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Original article

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Current trends in stroke events, mortality, and case fatality in Switzerland: an epidemiologic update

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Abstract

Background: Stroke is a major cardiovascular disease. The last epidemiologic update of stroke events, mortality, and case fatalities (CF) in Switzerland was performed in 2004. Between 2004 and 2017, traditional- and non-traditional cardiovascular risk factors changed, life expectancy increased, stroke units were implemented, and stroke treatment standardized. Therefore, we present an update of Swiss stroke epidemiology.

Methods: Data were obtained from two databases, the Federal Hospital Discharge Statistics (HOST, $n = 1\,470\,259$) and the Cause of Death (CoD) database ($n = 66\,971$), to analyze stroke diagnoses coded according to I60-I64 (ICD 10) in 2017 in Switzerland. Discharge- and event rates for stroke, in- and out-of-hospital CF, and mortality were calculated.

Results: In 2017, there were 26 032 stroke discharges in Switzerland (45% women) compared to 13 996 discharges in 2004. The age-standardized event rate per 100 000 increased in women/men from 119.7/178.7 in 2004 to 265.1/396.7 in 2017. However, the absolute number of stroke deaths decreased between 2004 and 2017 from 3569 (60% women) to 2816 (59% women). The overall sex-stratified mortality rate approximately halved between 2004 and 2017 in women (from 77.5 to 38.5/100 000) and men (from 56.1 to 27.2/100 000). The overall CF halved between 2004 and 2017 from 22.7% to 10.5% and was higher in women (13.4%) compared to men (8.0%).

Conclusions: Compared to 2004, the rates of stroke events and discharges have increased in Switzerland. However, the overall CF rate and overall sex-stratified mortality rate has approximately halved. This suggests, among other factors, increased recognition and better treatments for stroke.

Keywords: stroke; cerebrovascular disease; Switzerland; case fatality; mortality; epidemiology.

Key Messages

- This study aimed to unravel trends in stroke epidemiology in Switzerland between the last update (2004) and the following decade (until 2017) with implementation of nation-wide high-level stroke care, without other confounders such as the COVID-pandemic.
- The rates of diagnosed stroke events and discharges due to stroke have increased between 2004 and 2017; however, the overall case fatality and mortality has approximately halved, and the absolute number of deaths due to stroke outside of hospitals is now a third of what it was in 2004.
- This is a significant achievement supporting the established diagnostic and therapeutic approaches in Switzerland.

Background

Stroke is a significant contributor to death and disability [1,2]. In 2017, cardiovascular diseases were responsible for 31.4% of all deaths in Switzerland [1]. The latest epidemiological analysis of stroke data in Switzerland dates back to 2004 and was published in 2009 [3]. However, since 2004, life circumstances and stroke treatments have transformed in Switzerland and worldwide.

Between 2004 and 2017, life expectancy at birth increased from 83.7 to 85.4 years for women and from 78.6 to 81.4 years for men in Switzerland [4]. Some attempts to improve stroke prevention were very successful [5, 6]. However, during the same time period, the prevalence of traditional- and non-traditional cardiovascular risk factors (CVRF) changed, with a rise and higher exposure of non-traditional CVRF in women compared to men [6]. The overall increase

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in hypertension, obesity, hypercholesterolemia, and sleep disorders in Switzerland between 2007 and 2017 could have a direct impact on stroke incidence [6]. Another important aspect is the population's increased awareness of stroke symptoms and stroke knowledge [7, 8]. Based on other stroke prevention campaigns, we expect similar trends; however, data on stroke awareness in the Swiss population are not yet available [9, 10]. Furthermore, stroke units were established, and telestroke networks created, resulting in lower in-hospital, 30-day, and 1-year mortality rates in those treated at certified hospitals [11–13]. In Switzerland, most patients receive specialized care on stroke units or stroke centers, which are certified according to current European standards [14, 15]. Quality control mechanisms and their respective audits were implemented and the stroke treatment chain was standardized. This study aimed at unraveling trends in stroke epidemiology in Switzerland between 2004 and 2017, the period of implementation of nation-wide high-level stroke care, without other confounders such as the COVID-pandemic.

Methods

Data sources

We conducted a retrospective study using data from the Federal Statistical Office (FSO) in Switzerland. Two different databases were used for the period 1 January to 31 December 2017: (1) Federal Hospital Discharge Statistics database (HOST) and (2) Cause of Death (CoD) statistics [16, 17]. In 2017, all hospitalizations in Swiss hospitals were coded in the HOST database. Each entry in the database represents a single hospitalization, allowing for multiple entries from the same patient. The CoD was recorded in accordance with WHO guidelines in the CoD database [18]. The civil registry offices receive and record all data related to mortality. This information is then centrally coded in the FSO's CoD database. Linking both databases to determine stroke events is right now not possible due to Switzerland's data protection laws. The data were coded according to the International Classification of Disease, Version 10, revision 2016 (ICD-10) [18]. The discharge diagnoses (principal diagnosis or/and one of the second to fifth diagnosis position) included ICD-codes referring to an acute onset stroke like subarachnoid hemorrhage (I60), intracerebral hemorrhage (I61), other non-traumatic intracranial hemorrhage (I62), cerebral infarct (I63), and stroke non-specified as hemorrhage or infarct (I64). ICD-codes including entities with relation to strokes as an underlying etiology or result of strokes, but not acute stroke events per se, were excluded (I65-I69) [3, 19]. Since ischemic strokes and hemorrhagic strokes might have a different outcome, we performed a subanalysis comparing discharge- and mortality rates of ischemic strokes (I63) with hemorrhagic strokes (I60, I61, I62), referring to the analysis of Ananth *et al.* [20]. See the supplementary material for the detailed methodological approach.

