

# Long-Term Trends in the Stroke Prognosis Among Rural Residents in China: A Population-Based Surveillance Study

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**Objective:** Although stroke mortality has remained stable over the past decade, the long-term trends of stroke burden are scarce in China, especially in low-income populations. Thus, we aimed to explore the secular trends in the prognosis of stroke in a low-income population in China.

**Methods:** This was a population-based stroke surveillance study that included all of the participants in the Tianjin Brain Study. Stroke management and outcomes were evaluated for all stroke patients. Trends in the burden of stroke were assessed as annual percentage changes.

**Results:** Overall, 1462 stroke cases occurred from 1992 to 2018, and 58.7% of patients were male. The rates of diagnosis by neuroimaging and of hospitalization increased noticeably across sexes and ages for all stroke types, and the greatest increases were observed among elderly women; diagnosis by neuroimaging increased by 4.7% and the rate of hospitalization increased by 12.4% (all  $P < 0.001$ ). Stroke fatality decreased by 3.7% annually among those aged <65 years and by 3.1% among patients aged  $\geq 65$  years; the corresponding rates were 7.4% and 3.5%, respectively, for women. The recurrence rate of ischemic stroke significantly decreased among all men, by 9.6% for those aged <65 years and by 3.1% for those aged  $\geq 65$  years; however, for women, this rate only significantly decreased for those aged  $\geq 65$  years.

**Conclusion:** Our findings suggest that the allocation of medical resources has improved over the past decades. However, it is crucial to enhance secondary stroke prevention for women aged <65 years by controlling risk factors in low-income populations.

**Keywords:** stroke burden, case fatality, recurrence, trends, low-income population

## Introduction

Stroke is the leading cause of death worldwide and has the highest disability-adjusted life-years lost of any disease; over 2 million new cases are diagnosed annually in China.<sup>1-4</sup> A global study pointed out that from 1990 to 2016, East Asia, especially China, had the highest age-standardized incidence of stroke at 354 per 100,000 person-years, followed by Eastern Europe, with an incidence of 181–218 per 100,000 person-years. The lowest incidence is in central Latin America, 97 per 100,000 person-years.<sup>5</sup> Previous studies have shown that, while stroke prevalence and incidence have increased markedly, mortality has remained stable over the past decade.<sup>6-8</sup> The National Epidemiological Survey of Stroke in China, which studied 480,687 individuals aged 20 years and older from 31 provinces between 2012 and 2013, reported an age-standardized stroke mortality of 115 cases per 100 000.<sup>7</sup>



Nevertheless, stroke care and in-hospital outcomes have substantially improved following the reform of the national healthcare system in China.<sup>7</sup> The most noticeable progress has been in the secondary prevention of stroke. The rates of recurrence within 1 year and case fatality both noticeably decreased from 2007 to 2012, from 17.7% to 6.7% for recurrence and from 14.3% to 8.5% for case fatality.<sup>9–11</sup> The Chinese government conducted a series of large-scale regional and national studies to evaluate the efficiency of secondary stroke prevention.<sup>12–14</sup> However, long-term trends in stroke burden, as defined by stroke management and outcomes, remain scarce in China, notably among low-income populations.

Thus, we aimed to explore the secular trends in the prognosis of stroke in a low-income population in China from 1992 to 2018.

## Methods

### Tianjin Brain Study

The Tianjin Brain Study (TBS) is a population-based stroke surveillance study that has been ongoing in a township in Tianjin, China since 1985. Data collection for the TBS has been described in detail elsewhere.<sup>15–18</sup> All participants in the TBS lived in the Yangjinzhuang township of Ji county in Tianjin, China. From 1992 to 1998, the permanent population of the area remained stable, between 14,583–14,936. All stroke events and all-cause deaths were registered in real time, and the demographic changes were recorded annually.

The study protocol was approved by the ethics committee of Tianjin Medical University General Hospital (TMUGH), and written informed consent was obtained from each participant (contract number: IRB2018-099-01).

