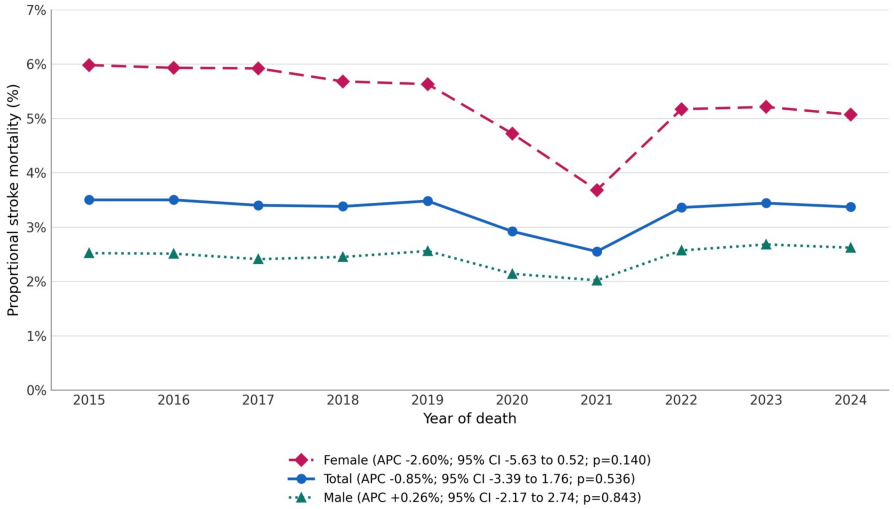


FIGURE 3: Temporal trend in proportional stroke mortality (underlying cause) among individuals aged 20 to 49 years in Brazil, 2015 to 2024, by sex.

Trends were assessed using Prais-Winsten regression; annual percent change (APC), 95% confidence interval, and p-value are shown in the legend for each series.

When stroke was recorded as the underlying cause of death, analysis of multiple causes on the remaining lines of the death certificate showed that hypertension (I10-I15) was the most frequently recorded condition, present in n = 21,926 (30.7%) of deaths. Hypertension prevalence was significantly higher among females (n = 11,153; 32.8%) than males (n = 10,771; 28.9%) (PR = 0.88; 95% CI: 0.86-0.90; $p < 0.001$), increasing progressively with age, from n = 202 (9.1%) at 20-24 years to n = 10,813 (36.4%) at 45-49 years, with a significant trend by the Cochran-Armitage test ($\chi^2 = 1,754.13$; $p < 0.001$) (Table 1).

Condition	Total, n (%)	Male, n (%)	Female, n (%)
Hypertension (I10-I15)	21,926 (30.73)	10,771 (28.88)	11,153 (32.76)
Sepsis (A40-A41)	10,449 (14.64)	5,729 (15.36)	4,718 (13.86)
Cerebral edema (G93)	10,025 (14.05)	4,760 (12.76)	5,264 (15.46)
Pneumonia (J12-J18)	8,781 (12.31)	5,088 (13.64)	3,693 (10.85)
Shock (R57)	6,269 (8.79)	3,289 (8.82)	2,979 (8.75)
Respiratory failure (J96)	6,061 (8.49)	3,282 (8.80)	2,779 (8.16)
Renal disease (N17-N19)	5,797 (8.12)	3,252 (8.72)	2,543 (7.47)
Diabetes mellitus (E10-E14)	3,495 (4.90)	1,633 (4.38)	1,862 (5.47)
Psychoactive substance use disorders (F11-F19)	2,345 (3.29)	1,233 (3.31)	1,112 (3.27)
Alcohol use disorders (F10)	2,338 (3.28)	1,888 (5.06)	450 (1.32)
Aspiration pneumonia (J69)	2,218 (3.11)	1,350 (3.62)	868 (2.55)
Smoking (F17)	1,854 (2.60)	912 (2.45)	942 (2.77)
Obesity (E66)	1,198 (1.68)	480 (1.29)	718 (2.11)
Epilepsy (G40-G41)	1,018 (1.43)	680 (1.82)	338 (0.99)
Cardiac arrest (I46)	886 (1.24)	491 (1.32)	395 (1.16)
Heart failure (I50)	840 (1.18)	482 (1.29)	358 (1.05)
Pulmonary edema (J81)	770 (1.08)	405 (1.09)	365 (1.07)
Atrial fibrillation (I48)	220 (0.31)	118 (0.32)	102 (0.30)
Dyslipidemia (E78)	157 (0.22)	82 (0.22)	75 (0.22)
Pregnancy, childbirth, and puerperium (O00-O99)	2 (0.00)	0 (0.00)	2 (0.01)

TABLE 1: Conditions associated with death from cerebrovascular disease (stroke) as the underlying cause, by sex, among young adults (20–49 years) in Brazil, 2015–2024.

