Original article

Surveillance of trend and distribution of stroke mortality by subtype, age, gender, and geographic areas in Tianjin, China, 1999–2006

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Background **The purpose of this study was to analyze the epidemiological trend and distribution of stroke mortality in the city of Tianjin, China, in order to provide evidence for the prevention and control of stroke.**

Methods **The study was based on 102 718 cases of stroke mortality in Tianjin between 1999 and 2006. The cause of death was coded according to the International Classification of Diseases into stroke subtypes. Standardized mortality rates were calculated for stroke and its subtypes, adjusted for age and gender using the year 2000 world standard population. The age, gender, and geographic distribution of stroke and subtype mortality were analyzed. χ^2-tests were used to determine the statistical significance of differences in mortality trends.**

Results **The stroke mortality rate in Tianjin declined from 133·52/100 000/year in 1999 to 102·52/100 000/year in 2006. The stroke mortality rate for males was higher than that for females. Stroke mortality rates increased with increasing age. The subtypes of stroke have changed considerably in Tianjin. Hemorrhagic was major in 1999–2001, while cerebral infarction attained the first rank and accounted for more than 50% of stroke mortality in 2002–2006. The most pronounced finding was that the proportion of ischemic stroke was 66·65% in the urban population and over 20% higher than that in the rural area. Stroke in the suburban area was mainly hemorrhagic stroke, up to 62·67%.**

Conclusions **There are significant differences in the distribution of stroke mortality by subtype, age, gender, and geographic areas in Tianjin, China. Various subtypes of stroke are associated with different risk factors and therefore require different public health prevention and control measures. This study provides pertinent information for formulation of measures for the prevention and control of stroke.**

Key words: control, mortality, prevention, stroke, surveillance

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Stroke is the second most common cause of death and the leading cause of adult disability worldwide (1). Almost six million people worldwide died from stroke in 2005, and nearly 90% of these deaths occurred in developing countries. Without immediate preventive action, it is estimated that death from stroke will increase over the next decade globally by 12% and in developing countries by 20% (2). Developing countries have the highest stroke mortality rates in the world, comprising over two-thirds of stroke deaths worldwide. Patterns of stroke subtypes and causes of stroke differ between developing and developed countries (3). There is a tendency toward a higher proportion of hemorrhagic strokes in Asian individuals; most studies have suggested that the proportion of intracerebral hemorrhage (ICH) is significantly higher in Asian individuals (up to 35% of the total) than in individuals of European descent (4). China is the largest developing nation in the world, with one-fifth of the world's population living on its land mass. Chronic diseases now account for an estimated 80% of all death and 70% of disability-adjusted life-years lost in China. The leading causes of death in China are scaled from highest to lowest:

1. vascular disease,
2. cancer, and
3. chronic lower respiratory disease.

Unlike the pattern seen in western countries, in China, the number of patients who die from stroke is more than three times than from coronary heart disease (1).

Many epidemiological investigations including cohort studies on stroke onset and death have been conducted in several European countries, America, and Japan. These studies illustrate the characteristics of different subtypes of stroke and the threat to populations, and provide a scientific base for effective prevention and control of stroke (5–7). However, similar research has rarely been reported for China. As China has a large population and a unique ethnic composition, a Chinese study on the trend and distribution of characteristics of stroke will be of great significance for the formulation of strategies for reduction of stroke onset and death.

This study looked at the distribution of the epidemiologic characteristics of 102 718 cases of stroke mortality between 1999 and 2006 in Tianjin, China. Tianjin is the third largest city in China. It is located in the northeast of the North China plain, with the Bohai Sea to its east and Yanshan Mountain to its north, and covers an area of 11 920 km^2. The resident population in the city was about 10 million, with a 40% urban population and a 60% suburban population. Among them, the Han ethnic population accounts for 97%. Cerebrovascular disease (stroke) has been the main cause of death in the Tianjin population, and in recent years, is either the first or the second leading cause of death. Stroke caused a serious disease burden in Tianjin in terms of deaths, illness and disability. It is also associated with expensive medical expenditure, lost labour productivity and indirectly leads to family poverty. It is important that China focuses attention on this major public health challenge and develops strategies to decrease stroke burden. Our study presented the epidemiologic characteristics of secular stroke mortality in the Chinese population, which should prove useful in formulating measures of stroke control, both locally and nationally.