Data preparation and calculations

To allow comparability, we used the same data preparation approach as Meyer *et al.* [3]. The different cases are shown in the supplementary material. The Swiss Census population dataset was re-stratified based on the age groups recommended by EUROCISS for both sexes [21]. Similarly, the European standard population dataset was also re-stratified to match the recommended age groups. The resulting datasets were normalized to a population of 100 000.

The following calculations were made and are detailed in the supplementary material: (1) age- and sex-specific discharge rates, (2) age- and sex-specific event rates of stroke, (3) age- and sex-specific mortality rates, (4) overall case fatality (CF), (5) in-hospital CF, (6) out-of-hospital CF, and (7) percentage of out-of-hospital deaths among total deaths.

The supplementary material includes additional formulas for standardized rates adjusted to the European standard population, overall and stratified by sex. Wilson 95% confidence intervals based on the Poisson distribution were used for rates, and 95% Clopper–Pearson confidence intervals for a proportion based on the binomial distribution were used for the CF [22, 23]. The use of Clopper–Pearson confidence intervals is generally regarded as more conservative but ensures that the nominal coverage probability is at least 0.95 [24]. We did not use *P*-values for comparing findings at different times, as we were not testing hypotheses, but rather focused on describing stroke cases and trends [3]. The analyses were conducted using the R programming language [25]. Analysis-specific packages can be found in the supplementary material.

Results

Absolute numbers of hospital discharges and deaths from stroke (HOST + CoD)

Switzerland registered a total of 1 470 259 hospitalizations. According to the HOST database, there were 26 032 total stroke discharges, with 11 744 (45%) women and 14 288 (55%) men (Fig. 1). Totally, 5890 patients with the diagnosis stroke were discharged two or more times (44% women, 56% men). The CoD database reported 2816 deaths due to stroke, 1660 (59%) of them women and 1156 (41%) men.

Hospital discharge rate from stroke (HOST)

For both sexes, hospital discharge rates increased with age (Table 1). Between 15 and 34 years of age, women had minimally higher rates of hospital discharge due to stroke compared to men, but between 35 and 85+ years, men had higher stroke discharge rates (Fig. 2). Overall, the age-standardized discharge rate was 315.0/100 000 (men: 389.6/100 000, 95% CI 353.2–430.7; women: 253.7/100 000, 95% CI 224.6–287.2).

Estimated stroke events and stroke event rate (HOST + CoD)

The overall number of estimated stroke events, adjusted to the Swiss Census population, was 26 879, with 12 393 (46%) occurring in women and 14 486 (54%) in men. The overall sex-stratified event rate was 314.0/100 000 (287.8/100 000 in women and 340.5/100 000 in men), with the event rate increasing with age. Women aged 15–34 had a slightly higher event rate compared to men, while men aged 35–85+ had a notably higher event rate compared to women (Supplementary Table S1). The age-standardized event rate was 325.0/100 000 (women: 265.1/100 000, 95% CI 235–298.9; men: 396.7/100 000, 95% CI 359.8–438.0).

Stroke mortality rate (CoD)

Mortality increased exponentially in both groups with age and was always higher in men aged 35–84 compared to

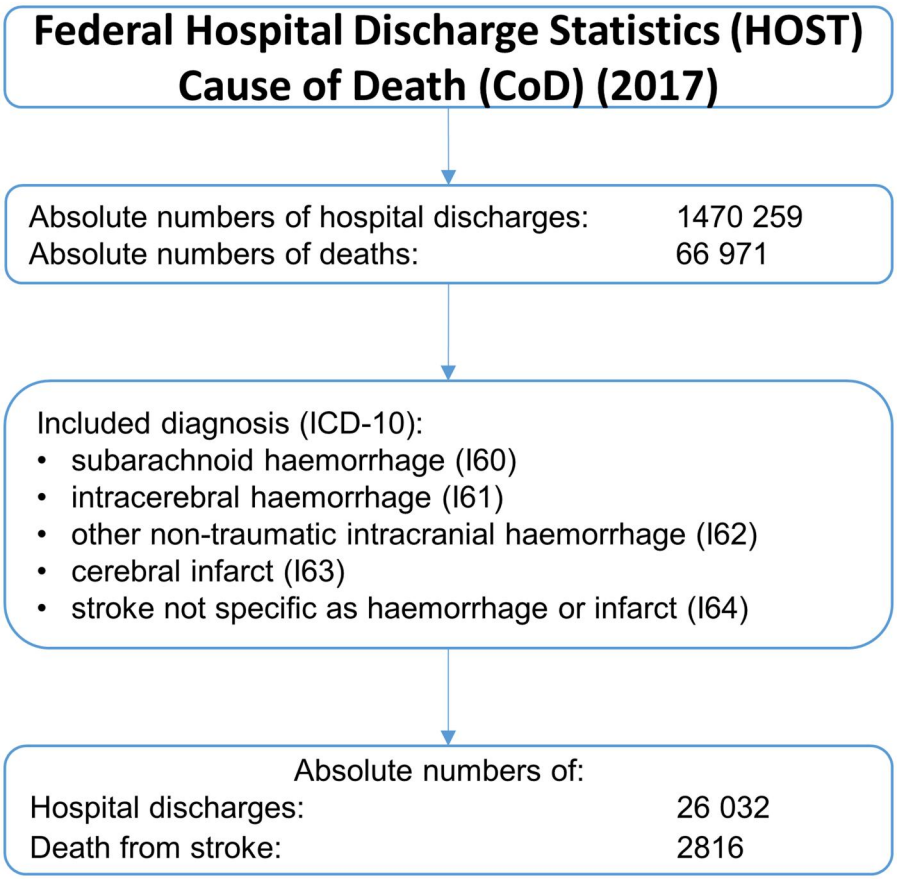

Figure 1. Flowchart of inclusion criteria and patient selection (Switzerland, 2017). ICD10: International Statistical Classification of Diseases and Related Health Problems, 10th Revision.