### Study Population and Design

The current study was a population-based stroke surveillance study that included all of the participants in the TBS. Briefly, the study participants resided in 18 administrative villages in Yangjinzhuang, a township in Tianjin; 95% of the residents were low-income farmers. The primary source of income was grain production, and the annual per capita income was <100 USD in 1991 and <1000 USD in 2010.<sup>19</sup>

### Definition of Stroke Type

First-ever strokes were defined as the first occurrences (ie, there was no history of stroke in the patient's medical

records) of rapidly developing signs of focal neurologic disturbances of presumed vascular etiology lasting >24 hours.<sup>20</sup> Stroke events included the ischemic and hemorrhagic stroke subtypes. In this study, we analyzed management and outcomes according to stroke type (ischemic stroke (IS) and intracerebral hemorrhage (ICH)). Transient ischemic attacks and subarachnoid hemorrhages were excluded from this study.

During the early phase of this study (1992–1998), strokes were confirmed mainly on the basis of clinical examinations by senior neurologists for non-hospitalized patients and using medical records for hospitalized patients.

### Procedures for Ascertaining Stroke Events

The procedures for ascertaining stroke events have been described previously.<sup>15</sup> Briefly, stroke events were reported using predefined procedures. First, local village physicians reported initial stroke events to the community hospital within 24 h of stroke onset. Then, community hospital physicians visited the patients' homes to obtain clinical information and perform the initial diagnosis, which included taking histories of previous diseases and symptoms within 72 h after stroke onset. Thereafter, physicians reported all of the initially confirmed stroke events, diagnosed using computed tomography (CT) and/or magnetic resonance imaging (MRI), to TMUGH on a monthly basis. Suspected stroke events (ie, those with signs and symptoms of stroke but without confirmatory CT/MRI findings) were reported in real time. Finally, neurologists from TMUGH identified suspected cases via door-to-door interviews as soon as possible. Patients with a first-ever stroke and those with recurrent stroke were ascertained using the same procedure.

### Definition of Stroke Management and Outcomes

Stroke management is based on the rates of strokes diagnosed by neuroimaging and of hospitalization. The rate of neuroimaging was defined as the proportion of patients who were diagnosed by CT or MRI from among all stroke patients. The hospitalization rate was defined as the proportion of inpatients from among all stroke patients. Stroke outcomes included the case fatality rate and the stroke recurrence rate. Case fatality was defined as the proportion of patients who died within 1 year after initial

stroke among all stroke patients. Patients who died from other causes, including cancer, accident, and other non-stroke-related diseases, were excluded. The stroke recurrence rate was defined as the proportion of patients who had a recurrent stroke within 1 year of the first stroke occurrence among all stroke patients.

## Statistical Analysis

Age is presented as mean (standard deviation [SD]), and the difference between two groups (sex and study period) was compared using the Student's *t*-test. Categorical variables are presented as number (%), and the difference between two groups (sex and study period) was compared using the chi-squared test. The burden of stroke was compared for three periods (1992–2000, 2001–2009, and 2010–2018) using the chi-squared test. Trends in the burden of stroke were assessed as annual percentage changes (APCs) using the following regression model:  $\text{Ln}(r_t) = a + bt$ , where  $\text{Ln}$  denotes the natural logarithm and  $t$  is the year. The trend,  $b$ , was estimated using ordinary regression, and  $100 \times b$  represents the estimated APC in the burden of stroke (including rates of patients diagnosed by neuroimaging, rates of hospitalization, case fatality, and recurrence). All statistical analyses were performed using

SPSS for Windows (version 15.0; SPSS, Chicago, IL, USA); a *P*-value  $< 0.05$  was considered statistically significant.

## Results

### Demographic Characteristics for All Stroke Patients During the Study Period

Overall, 1462 stroke cases occurred from 1992 to 2018, and 58.7% ( $n=858$ ) patients were male. The average age at stroke onset was 65.85 years; the mean age at the first-ever stroke was significantly younger in 2010–2018 than in 1992–2000. Although 38.7% of stroke patients had no formal education, the percentage of patients who were formally educated in primary school increased noticeably from 4.5% in 1992–2000 to 27.1% in 2010–2018. Moreover, ischemic stroke accounted for 77.6% of cases, with an increasing tendency (Table 1).