Subjects and methods

Subjects of this study included all cases of death among residents who had official residential permits in Tianjin, and who died of stroke between 1999 and 2006, with confirmed medical death certificates. Cause of death classification was based on ICD-9 and ICD-10. ICD-9 was used to code deaths between 1999 and 2002. ICD-10 was used for deaths between 2003 and 2006. Based on ICD-9 and ICD-10 (ICD-9: 430–438, excluding 435; ICD-10: I60–I69), cerebrovascular diseases were further classified into subtypes as follows:

- cerebral infarction (CI) (ICD-9: 434; ICD-10: I63),
- intracerebral hemorrhage (ICH) (ICD-9: 431; ICD-10: I61),
- subarachnoid hemorrhage (SAH) (ICD-9: 430; ICD-10: I60), and
- undetermined stroke (UND).

Death data were collected for this study through the all-cause mortality surveillance system that monitors the residential population in Tianjin. Death certificates filled out by clinical doctors from hospitals and community clinical centers in the city are required by law to be mailed to the district or county Centers for Disease Control and Prevention (CDC). The nonhospital deaths included in reporting were from interviews conducted by community clinicians, door to door. The district or county CDCs are responsible for collecting and verifying these medical death certificates, and then reporting the mortality data to the CDC of Tianjin on a monthly basis. Tianjin CDC is responsible for reviewing, sorting, and analyzing the data, and investigating missing reports, controlling data quality, and providing technical training to staff involved in the surveillance process.

Each death certificate recorded 53 fields (variables). Death records with missing fields were excluded from the study. Statistical software SPSS 11·0 was used for data analysis. Standardized mortality rates were calculated using the World Health Organization year 2000 world standard population. The mortality rates and proportions of different subtypes of stroke were analyzed. The χ^2-test was used to determine the significance of mortality rates and proportions. A significance level of 0·05 (two-sided) was used.

Results

A total of 107 390 stroke deaths were recorded in the surveillance database between 1999 and 2006. The 4672 records with missing data were excluded from analysis, accounting for 4·35%. This resulted in an effective sample size of 102 718 stroke deaths; over 80% had had CT scanning. Thus, our data are reliable. From the 53 fields per death record, we had a total of 5 444 054 pieces of information for the analysis.

1. *Ranking of stroke as a leading cause of death between 1999 and 2006 in Tianjin*

Stroke accounted for 23–26% of the total deaths in Tianjin, and was the number one cause of death between 1999 and 2001 and the number two cause of death between 2002 and 2006 (Table 1).

2. *Secular trend of stroke mortality between 1999 and 2006 in Tianjin*

The stroke mortality rates in males, females, and both genders declined ($P = <0{\cdot}01$) between 1999 and 2006 in Tianjin (Table 2, Fig. 1). The standardized mortality rate for stroke for males declined from 157·74/100 000/year in 1999 to 120·17/100 000/year in 2006, a decline of 23·82%. The standardized mortality rate for females declined from 109·31/100 000/year to 84·87/100 000/year in 8 years (a decline of 22·36%); the total stroke standardized mortality rate declined from 133·52/100 000/year to 102·52/100 000/year (a decline of 23·22%). All χ^2-tests for trend were statistically significant.

3. *Distribution of stroke mortality by age and gender*

Standardized male stroke mortality rates were higher than those for females over 25 years old (Table 3). The stroke mortality rates for both males and females increased with increasing age, with an obvious increment in the age groups of 45–54 and 55–64 years. χ^2-trend tests across age groups were statistically significant for stroke for all age groups from 1999 to 2006. In general, the stroke mortality rates by age and gender (except for the age group of 15–24 years) declined over the

Table 1 Ranking of top 5 causes of death and proportion of all deaths, Tianjin, 1999–2006

	Stroke		Cardiovascular disease		Cancer		Respiratory disease		Injury and poison	
Year	Rank	Proportion of all deaths (P) (%)	Rank	P (%)	Rank	P (%)	Rank	P (%)	Rank	P (%)
1999	1	26·04	2	24·99	3	18·53	4	11·90	5	5·05
2000	1	25·81	2	24·11	3	19·12	4	13·54	5	4·80
2001	1	25·87	2	23·67	3	20·24	4	13·10	5	4·40
2002	2	23·16	1	24·02	3	20·62	4	14·26	5	4·40
2003	2	23·04	1	24·64	3	20·33	4	13·19	5	4·97
2004	2	23·51	1	24·91	3	20·53	4	12·70	5	5·00
2005	2	24·67	1	26·65	3	20·26	4	11·17	5	5·05
2006	2	25·58	1	26·12	3	21·46	4	10·28	5	4·94