Table 1. Age- and sex-specific absolute number of stroke discharges and discharge rates per 100 000 population in 2017

	Women				Men			
Age groups (yr)	No. of cases	Population	Rate	95% CI	No. of cases	Population	Rate	95% CI
<5	15	212 201	7.1	4.3–11.7	24	224 251	10.7	7.2–15.9
5–14	11	407 737	2.7	1.5–4.8	19	430 248	4.4	2.8–6.9
15–24	74	452 981	16.3	13–20.5	50	482 720	10.4	7.9–13.7
25–34	161	589 331	27.3	23.4–31.9	156	608 235	25.6	21.9–30
35–44	286	590 881	48.4	43.1–54.3	400	606 692	65.9	59.8–72.7
45–54	747	649 861	114.9	107–123.5	1231	666 860	184.6	174.6–195.2
55–64	1213	541 522	224.0	211.7–237	2410	545 684	441.6	424.4–459.6
65–74	2330	428 534	543.7	522.1–566.2	3528	393 770	896.0	866.9–926
75–84	3881	288 463	1345.4	1303.7–1388.4	4346	223 016	1948.7	1891.7–2007.5
85+	3026	144 594	2092.8	2019.5–2168.7	2124	72 570	2926.8	2805–3054
All	11 744	4 306 105	272.7	267.8–277.7	14 288	4 254 046	335.9	330.4–341.4
ASR			253.7	224.6–287.2			389.6	353.2–430.7

All: overall sex-stratified rates; ASR: age-standardized rates adjusted-the European standard population; CI: confidence interval; yr: years.

women (Fig. 3). However, women older than 85 years had a higher mortality rate (715.8/100 000) compared to men (661.4/100 000) (Table 2). The overall sex stratified mortality rate was different in women (38.5/100 000, 95% CI 36.7–40.4) compared with men (27.2/100 000, 95% CI 25.7–28.8). The overall age-standardized mortality rate was 33.7/100 000 (32.2/100 000 in women, 35.1/100 000 in men).

CF from stroke (HOST + CoD)

The overall CF from stroke was 10.5% (women: 13.4%, CI 12.8–14.0 and men: 8.0%, CI 7.5–8.4) (Table 3). Women also had higher in-hospital CF than men (8.2%, 95% CI 7.7–8.7 vs. 6.6%, 95% CI 6.2–7.1) (Fig. 4). The out-of-hospital CF was lower in both sexes (3.2%, CI 2.9–3.4) compared to 2004 (11.0%, CI 10.5–11.6), and higher in women (5.2%, CI 4.9–5.6) than in men (1.4%, CI 1.2–1.6).

Percentage of out-of-hospital death from stroke (HOST + CoD)

Out of the total deaths from stroke, 30.1% occurred outside the hospital, with 847 patients passing away (77% women

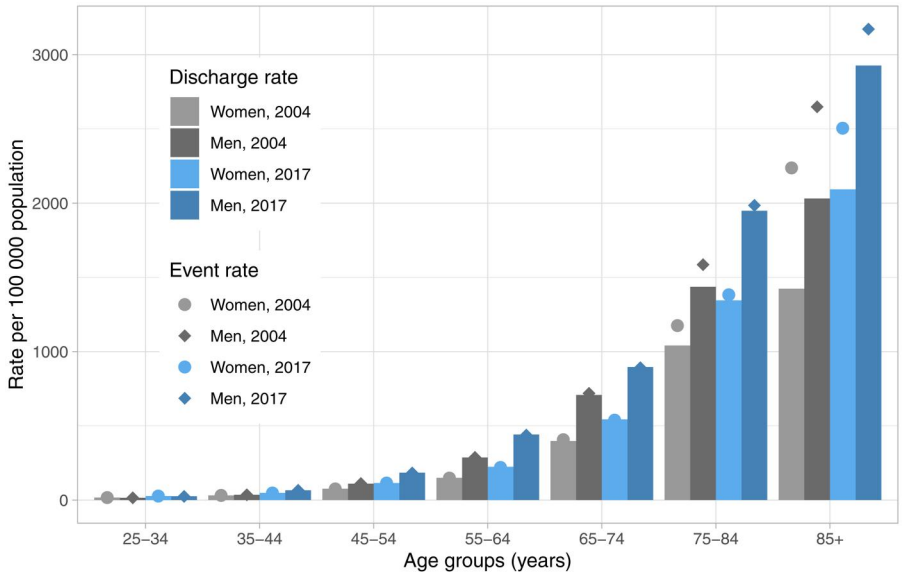

Figure 2. Age- and sex-specific hospital discharge rates and event rates from stroke per 100 000 population (Switzerland, 2017). The graph shows the age-specific discharge rates and event rates for women and men in 2004 (gray) and 2017 (blue). The age-specific event rates are presented as dots for 2004 (gray) and 2017 (blue).