### Stroke Management and Outcomes

Overall, the rates of patients diagnosed by neuroimaging and of hospitalization increased significantly over time in each of the three study periods: 1992–2000, 2001–2009, and 2010–2018. Similar trends were found across sexes, stroke types, and age groups. Case fatality within 1 year of

**Table 1** Demographical Characteristics of All Patients by Study Periods

Category	1992–2000	2001–2009	2010–2018	Overall
Case, n (%)	245 (16.8)	509 (34.8)	708 (48.4)	1462 (100.0)
Gender:				
Men	153 (62.4)	294 (57.8)	411 (58.1)	858 (58.7)
Women	92 (37.6)	215 (42.2)	297 (41.9)	604 (41.3)
Age, years, means (SD)	65.93 (11.39)	66.87 (11.98)	65.08 (11.96)	65.85 (11.89)
Age group, n (%):				
<45	15 (6.1)	20 (3.9)	30 (4.2)	65 (4.4)
45~	79 (32.2)	194 (38.1)	346 (48.9)	619 (42.3)
≥65	151 (61.6)	295 (58.0)	332 (46.9)	778 (53.2)
Education, years, means (SE)	1.36 (0.16)	2.77 (0.14)	4.76 (0.13)	3.50 (0.09)
Education group, n (%):				
0 year	172 (70.2)	231 (45.4)	163 (23.0)	566 (38.7)
1–6 years	62 (25.3)	228 (44.8)	353 (49.9)	643 (44.0)
> 6 years	11 (4.5)	50 (9.8)	192 (27.1)	253 (17.3)
Stroke subtypes, n (%):				
Ischemic stroke	176 (71.8)	379 (74.5)	580 (81.9)	1135 (77.6)
Hemorrhagic stroke	51 (20.8)	104 (20.4)	116 (16.4)	271 (18.5)
Undefined	18 (7.3)	26 (5.1)	12 (1.7)	56 (3.8)

**Abbreviations:** SD, standard deviation; SE, standard error.

initial stroke decreased remarkably over time, with a decline of 34% overall, 35.6% for men, and by 27.0% for patients aged 65 years and older. However, the recurrence rate remained stable during the three periods across all sex, age, and stroke types (Table 2).

## APC in Stroke Burden

Table 3 shows the rate of diagnosis by neuroimaging increased significantly across all sex, age, and stroke type groups, with annual increases of 4.0% overall and

of 5.2% for those aged  $\geq 65$  years (all  $P < 0.001$ ). The hospitalization rate increased remarkably over the three periods for all sex, age, and stroke type groups, with an overall annual increase of 11.2%. The greatest increase was observed among patients aged  $\geq 65$  years, who had an increase of 15.4%. There was a noticeable decline in case fatality across sex, age, and stroke type (except ICH) groups over the past decade, with an overall decline of 3.5%. The greatest decline was observed in women, who had an annual decrease of 4.4% (all  $P < 0.05$ ). The

**Table 2** Burden of Stroke During 1992 to 2018 by Gender and Stroke Types

Category	1992–2000	2001–2009	2010–2018	P
Total:				
Diagnosis by CT	118 (51.8)	381 (74.9)	641 (90.5)	<0.001
Hospitalized	17 (6.9)	82 (16.1)	384 (54.2)	<0.001
Case Fatality	67 (27.3)	105 (20.6)	127 (17.9)	0.002
Recurrence	19 (7.8)	49 (9.6)	67 (9.5)	0.523
Men:				
Diagnosis by CT	75 (49.0)	229 (77.9)	368 (89.5)	<0.001
Hospitalized	10 (6.5)	41 (13.9)	229 (55.7)	<0.001
Case Fatality	43 (28.1)	63 (21.4)	77 (18.7)	0.020
Recurrence	14 (9.2)	33 (11.2)	44 (10.7)	0.698
Women:				
Diagnosis by CT	52 (56.5)	152 (70.7)	273 (91.9)	<0.001
Hospitalized	7 (7.6)	41 (19.1)	155 (52.2)	<0.001
Case Fatality	24 (26.1)	42 (19.5)	50 (16.8)	0.058
Recurrence	5 (5.4)	16 (7.4)	23 (7.7)	0.510
IS:				
Diagnosis by CT	86 (48.9)	281 (74.1)	529 (91.2)	<0.001
Hospitalized	10 (5.7)	53 (14.0)	305 (52.6)	<0.001
Case Fatality	25 (14.2)	36 (9.5)	67 (11.6)	0.649
Recurrence	18 (10.2)	40 (10.6)	59 (10.2)	0.932
ICH:				
Diagnosis by CT	41 (80.4)	100 (96.2)	112 (96.6)	0.001
Hospitalized	7 (13.7)	29 (27.9)	79 (68.1)	<0.001
Case Fatality	25 (49.0)	44 (42.3)	48 (41.4)	0.649
Recurrence	1 (2.0)	9 (8.7)	8 (6.9)	0.382
< 65 years:				
Diagnosis by CT	72 (76.6)	197 (92.1)	372 (98.9)	<0.001
Hospitalized	15 (16.0)	54 (25.2)	226 (60.1)	<0.001
Case Fatality	11 (11.7)	20 (9.3)	37 (9.8)	0.718
Recurrence	0	12 (5.6)	21 (5.6)	0.067
$\geq 65$ years:				
Diagnosis by CT	55 (36.4)	184 (62.4)	269 (81.0)	<0.001
Hospitalized	2 (1.3)	28 (9.5)	158 (47.6)	<0.001
Case Fatality	56 (37.1)	85 (28.8)	90 (27.1)	0.040
Recurrence	19 (12.6)	37 (12.5)	46 (13.9)	0.645