PR: prevalence ratio, calculated as the ratio of prevalence among males to prevalence among females. Differences in comorbidity frequency by sex were assessed using the prevalence ratio; the significance of the trend across age groups was assessed using the Cochran-Armitage trend test (see Results).

In-hospital complications were frequent in the causal chain of death: sepsis (A40-A41) in n = 10,449 (14.6%), cerebral edema (G93) in n = 10,025 (14.1%), pneumonia (J12-J18) in n = 8,781 (12.3%), shock (R57) in n = 6,269 (8.8%), respiratory failure (J96) in n = 6,061 (8.5%), and renal disease (N17-N19) in n = 5,797 (8.1%). All these conditions, except shock ($p = 0.413$) and renal disease ($p = 0.198$), showed a significant increasing trend with age ($p < 0.001$ for all). Sepsis was more prevalent among males (PR = 1.11; 95% CI: 1.07-1.15; $p < 0.001$), as were pneumonia (PR = 1.26; 95% CI: 1.21-1.31; $p < 0.001$) and aspiration pneumonia (PR = 1.42; 95% CI: 1.31-1.54; $p < 0.001$). Cerebral edema, in turn, was significantly more frequent among females (male-to-female PR = 0.83; 95% CI: 0.80-0.86; $p < 0.001$) (Figure *4*).

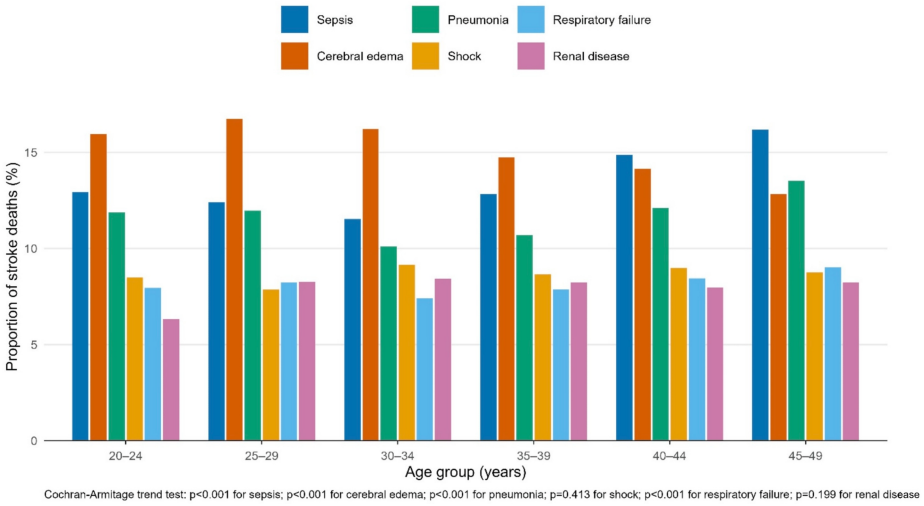


FIGURE 4: Proportional distribution of in-hospital complications recorded as multiple causes of death in stroke deaths, by age group.

The increasing trend with age was statistically significant for all complications shown (Cochran-Armitage trend test, $p < 0.001$), except shock ($p = 0.413$) and renal disease ($p = 0.198$).

Alcohol-related disorders (F10) were recorded in n = 2,338 (3.3%) of deaths, showing the largest sex difference among all comorbidities analyzed: a male-to-female PR of 3.83 (95% CI: 3.46-4.24; $p < 0.001$), indicating nearly four times higher prevalence among men (n = 1,888; 5.1%) than women (n = 450; 1.3%). Smoking (F17) was recorded in n = 1,854 (2.6%) of cases, with a slight and paradoxical predominance among females (PR = 0.88; 95% CI: 0.81-0.97; $p = 0.008$). Both showed a significant increasing trend with age ($p < 0.001$).

Obesity (E66) was present in n = 1,198 (1.7%) of deaths, with significantly higher prevalence among women (n = 718; 2.1%) than men (n = 480; 1.3%; PR = 0.61; 95% CI: 0.54-0.68; $p < 0.001$) and no significant trend by age group ($p = 0.364$). Diabetes mellitus (E10-E14) was recorded in n = 3,495 (4.9%) of cases, with a progressive increase by age group from n = 46 (2.1%) at 20-24 years to n = 1,907 (6.4%) at 45-49 years ($\chi^2 = 300.00$; $p < 0.001$) and significantly higher prevalence among women (n = 1,862; 5.5%) than men (n = 1,633; 4.4%; PR = 0.80; 95% CI: 0.75-0.85; $p < 0.001$).