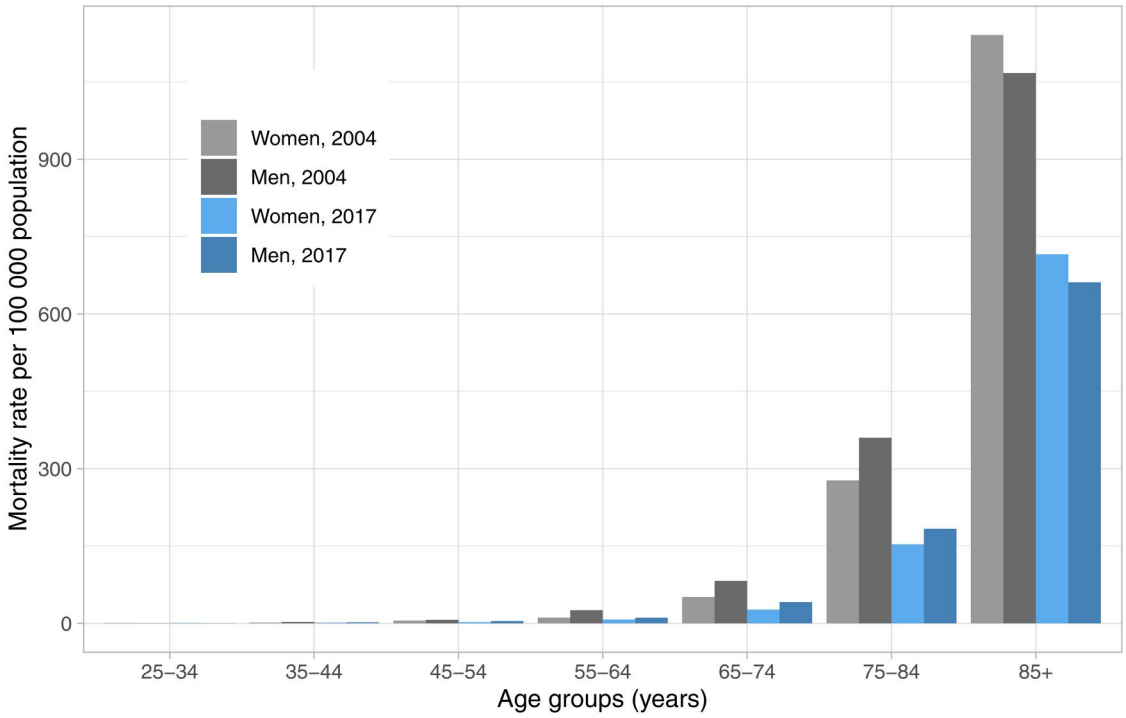

Figure 3. Sex-stratified mortality rates from stroke per 100 000 population (Switzerland, 2017). The graph depicts sex-stratified mortality rates from stroke in 2017 (blue) in comparison to 2004 (gray) for women and men.

and 23% men). The remaining 1969 patients (51% women and 49% men) died inside the hospital.

Conclusions

Our epidemiological update on stroke has revealed the following key findings:

1) The overall number of diagnosed stroke events in Switzerland increased by +71% from 15 733 to 26 879 cases (46% women) since 2004.
2) There were 26 032 stroke discharges in Switzerland (45% women, 55% men) in 2017. This is a +86% increase compared to 2004 (13 996 discharges).
3) The absolute number of stroke deaths (2816 deaths, 59% women) decreased by approximately −21% compared to 2004 (3568 deaths).
4) The overall sex-stratified mortality rate approximately halved in women (from 77.5 to 38.5/100 000) and men (from 56.1 to 27.2/100 000) between 2004 and 2017 and was higher in men compared to women in the age group 35-84, but higher in women from 85 years onward.

Table 2. Age- and sex-specific absolute number of deaths due to stroke, and stroke mortality rates per 100 000 population in 2017

	Women				Men			
Age groups (yr)	No. of deaths	Population	Rate	95% CI	No. of deaths	Population	Rate	95% CI
<5	1	212 201	0.5	0.1–2.7	1	224 251	0.4	0.1–2.5
5–14	0	407 737	0.0	0–0.9	0	430 248	0.0	0–0.9
15–24	1	452 981	0.2	0–1.3	1	482 720	0.2	0–1.2
25–34	4	589 331	0.7	0.3–1.7	1	608 235	0.2	0–0.9
35–44	8	590 881	1.4	0.7–2.7	12	606 692	2.0	1.1–3.5
45–54	15	649 861	2.3	1.4–3.8	30	666 860	4.5	3.2–6.4
55–64	40	541 522	7.4	5.4–10.1	60	545 684	11.0	8.5–14.2
65–74	114	428 534	26.6	22.1–32	162	393 770	41.1	35.3–48
75–84	442	288 463	153.2	139.6–168.2	409	223 016	183.4	166.5–202.1
85+	1035	144 594	715.8	673.5–760.8	480	72 570	661.4	604.8–723.3
All	1660	4 306 105	38.5	36.7–40.4	1156	4 254 046	27.2	25.7–28.8
ASR			32.2	22.7–45.2			35.1	25.2–48.7

All: overall sex-stratified rates; ASR: age-standardized rates adjusted-the European standard population; CI: confidence interval; yr: years.

Table 3. Overall case fatality, in-hospital case fatality, and out-of-hospital case fatality in 2017

	Women		Men		Total	
		95% CI		95% CI		95% CI
Overall CF (%)	13.4	12.8–14	8.0	7.5–8.4	10.5	10.1–10.8
In-hospital CF (%)	8.2	7.7–8.7	6.6	6.2–7	7.3	7–7.6
Out-of-hospital CF (%)	5.2	4.9–5.6	1.4	1.2–1.6	3.2	2.9–3.4

CF: case fatality; CI: confidence interval.

5) The overall CF halved from 22.7% (2004) to 10.5% (2017) and was higher in women (13.4%, CI 12.8–14.0) compared to men (8.0%, CI 7.5-8.4).
6) The out-of-hospital deaths due to stroke accounted for 30.1% of all deaths (77% women, 23% men) in 2017 and was lower than in 2004 (48.7%).