**Abbreviation:** CT, computed tomography.

**Table 3** APC of Stroke Burden During 1992 to 2018 by Gender and Stroke Types

Category	Diagnosis by CT		Hospitalized		Case Fatality		Recurrence	
	APC (95% CI)	P	APC (95% CI)	P	APC (95% CI)	P	APC (95% CI)	P
Total	4.0 (2.7, 5.3)	<0.001	11.2 (9.3, 13.1)	<0.001	-3.5 (-5.7, -1.4)	0.003	-1.7 (-4.1, 0.7)	0.150
Gender:								
Men	4.0 (2.6, 5.3)	<0.001	10.2 (7.2, 13.2)	<0.001	-3.5 (-6.1, -0.9)	0.012	-2.0 (-4.4, 0.5)	0.106
Women	4.1 (2.4, 5.9)	<0.001	9.5 (6.2, 12.8)	<0.001	-4.4 (-7.5, -1.3)	0.008	-4.1 (-7.4, -0.8)	0.018
Age group								
< 65 years	2.2 (1.3, 3.1)	<0.001	6.8 (4.8, 8.7)	<0.001	-3.7 (-6.8, -0.6)	0.024	-5.3 (-11.1, 0.6)	0.074
≥ 65 years	5.2 (3.5, 6.9)	<0.001	15.4 (11.9, 19.0)	<0.001	-3.1 (-5.3, -0.9)	0.009	-1.4 (-3.6, 0.8)	0.191
Stroke types:								
IS	5.0 (3.0, 6.9)	<0.001	11.8 (9.3, 14.4)	<0.001	-3.6 (-6.3, -0.9)	0.012	-3.6 (-5.9, -1.2)	0.005
ICH	1.5 (0.7, 2.3)	0.001	5.0 (0.7, 9.3)	0.026	-1.0 (-3.5, 1.4)	0.383	-1.3 (-5.8, 3.2)	0.521

**Abbreviations:** CT, computed tomography; APC, annual proportion of change; CI, confidence interval; IS, ischemic stroke; ICH, intracerebral hemorrhage.

recurrence rate significantly decreased by 4.1% for women and by 3.6% for the IS during the study period.

### APC by Sex, Age, and Stroke Type

The rates of diagnosis by neuroimaging and of hospitalization increased noticeably across sex and age for all stroke types and particularly for IS, with the most obvious increases for men and women ≥65 years of age (all  $P<0.05$ ). The greatest increases were observed among elderly women, who showed a 4.7% increase in the rate of diagnosis by neuroimaging and a 12.4% increase in the

rate of hospitalization (all  $P<0.001$ ). Case fatality from stroke decreased by 3.7% annually among those aged <65 years and by 3.1% among the elderly (aged ≥65 years); the corresponding rates were 7.4% and 3.5% among women specifically (all  $P<0.05$ ). However, there was no significant improvement among men aged <65 years. The recurrence rate of IS significantly decreased among men, by 9.6% ( $P=0.044$ ) for those aged <65 years and by 3.1% ( $P=0.033$ ) for those aged ≥65 years, with a decrease of 4.3% ( $P=0.002$ ) among women aged ≥65 years (Table 4).