Psychoactive substance use disorders (F11-F19) were recorded in n = 2,345 (3.3%) of deaths, without a significant difference between sexes (PR = 1.01; 95% CI: 0.93-1.10; $p = 0.781$), but with a significant increasing trend with age ($\chi^2 = 59.86$; $p < 0.001$).

Excluding diseases of the circulatory system, the conditions most frequently recorded on death certificate lines when stroke was the underlying cause belonged to Chapter X, diseases of the respiratory system (n = 20,069; 28.1%), followed by Chapter XVIII, symptoms and ill-defined conditions (n = 16,292; 22.8%), Chapter VI, diseases of the nervous system (n = 14,548; 20.4%), Chapter I, infectious and parasitic diseases (n = 12,217; 17.1%), Chapter XIV, diseases of the genitourinary system (n = 7,480; 10.5%), Chapter IV, endocrine and metabolic diseases (n = 6,170; 8.7%), and Chapter V, mental and behavioral disorders (n = 5,420; 7.6%).

Most stroke deaths as the underlying cause occurred in hospital settings (n = 64,134; 89.9%), while n = 7,199 (10.1%) occurred outside hospital settings and n = 16 (0.02%) had an unrecorded place of death. Hemorrhagic and ischemic stroke showed a similar proportion of hospital deaths (n = 35,622; 92.7% and n = 4,372; 92.6%, respectively), whereas unspecified stroke (n = 12,807; 84.6%) and other cerebrovascular diseases (n = 11,333; 86.8%) showed a lower hospital proportion. This difference across subtypes in place of death was statistically significant ($\chi^2 = 954.65$; df = 3; $p < 0.001$). It suggests that some deaths classified as unspecified stroke occurred without access to imaging diagnosis in settings with limited diagnostic resources (Figure *2*).

Discussion

This study found 71,349 stroke deaths as the underlying cause (3.26% of all deaths) among adults aged 20-49 years in Brazil, with proportional mortality significantly higher among females (n = 34,047; 5.20%) than males (n = 37,296; 2.43%). These findings partially corroborate the international literature. The higher proportional mortality from stroke among females contrasts with global data showing higher absolute mortality rates among young men; recent Latin American studies, however, describe unfavorable trends

among young women, with rising stroke incidence in this population [23,24].

The concentration of n = 29,680 (41.6%) of deaths in the 45-49-year age group and the progressive increase with age are consistent with patterns described globally [9]. In Brazil, previous studies documented a decline in stroke mortality between 1997 and 2012 among adults aged 15-49 years [23,24]. This trend suggests that the elevated proportional mortality observed here reflects a reduction in other causes of death within this age group, particularly among women. Vascular malformations, uncontrolled hypertension, and sympathomimetic drug use are among the factors that plausibly contribute to this disparity.

The high proportion of hemorrhagic stroke (n = 38,447; 53.9%) observed among young Brazilian adults reflects the pattern characteristic of low- and middle-income countries, where intracerebral hemorrhage accounts for nearly twice the proportion found in high-income countries (29.5% vs. 15.8%). In Latin America and the Caribbean, intracerebral hemorrhage accounts for 42% of the overall stroke burden, with hypertension as the leading modifiable risk factor, carrying a population-attributable fraction of 53% [25].

Inadequate blood pressure control in low- and middle-income countries, together with a higher prevalence of undiagnosed or untreated hypertension, helps explain the greater occurrence of hemorrhagic stroke in this population [26,27]. Large multinational studies confirm hypertension as the risk factor most strongly associated with intracerebral hemorrhage [28]. Community-based blood pressure control programs have been shown to substantially reduce cardiovascular events, including stroke, supporting hypertension control as a population-level prevention strategy [29].

The high proportion of unspecified stroke (n = 15,131; 21.2%) represents an important diagnostic limitation in the Brazilian context. In low- and middle-income countries, only 13%-36% of stroke patients undergo neuroimaging, even in areas where equipment is available. In Brazil, barriers include limited access to reliable neuroimaging, a shortage of neurologists and neurosurgeons, and emergency services poorly equipped for acute stroke management. The absence of neuroimaging precludes distinguishing between ischemic and hemorrhagic stroke, resulting in death certificates coded as unspecified stroke [30].

This diagnostic limitation likely underestimates the true proportion of ischemic stroke, which accounts for 62.4% of incident cases globally but only n = 4,719 (6.6%) in this Brazilian series [31].

Hypertension was the most prevalent comorbidity (n = 21,926; 30.7%) and is recognized as the leading modifiable risk factor among young adults with stroke, carrying a population-attributable risk that increases with age [6]. The higher prevalence among women (n = 11,153; 32.8%) than men (n = 10,771; 28.9%) and the progressive increase with age (from n = 202; 9.1% at 20-24 years to n = 10,813; 36.4% at 45-49 years) found in this study reflect well-established epidemiological patterns, although the prevalence observed here is lower than reported in global studies (36.6%-52.1%), possibly reflecting underreporting on Brazilian death certificates [4,6,32].