Hospital discharge rates and event rates suggest more stroke diagnoses in 2017

Unfortunately, using the HOST and CoD databases, which does not differentiate between first-ever and recurrent stroke events, it is impossible to derive the true incidence rates of stroke events in Switzerland and compare them with other countries. The higher event and hospital discharge rates for stroke in Switzerland 2017 compared to 2004 could reflect a true increase in stroke incidence. In line with this, the overall increase in hypertension, obesity, hypercholesterolemia, and sleep disorders in Switzerland between 2007 and 2017 may support these findings [6]. However, the higher number of hospital discharges with a diagnosis of "stroke" is more likely due to the systemic assessment of diagnoses after implementation of the Diagnosis-Related Groups system (DRG-system) as a reimbursement tool in Switzerland in 2012. Similar effects on the number of patients discharged with the diagnosis "stroke" were seen in the USA and in Poland after the introduction of the DRG-system [26, 27]. It is likely that the introduction of DRGs led to a shift toward more accurate and specific discharge coding [28, 29]. Besides, better awareness of stroke symptoms and improved availability of diagnostics tools and treatments are likely adding to the increased hospital discharge rates of patients with a stroke diagnosis [5, 7, 8, 11–13, 30–32]. Minor additional contributors between 2005 and 2017 could be the overall increase in population from 7.46 to 8.48 million people, a higher median age (42.45 vs 40.10 years), and the rise in the percentage of non-Swiss citizens from 20.7% to 25.1%, including a higher percentage of different ethnicities [33, 34]. The Global Burden of Disease (GBD)-Study reported similar results with a 70% increase in the absolute number of strokes between 1990 and 2019 [35]. However, the GBD-Study also found a 17% reduction in the age-standardized incidence rate of stroke. This goes in line with The Greater Cincinnati/Northern Kentucky Stroke Study (GCNKSS), which reported a decrease in overall stroke incidence for both sexes from the early 1990s to 2015 [36]. Stroke databases in Europe such as the Swedish Stroke Registry found a reduction in all ischemic strokes from 290/100 000 in 2010 to 228/100 000 in 2019 [37]. Therefore, our data from Switzerland are in line with global and European trends regarding better recognition and diagnosis of stroke, reflected in an increased count of absolute stroke event rates.

Mortality rate and CFs from stroke decreased

It is a positive development that the absolute number of stroke deaths in 2017 ($n=2816$) was approximately 21% lower than in 2004 ($n=3568$). Between 2004 and 2017, the sex-stratified mortality rate decreased from 77.5 to 38.5/100 000 for women and from 56.1 to 27.2/100 000 for men. Improved stroke prevention and awareness of stroke symptoms, as well as better treatment options, may play a key role in lower number of stroke deaths and lower mortality rates in 2017 [5–8, 30–32]. Others like the GBD-Study 2020 (data from 2010 to 2020) and data from the USA (from 2000 to 2015) also reported a decrease in the age-standardized mortality rate [38, 39]. Unfortunately, a comparison of trends in the mortality rates between ischemic vs. hemorrhagic strokes from 2004 to 2017 cannot be made from our subanalysis, due to the lack of the original 2004 data. Others have shown a trend toward a steeper decline in the mortality rate for ischemic compared to hemorrhagic strokes between 1975 and 2019 in the USA of people aged 18–84 years [20]. However, more men died due to hemorrhagic strokes compared to ischemic strokes in Switzerland (supplementary material, results). These results indicate that special emphasis should be placed on patients with hemorrhagic stroke in order to reduce the absolute number of deaths and improve outcome. For all stroke deaths combined, our study found that the proportion of women dying was 44% higher than in men. These data are supported by numbers from the USA, where about 41% more women ($n=81\ 617$) died from stroke in 2015

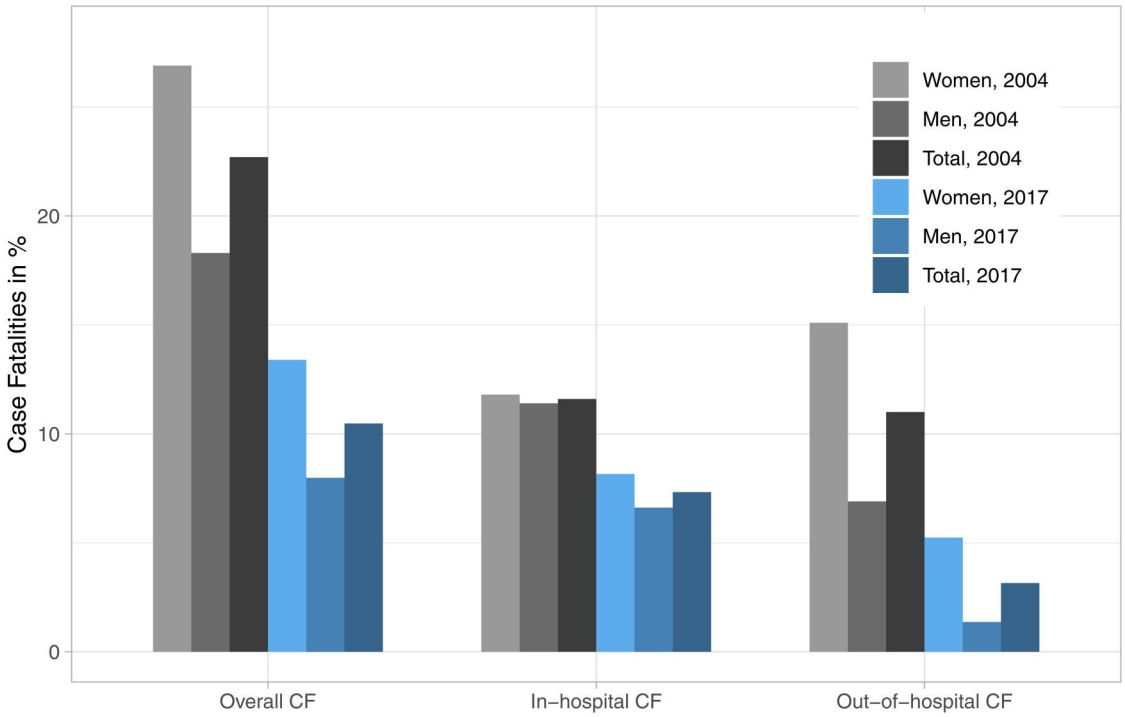

Figure 4. Case fatalities from stroke across both sexes (Switzerland, 2017). The graph shows the overall, in-hospital, and out-of-hospital case fatalities from stroke in 2017 (blue) compared to 2004 (gray), with percentages for women and men.