**Table 4** APC of First-Ever Stroke Burden by Gender, Age, and Stroke Types During 1992 to 2018

Category	Total		Men		Women	
	< 65 Years	≥ 65 Years	< 65 Years	≥ 65 Years	< 65 Years	≥ 65 Years
Stroke, n (%):						
Diagnosis by CT	2.2 (1.3, 3.1)*	5.2 (3.5, 6.9)*	1.7 (0.3, 3.0)*	4.7 (2.9, 6.4)*	1.6 (0.7, 2.4)*	4.7 (2.4, 7.0)*
Hospitalized	6.8 (4.8, 8.7)*	15.4 (11.9, 19.0)*	5.2 (2.3, 8.0)*	11.7 (7.8, 15.6)*	5.5 (2.2, 8.7)*	12.4 (8.0, 16.7)*
Case Fatality	-3.7 (-6.8, -0.6)*	-3.1 (-5.3, -0.9)*	-3.2 (-8.5, 2.1)	-2.7 (-4.9, -0.4)*	-7.4 (-10.0, -4.7)*	-3.5 (-6.8, -0.1)*
Recurrence	-5.3 (-11.1, 0.6)	-1.4 (-3.6, 0.8)	-7.7 (-14.1, -1.3)*	-1.2 (-3.6, 1.1)	-0.2 (-8.3, 8.0)	-3.8 (-6.7, -1.0)*
IS, n (%):						
Diagnosis by CT	2.1 (1.1, 3.2)*	5.1 (3.6, 6.7)*	1.8 (0.4, 3.2)*	4.6 (2.6, 6.5)*	0.4 (-0.3, 1.1)	4.4 (2.1, 6.8)*
Hospitalized	6.8 (4.2, 9.4)*	13.9 (9.1, 18.8)*	5.1 (1.3, 9.0)*	10.8 (5.0, 16.7)*	2.5 (-1.6, 6.7)	13.5 (5.6, 21.3)*
Case Fatality	-2.3 (-6.5, 1.8)	-2.7 (-5.2, -0.2)*	-1.6 (-39.7, 36.5)	-2.5 (-6.6, 1.6)	—	-2.8 (-6.4, 0.7)
Recurrence	-7.3 (-14.6, 0.1)	-3.1 (-5.2, -0.9)*	-9.6 (-18.8, -0.3)*	-3.1 (-5.9, -0.3)*	-1.5 (-6.5, 9.5)	-4.3 (-6.7, -1.8)*
ICH, n (%):						
Diagnosis by CT	0.6 (-0.1, 1.3)	0.8 (-0.3, 1.9)	0.0 (-0.2, 0.1)	0.7 (-0.8, 2.2)	0.3 (-0.2, 0.8)	0.4 (-0.8, 1.0)
Hospitalized	2.9 (0.2, 5.6)*	6.0 (0.5, 11.4)*	1.2 (-2.8, 5.2)	0.5 (-4.5, 5.6)	2.1 (-1.5, 5.8)	3.4 (-1.7, 8.4)
Case Fatality	-2.1 (-5.7, 1.6)	-0.7 (-3.2, 1.8)	-1.2 (-7.1, 4.8)	-0.4 (-3.9, 3.2)	-2.7 (-5.4, 0.1)	-1.7 (-3.9, 0.5)
Recurrence	1.4 (-10.8, 13.5)	2.7 (-8.6, 14.0)	3.6 (-25.1, 32.3)	12.9 (-86.4, 100)	-20.9 (-37.3, -4.4)*	-3.1 (-13.5, 7.2)

**Note:** \* $P<0.05$  compared between 1992–2008 and 2009–2018.

**Abbreviations:** CT, computed tomography; IS, ischemic stroke; ICH, intracerebral hemorrhage.

In addition, the prevalence of hypertension, diabetes, smoking and alcohol in stroke patients showed in the [Supplemental Table 1](#). The prevalence of diabetes increased during the three study stages, from 2.5% during 1992–2000, 10.5% during 2001–2009, to 17.8% during 2010–2018 ( $P < 0.001$ ). Inversely, the rate of smoking decreased ( $P = 0.050$ ).

## Discussion

This is the first report on long-term trends related to stroke management and burden in a low-income population in China. Since 1992, the rates of patients diagnosed by neuroimaging and of those hospitalized for stroke have increased substantially across sex, age, and stroke types; elderly women were observed to have the greatest increases. Moreover, there was a significant decrease in case fatality among women, with a decline of 7.4% among women aged <65 years and of 3.5% among women aged  $\geq 65$  years. However, the recurrence rate of IS did not improve remarkably in women aged <65 years old.