The documented in-hospital complications, sepsis (n = 10,449; 14.6%), cerebral edema (n = 10,025; 14.1%), pneumonia (n = 8,781; 12.3%), and respiratory failure (n = 6,061; 8.5%), are consistent with the literature identifying infections and neurological complications as leading causes of post-stroke mortality among young adults [32,33]. The higher prevalence of sepsis and pneumonia among men may relate to greater stroke severity in this group, while the higher frequency of cerebral edema among women warrants further investigation. The increase in these complications with age reflects greater severity and accumulated comorbidity [34,35].

Alcohol use showed the largest disparity between sexes (PR = 3.83), with prevalence nearly four times higher among men (n = 1,888; 5.1%) than women (n = 450; 1.3%), consistent with studies identifying heavy alcohol consumption as a significant risk factor for stroke among young adults, particularly hemorrhagic stroke. The low recorded prevalence of smoking (n = 1,854; 2.6%), obesity (n = 1,198; 1.7%), and diabetes (n = 3,495; 4.9%) contrasts sharply, by comparison, with international data reporting smoking in 49.2%, obesity in 23.9%-40.4%, and diabetes in 11.8%-23.8% of young stroke patients, suggesting substantial underreporting of these risk factors on Brazilian death certificates, a recognized limitation of mortality systems that capture only the information recorded by certifying physicians [36].

The high proportion of in-hospital stroke deaths (n = 64,134; 89.9%) is consistent with international data showing that approximately half of stroke deaths occur after hospital admission. The similar proportion of hospital deaths between hemorrhagic (n = 35,622; 92.7%) and ischemic stroke (n = 4,372; 92.6%) reflects the severity of both subtypes, although hemorrhagic stroke carries an in-hospital mortality rate roughly three times higher than ischemic stroke [37,38].

The lower proportion of hospital deaths among unspecified stroke cases (n = 12,807; 84.6%) suggests limited access to diagnostic neuroimaging, resulting in inadequate subtype classification. This significant difference across subtypes in place of death ($p < 0.001$) may reflect regional inequalities in access to health services and diagnostic resources in Brazil, where deaths classified as unspecified frequently occur in settings with lower technological availability.

These findings should generalize to the Brazilian population of young adults captured by SIM, given the system's near-complete national coverage. However, regional disparities in access to diagnostic neuroimaging and emergency stroke care across Brazilian states, previously documented in national mortality trend analyses [3], may limit the applicability of subtype-specific findings, particularly for unspecified stroke, to settings with different resource availability outside Brazil.

Limitations

This study has limitations inherent to the use of secondary data, including underreporting of behavioral factors such as alcohol use and obesity [8,25] and diagnostic imprecision in unspecified stroke cases. These patterns reflect information bias, specifically outcome and exposure misclassification arising from variable diagnostic and reporting practices across certifying physicians and health care settings; misclassification between unspecified and hemorrhagic or ischemic stroke subtypes is likely differential, associated with unequal access to neuroimaging, and may bias subtype-specific estimates. Selection bias is expected to be minimal, because SIM captures the near-complete national census of registered deaths rather than a sample, so no differential selection into the dataset occurred; residual underrepresentation is limited to deaths that were never certified or registered, which cannot be quantified from this data source. The low frequency of pregnancy-, childbirth-, and puerperium-related records (n = 2; 0.01%) suggests underregistration of eclampsia. The absence of socioeconomic variables limits the analysis of social determinants of health. Because SIM does not include a non-fatal comparison group or individual-level clinical severity data, multivariable adjustment for potential confounders was not performed; the associations described here should be interpreted as unadjusted, population-level patterns rather than individual-level risk estimates. Future studies linking hospitalization microdata (Hospital Information System, SIH-RD) with mortality records could incorporate a survivor comparison group, enabling a true cohort design capable of estimating individual-level risk and functional outcomes beyond mortality.

Conclusions

Stroke among young adults in Brazil was predominantly hemorrhagic, with hypertension as the main associated comorbidity and a stationary temporal trend between 2015 and 2024. The frequency of complications such as cerebral edema, sepsis, and respiratory failure suggests a potentially modifiable chain of clinical deterioration within the hospital setting. Sex-based differences in risk factors, with a stronger association between alcohol use and male deaths and a higher prevalence of obesity and diabetes among women, indicate the need for targeted preventive strategies. These findings reinforce the importance of early hypertension screening and improved hospital care to prevent complications and reduce premature stroke mortality in this population.

Additional Information

Author Contributions

All authors have reviewed the final version to be published and agreed to be accountable for all aspects of the work.

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Disclosures

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