compared to men ($n = 57\ 750$) [40]. The higher mortality rate of female stroke patients, especially those aged 85 years or older, is likely due to their older age at stroke onset, higher stroke severity, poorer pre-stroke function, and higher prevalence of comorbidities, such as atrial fibrillation [41–43]. In addition, more women died due to stroke after age 85 (1035 women vs. 480 men) and more men died before age 85 (676 men vs. 625 women), leading to a higher mortality rate at age 85 or older in women. Between 2004 and 2017, however, there was a distinct decrease in the overall CF for both women and men. The CF percentage of women decreased from 26.9% to 13.4% (95% CI 12.8–14), while the percentage of men decreased from 18.3% to 7.5% (95% CI 7.5–8.4). The out-of-hospital CF was strikingly lower in 2017, decreasing from 11.0% in 2004 to 3.2%. The difference between 2004 and 2017 may be because the total proportion of people dying due to stroke decreased by approximately −21%, and the fraction of in-hospital survivors and stroke discharges increased about +86%. In line with our results, the CF in the GCNKSS data declined from 1993/1994 to 2015, with women showing a higher CF (12.8%, 95% CI 10.5–15.6) than men (9.2%, 95% CI 7.3–11.6) [36]. In 2004, 48.7% of all stroke-related deaths occurred outside of the hospital, while in 2017, this figure decreased to 30.1%. Here, too, women died 3.3 times more often outside the hospital compared to men. Nonetheless, it is important to appreciate the notable reduction in out-of-hospital deaths over this time in Switzerland.

Strengths and limitations

The study's strength lies in the annual collection of data using the same, standardized methodology since the early 1990s, ensuring optimal reproducibility of the data. Another strength of this study is the same data preparation approach as Meyer *et al.* [3], allowing for direct comparability of results from 2004 to 2017. However, the lack of linkage between the HOST and CoD databases is a major limitation. Consequently, it is not possible to calculate incidence rates of first stroke or to distinguish between first stroke and recurrent stroke. A further limitation is that because we included the principal diagnosis and/or second to fifth diagnosis position for stroke, we cannot differentiate, whether the patient died because of stroke (principal diagnosis) or died with stroke (another principal diagnosis and stroke as second to fifth diagnosis position). Therefore, we expect a slight overestimation of total CF and the in-hospital CF, as the number of in-hospital survivors is likely to be too small and the number of in-hospital deaths is likely to be too large. Another minor limitation is that only the first six diagnoses were included, which may result in a potential lack of detection of stroke cases. However, our experience shows that a new stroke diagnosis on the sixth or higher position is quite very rare. The exclusion of the ICD-codes I65-69 could lead to an underestimation of stroke rates. Since these diagnosis codes focus on non-acute conditions with relation to stroke, but not to acute stroke events, we believe that bias due to this limitation is rather small. There are no validation studies for the correctness of diagnoses in Switzerland. However, each diagnosis in Switzerland is not only generated by the physician, but also controlled by the medical encoding department in each hospital due to high cost pressure to ensure the correct diagnosis. Similarly, excluding ICD-codes I65-69 provides the best comparability with previous data in Switzerland. However, comparisons with other studies that used a different definition (including I65-I69) should be made with caution. When describing the results regarding sex differences, it is important to remember that our study reports a 1-year observation, and therefore, small differences, such as discharge and event rates in young groups, must be interpreted with caution. To ensure

the best comparability with Meyer *et al*. [3], we also excluded transient ischemic attacks with the diagnosis code G45.

Conclusion

The data presented here offer new insights into current trends in stroke epidemiology in Switzerland. The rates of stroke events and discharges have increased compared to 2004, most likely reflecting increased awareness of stroke symptoms among the population and improved, more accessible medical infrastructures. At the same time, the overall CF and mortality has approximately halved, and the absolute number of deaths due to stroke outside of hospitals is now a third of what it was in 2004. This is a significant achievement for the established diagnostic and therapeutic approaches in Switzerland. Based on similar findings in other countries, stroke clinicians, researchers, and partner disciplines are on the right track to reduce stroke mortality and CF as one of the leading causes of death in industrial countries [36–38]. Further investigation into the optimization and homogenization of stroke data, particularly in linking the HOST and CoD databases to calculate stroke incidence in Switzerland, is recommended.

Ethics approval

The clarification of responsibility was made by the Kantonale Ethikkommission (BASEC-Nr. Req-2021-01214). The research project does not fall within the scope of the Human Research Act (HRA). Therefore, an authorization from the ethics committee was not required. This study was completed in accordance with the Helsinki Declaration as revised in 2013.

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Author contributions

M.H.: researched literature, conception and design of the study, acquisition and interpretation of data, writing of first manuscript, approval of the version to be published. E.M.: analysis of data, interpretation of data, approval of the version to be published. C.M.: analysis of data, interpretation of data, approval of the version to be published. A.R.L.: critical revision of manuscript for intellectual content, approval of the version to be published. K.N.: critical revision of manuscript for intellectual content, approval of the version to be published. M.A.: critical revision of manuscript for intellectual content, approval of the version to be published. S.W.: conception and design of the study, interpretation of data, drafting significant portion of manuscript, study supervision, critical revision of manuscript for intellectual content, approval of the version to be published. All authors reviewed and edited the manuscript and approved the final version of the manuscript.

Supplementary data

Supplementary data is available at *IJE* online.

Conflict of interest: None declared.

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Data availability

The data underlying this article were provided by the Swiss Federal Office of Statistics (FSO) by permission. Data will be shared on request to the corresponding author with permission of the Swiss Federal Office of Statistics (FSO). Open access is not permitted.