Neuroimaging is the most important approach for distinguishing stroke subtypes, evaluating vascular patency and tissue vitality, and assessing the patient's eligibility for treatment as well as functional outcome.<sup>21,22</sup> Furthermore, immediate CT scanning for acute stroke can reduce costs and improve quality of life.<sup>23</sup> CT was widely used in Chinese hospitals, in which approximately 90% of patients with IS underwent brain CT<sup>5</sup> and almost 50% of patients underwent MRI.<sup>24</sup> In this low-income population in China, we found that the rate of patients diagnosed by neuroimaging has increased substantially across sexes, ages, and stroke types since 1992, and elderly women had the greatest increase. The rate of patients diagnosed by neuroimaging was only 51.8% in the time period of 1992 to 2000, whereas for 2010 to 2018, 90.5% of stroke patients were diagnosed through neuroimaging. The rate of patients diagnosed by neuroimaging increased by 4.0% annually. The upward trend in the use of neuroimaging from 1992 to 2018 indicates that the level of medical care improved markedly in this low-income population in China following the national healthcare reform.

Between 2008 and 2014, 50.5% of overall stroke patients were hospitalized in a stroke unit or intensive care unit (the rates by subtype were 51.1% for IS and 52.0% for ICH); and the average annual crude rates of IS patients hospitalized had increased for men and women aged 65 to 74 years but had decreased for those aged 75 to 84 years, while the opposite trend was observed for hemorrhagic stroke patients.<sup>25</sup> Moreover, the age-specific acute IS hospitalization rates

two national studies in the United States increased for individuals aged 15 to 44 years from 1995 to 2008<sup>26</sup> and for those aged 25 to 65 years from 2000 to 2010.<sup>27</sup> A retrospective study performed in China showed that being hospitalized at an early stage of stroke was essential for recovery.<sup>28</sup> However, prior to 2000, only 6.9% of stroke patients were hospitalized in this low-income population, demonstrating the poor medical care they previously received. The rate of hospitalization for stroke increased to 54.2% during 2010 to 2018; the rates of hospitalization increased substantially across sex, age, and stroke types. More importantly, the greatest increase in the annual hospitalization rate for stroke was observed among women aged 65 years and older (12.4%), suggesting that the healthcare reform in China vastly improved the number of women seeking medical advice, who are often affected by traditional culture and the lower social status for women. Changes in hospitalization rates reflected, to some extent, the improvement in stroke management and diagnosis in this low-income population, and in particular that the healthcare reform beginning in 2009 facilitated improvement in healthcare services for elderly women. Improved medical imaging, better knowledge of stroke symptoms among physicians and the overall population, and the deployment of stroke wards across the country may have improved the accuracy and speed of diagnosis and increased the rate of hospitalization.<sup>27</sup> Furthermore, the improvement in the reformed healthcare system and in income improved the ability of rural residents to pay for medical care.

The age-standardized rate of stroke mortality had decreased by 33.4% overall from 1990 to 2017 and the mortality rate had decreased for all regions of varying socioeconomic status.<sup>29</sup> Stroke mortality rates decreased by 55% from 2001 to 2010, and the mean annual mortality change was  $-6.0\%$  for men and  $-6.1\%$  for women.<sup>30</sup> Similar trends were found in 7 Western European countries.<sup>31</sup> Consistent with this global trend, there was a 33.5% decrease in the age-standardized stroke mortality from 1990 to 2017 in China.<sup>32</sup> However, mortality from stroke in rural areas remained relatively stable from 2003 to 2015, and was consistently higher than that in urban areas.<sup>1</sup> In addition to stroke, the mortality rate of lung cancer and CHD disease in the region is also showing an upward trend.<sup>33,34</sup> From 1999 to 2016, the crude lung cancer death rate increased by 58.5%, and the average annual change percentage (AACP) was 2.9%. However, the age-standard YLL rate in 2016 was 13.3% lower than that in 1999, and the AACP was  $-0.8\%$ .<sup>33</sup> From 1999 to