Use of artificial intelligence (AI) tools

AI tools were not used in this study or writing the paper.

References

1. Swiss Federal Office of Statistics. Todesursachenstatistik 2017. https://www.bfs.admin.ch/bfs/de/home/statistiken/kataloge-datenbanken/medienmitteilungen.assetdetail.11227248.html. 2017. Date accessed 01 February 2024.
2. Roth GA, Mensah GA, Johnson CO *et al.*; GBD-NHLBI-JACC Global Burden of Cardiovascular Diseases Writing Group. Global burden of cardiovascular diseases and risk factors, 1990-2019: update from the GBD 2019 study. *J Am Coll Cardiol* 2020;**76**:2982–3021. https://doi.org/10.1016/j.jacc.2020.11.010
3. Meyer K, Simmet A, Arnold M, Mattle H, Nedeltchev K. Stroke events, and case fatalities in Switzerland based on hospital statistics and cause of death statistics. *Swiss Med Wkly* 2009;**139**:65–9. https://doi.org/10.4414/smw.2009.12448
4. Swiss Federal Office of Statistics. Lebenserwartung in der Schweiz 2017. https://www.bfs.admin.ch/bfs/de/home/statistiken/bevoelkerung/geburten-todesfaelle/lebenserwartung.html. 2017. Date accessed 01 February 2024.
5. Dawson J, Béjot Y, Christensen LM *et al.* European Stroke Organisation (ESO) guideline on pharmacological interventions for long-term secondary prevention after ischaemic stroke or transient ischaemic attack. *Eur Stroke J* 2022;**7**:I–II. https://doi.org/10.1177/23969873221100032
6. Hänsel M, Steigmiller K, Luft AR, Gebhard C, Held U, Wegener S. Neurovascular disease in Switzerland: 10-year trends show non-traditional risk factors on the rise and higher exposure in women. *Eur J Neurol* 2022;**29**:2851–60. https://doi.org/10.1111/ene.15434
7. Patel A, Fang J, Gillespie C *et al.* Awareness of stroke signs and symptoms and calling 9-1-1 among US adults: national health interview survey, 2009 and 2014. *Prev Chronic Dis* 2019;**16**:E78. https://doi.org/10.5888/pcd16.180564
8. Visaria A, Dharamdasani T, Gaur S *et al.* Effectiveness of a cultural stroke prevention program in the United States-South Asian Health Awareness About Stroke (SAHAS). *J Immigr Minor Health* 2021;**23**:747–54. https://doi.org/10.1007/s10903-020-01071-w
9. Gallino A. A Swiss national strategy for 2017-2024. *Eur Heart J* 2017;**38**:3117–8. https://doi.org/10.1093/eurheartj/ehx602
10. Bassetti CLA, Endres M, Sander A *et al.* The European Academy of Neurology brain health strategy: one brain, one life, one approach. *Eur J Neurol* 2022;**29**:2559–66. https://doi.org/10.1111/ene.15391
11. Man S, Schold JD, Uchino K. Impact of stroke center certification on mortality after ischemic stroke: the Medicare cohort from 2009 to 2013. *Stroke* 2017;**48**:2527–33. https://doi.org/10.1161/STROKEAHA.116.016473
12. Sood R, Annoni JM, Humm AM *et al.* Distance neurological supervision using telestroke does not increase door-to-needle time in