2008, the age-standardized CHD mortality rate in Tianjin increased slightly, but the CHD mortality rate in various countries in the Americas and Europe showed a downward trend.<sup>34</sup> For patients with first-ever stroke, appropriate and sufficient secondary prevention strategies have the potential to reduce the burden of stroke by up to one-quarter.<sup>35</sup> Compared with the untreated group, patients treated with anticoagulants and antiplatelets had reduced risks of death and recurrence from ischemic stroke (by 73% and 75%, respectively).<sup>36</sup> However, the use of secondary prevention medications for cardiovascular disease (ie, coronary heart disease or stroke) is low worldwide (antiplatelet drugs, 25.3%;  $\beta$  blockers, 17.4%; angiotensin-converting enzyme inhibitors or angiotensin-II receptor blockers, 19.5%; and statins, 14.6%), especially in low-income countries and rural areas.<sup>37</sup> The use of antiplatelet and lipid-lowering treatments for secondary prevention has been shown to decline significantly after discharge from hospital in urban areas of China.<sup>38</sup> The discontinuation of medications for secondary prevention can be attributed to socioeconomic factors, such as the price of the drugs and reimbursement policies,<sup>39</sup> and poor compliance for long-term use drugs by patients and physicians.<sup>38</sup> In this study, the recurrence rate of stroke decreased remarkably annually among the elderly (by 3.1% for men and 4.3% for women) and among men aged <65 years (by 9.6%). However, for women aged <65 years, this improvement was observed for ICH but not for IS. These findings suggest that there may be more emphasis on ICH than on IS in low-income populations; the heavy burden of stroke in rural areas, especially for young and middle-aged women, remained. In China, all residents aged 60 years and older receive free annual physical examinations supported by the government; moreover, patients with chronic NCD, including hypertension, diabetes, and cardiovascular disease, are interviewed door-to-door by community physicians to promote medical education and guide therapy. This practice may partly explain the better outcomes among elderly patients than among the younger and middle-aged patients in this study.

There are several limitations of this study. First, the study population was not a nationally representative sample, as study subjects were from one township in northern China. However, we assessed long-term trends for the burden of stroke in one low-income population in this study; therefore, the representativeness of the study population did not impact these results. Second, a limited number of stroke cases occurred during the study period. However, the long

observation period was sufficient for the epidemiological study of stroke. Third, in this study's early observation period, the low rate of neuroimaging-based diagnoses may have affected the determination of stroke types and underrated stroke recurrence. Fourth, the effect of education stratification and blood pressure on stroke mortality is not accessed in this study, we will perform these stratified analysis futures. Finally, we did not collect the information of medication using, we will supplement it in the next study.

## Conclusion

In conclusion, the management for stroke has improved substantially across sex, age, and stroke type groups over the past decades in Tianjin, China. The greatest improvement was observed among elderly women. Moreover, among elderly women, the case fatality rate decreased by 3.5% annually and the recurrence rate decreased by 3.8%. However, the recurrence rate of IS in women aged <65 years did not improve significantly. These findings suggest that the allocation of medical resources has improved following economic development in China, and especially following healthcare reform that began in 2009. Women aged 65 years and older derived the greatest benefit from these improvements. However, it is crucial to enhance secondary stroke prevention by controlling risk factors in this low-income population, especially for women aged <65 years. At the same time, we should also pay attention to the risk of hypertension and cardiovascular disease in stroke patients to achieve early prevention. Moreover, to extend these benefits into rural China, it may be beneficial to implement integrated management into the care of patients with primary chronic NCD in low-income populations, such as by reducing the age at which free physical examination are available.

## Abbreviation

TBS, The Tianjin Brain Study; TMUGH, Tianjin Medical University General Hospital; IS, Ischemic Stroke; ICH, Intracerebral Hemorrhage; CT, computed tomography; MRI, magnetic resonance imaging; SD, standard deviation; APCs, annual percentage changes; NCD, Non-Communicable Disease.

## Data Sharing Statement

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

## Ethics Approval and Informed Consent

This study was conducted in accordance with the Declaration of Helsinki, and the study protocol was approved by the ethics committee of Tianjin Medical University General Hospital (TMUGH), and written informed consent was obtained from each participant (contract number: IRB2018-099-01).

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## Author Contributions

All authors contributed to data analysis, drafting or revising the article, have agreed on the journal to which the article will be submitted, gave final approval of the version to be published, and agree to be accountable for all aspects of the work.

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## Disclosure

The authors declare no conflicts of interest in this work.

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