acute ischemic stroke management: the experience of two regional stroke units. *Front Neurol* 2021;**12**:616620.
13. Fladt J, Engelter S, De Marchis GM *et al.* Stroke unit-/stroke center-management [stroke unit-/stroke center care]. *Ther Umsch* 2021;**78**:328–38. https://doi.org/10.1024/0040-5930/a001277
14. Walter S, Audebert HJ, Katsanos AH *et al.* European Stroke Organisation (ESO) guidelines on mobile stroke units for prehospital stroke management. *Eur Stroke J* 2022;**7**:XXVII-LIX. https://doi.org/10.1177/23969873221079413
15. Mead GE, Sposato LA, Sampaio Silva G *et al.* A systematic review and synthesis of global stroke guidelines on behalf of the World Stroke Organization. *Int J Stroke* 2023;**18**:499–531. https://doi.org/10.1177/17474930231156753
16. Swiss Federal Office of Statistics. Medizinische Statistik der Krankenhäuser. https://www.bfs.admin.ch/bfs/de/home/statistiken/gesundheit/erhebungen/ms.html. 2017. Date accessed 01 February 2024.
17. Swiss Federal Office of Statistics. Sterbeziffern für 30 wichtige Todesursachen nach Geschlecht. https://www.bfs.admin.ch/bfs/de/home/statistiken/kataloge-datenbanken/medienmitteilungen.assetdetail.11348828.html. 2017. Date accessed 01 February 2024.
18. WHO: International Statistical Classification of Disease and Related health Problems, 10th Revision, ICD 10. Geneva, 1994. https://icd.who.int/browse10/2016/en. 2017. Date accessed 01 February 2024.
19. Canadian Institute for Health Information. *Strokes [Job Aid]*. Ottawa, ON: CIHI, 2022.
20. Ananth CV, Brandt JS, Keyes KM, Graham HL, Kostis JB, Kostis WJ. Epidemiology and trends in stroke mortality in the USA, 1975-2019. *Int J Epidemiol* 2023;**52**:858–66. https://doi.org/10.1093/ije/dyac210
21. Steinbach K, Smet P, Holub J, Madsen M. Eurociss cardiovascular indicators surveillance set. Tech. rep., EUROCISS project. 2006. https://www.cuore.iss.it/eurociss/en/rapporto03/EUROCISS%20FINAL%20updated%20_2_.pdf. 2006. Date accessed 01 February 2024.
22. Held L, Rufibach K, Seifert B. *Medizinische Statistik: Konzepte, Methoden Anwendungen*. Pearson Deutschland, Munich, Germany, 2013. https://elibrary.pearson.de/book/99.150005/9783863267018. 2013. Date accessed 01 February 2024.
23. Clopper CJ, Pearson ES. The use of confidence or fiducial limits illustrated in the case of the binomial. *Biometrika* 1934;**26**:404–13.
24. Brown LD, Cai TT, DasGupta A. Interval estimation for a binomial proportion. *Statist Sci* 2001;**16**:101–33. https://doi.org/10.1214/ss/1009213286
25. R Core Team. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria, 2020. http://www.R-project.org/. 2024. Date accessed 01 February 2024.
26. Rosko MD, Broyles RW. Short-term responses of hospitals to the DRG prospective pricing mechanism in New Jersey. *Med Care* 1987;**25**:88–99. https://doi.org/10.1097/00005650-198702000-00002
27. Bystrov V, Staszewska-Bystrova A, Rutkowski D, Hermanowski T. Effects of DRG-based hospital payment in Poland on treatment of patients with stroke. *Health Policy* 2015;**119**:1119–25. https://doi.org/10.1016/j.healthpol.2015.04.017
28. Assaf AR, Lapane KL, McKenney JL, Carleton RA. Possible influence of the prospective payment system on the assignment of discharge diagnoses for coronary heart disease. *N Engl J Med* 1993;**329**:931–5. https://doi.org/10.1056/NEJM199309233291307
29. Cohen BB, Pokras R, Meads MS, Krushat WM. How will diagnosis-related groups affect epidemiologic research? *Am J Epidemiol* 1987;**126**:1–9. https://doi.org/10.1093/oxfordjournals.aje.a114639
30. Strbian D, Michel P, Ringleb P *et al.* Relationship between onset-to-door time and door-to-thrombolysis time: a pooled analysis of 10 dedicated stroke centers. *Stroke* 2013;**44**:2808–13. https://doi.org/10.1161/STROKEAHA.113.000995
31. Altersberger VL, Wright PR, Schaedelin SA *et al.* Effect of admission time on provision of acute stroke treatment at stroke units and stroke centers-an analysis of the Swiss Stroke Registry. *Eur Stroke J* 2022;**7**:117–25. https://doi.org/10.1177/23969873221094408
32. Sarraj A, Hassan AE, Abraham MG *et al.*; SELECT2 Investigators. Trial of endovascular thrombectomy for large ischemic strokes. *N Engl J Med* 2023;**388**:1259–71. https://doi.org/10.1056/NEJMoa2214403
33. Swiss Federal Office of Statistics. Bevölkerungswachstum und -bestand. https://www.bfs.admin.ch/bfs/de/home/statistiken/bevoelkerung.assetdetail.26905445.html. 2017. Date accessed 01 February 2024.
34. Swiss Federal Office of Statistics. Anteil der ständigen ausländischen Wohnbevölkerung. https://www.bfs.admin.ch/bfs/de/home/statistiken/bevoelkerung/migration-integration/auslaendische-bevoelkerung/zusammensetzung.assetdetail.26905434.html. 2017. Date accessed 01 February 2024.
35. Feigin VL, Nguyen G, Cercy K *et al.*; GBD 2016 Lifetime Risk of Stroke Collaborators. Global, regional, and country-specific lifetime risks of stroke, 1990 and 2016. *N Engl J Med* 2018;**379**:2429–37. https://doi.org/10.1056/NEJMoa1804492
36. Madsen TE, Khoury JC, Leppert M *et al.* Temporal trends in stroke incidence over time by sex and age in the GCNKSS. *Stroke* 2020;**51**:1070–6. https://doi.org/10.1161/STROKEAHA.120.028910
37. Drescher C, Buchwald F, Ullberg T, Pihlsgård M, Norrving B, Petersson J. Epidemiology of first and recurrent ischemic stroke in Sweden 2010-2019: a Riksstroke study. *Neuroepidemiology* 2022;**56**:433–42. https://doi.org/10.1159/000527373
38. Yafasova A, Fosbøl EL, Christiansen MN *et al.* Time trends in incidence, comorbidity, and mortality of ischemic stroke in Denmark (1996-2016). *Neurology* 2020;**95**:e2343–53. https://doi.org/10.1212/WNL.0000000000010647
39. Tsao CW, Aday AW, Almarzooq ZI *et al.* American Heart Association Council on Epidemiology and Prevention Statistics Committee and Stroke Statistics Subcommittee. Heart disease and stroke statistics-2023 update: a report from the American Heart Association. *Circulation* 2023;**147**:e93–621. https://doi.org/10.1161/CIR.0000000000001123
40. Yang Q, Tong X, Schieb L *et al.* Vital signs: recent trends in stroke death rates—United States, 2000-2015. *MMWR Morb Mortal Wkly Rep* 2017;**66**:933–9. https://doi.org/10.15585/mmwr.mm6635e1
41. Abdel-Fattah AR, Pana TA, Smith TO *et al.* Gender differences in mortality of hospitalised stroke patients. Systematic review and meta-analysis. *Clin Neurol Neurosurg* 2022;**220**:107359. https://doi.org/10.1016/j.clineuro.2022.107359
42. Phan HT, Blizzard CL, Reeves MJ *et al.* Sex differences in long-term mortality after stroke in the INSTRUCT (INternational STRoke oUtComes sTudy): a meta-analysis of individual participant data. *Circ Cardiovasc Qual Outcomes* 2017;**10**:e003436. https://doi.org/10.1161/CIRCOUTCOMES.116.003436
43. Westphal LP, Rüttener L, Gasser T *et al.* Sex differences in the pre- and in-hospital setting of patients with stroke are driven by higher age and stroke severity. *Stroke* 2025;**56**:256–64. https://doi.org/10.1161/STROKEAHA.124.048303

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