Table 2 Stroke mortality rate (/100 000/year) by gender, Tianjin, 1999–2006

		Male (M)		Female (F)		Total	
Year	Population of Tianjin	Crude rate	Standardized mortality rate*	Crude rate	Standardized mortality rate†	Crude rate	Standardized mortality rate‡
1999	9 101 712	157·91	157·74	119·78	109·31	139·04	133·52
2000	9 120 007	163·29	158·52	123·75	108·86	143·72	133·69
2001	9 139 761	160·42	149·59	127·06	107·68	143·90	128·63
2002	9 190 530	154·09	137·28	116·70	94·29	135·57	115·78
2003	9 321 629	157·21	134·10	120·21	92·81	138·88	113·46
2004	9 325 493	153·95	126·52	116·24	86·29	135·27	106·41
2005	9 393 051	156·03	123·80	125·22	89·23	140·76	106·52
2006	9 488 942	138·77	120·17	111·64	84·87	125·27	102·52

χ^2 test for trend. *Male, $\chi^2 = 22{\cdot}18$; $P = 0{\cdot}00$. †Female, $\chi^2 = 13{\cdot}91$; $P = 0{\cdot}00$. ‡Both sexes, $\chi^2 = 17{\cdot}93$; $P = 0{\cdot}00$.

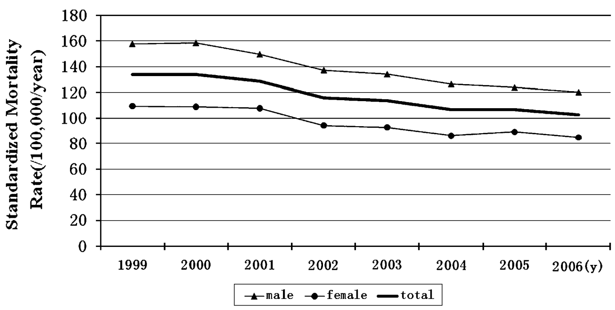

Fig. 1 Trend in stroke mortality by gender, Tianjin, 1999–2006.

8-year period. For example, the stroke mortality rates of males in the age group of 65–74 years declined from 480·47/100 000/year in 1999 to 363·91/100 000/year in 2006, a decline of 24·26%.

4. *Distribution of different subtypes of stroke mortality by gender*

Table 4 illustrates the distribution of stroke mortality rates by subtype and by gender. Mortality rates of both CI and ICH for males were higher than those for females, while the mortality rate of SAH for females was higher than that for males; all differences were statistically significant.

5. *Change of proportion of various stroke subtypes in total stroke mortality between 1999 and 2006 in Tianjin*

Table 5 demonstrates the change of proportion of various stroke subtypes over the 8 years. The proportion of ICH was the largest between 1999 and 2001, which was higher than that of CI, while the proportion of CI exceeded that of ICH from 2002 to 2006. The χ^2-test for trend shows that the proportion of CI presented a significantly increasing trend, while the proportion of ICH exhibited a significantly declining trend. Since 2002, CI has become the main subtype of total stroke death in Tianjin.

6. *Geographic distribution of the proportion of various stroke subtypes in total stroke mortality, Tianjin, 1999–2006*

There were statistically significant differences in the proportion of subtypes of stroke death between urban and suburban areas (Table 6). CI was the main cause of stroke death in urban areas, accounting for 48–66% of total stroke mortality, while ICH was the major cause in suburban areas. The proportion of SAH in urban areas was higher than that in suburban areas.

Discussion

This paper adds to the growing picture of stroke in developing countries. At present, most studies on the trend and distribu-

Table 3 Stroke mortality rate (/100 000/year) standardized to world standard population, by age and sex, Tianjin, 1999–2006

	1999		2000		2001		2002		2003		2004		2005		2006	
Age	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F
15–24	0·15	0·24	0·22	0·08	0·29	0·08	0·14	0·07	0·13	0·14	0·13	0·00	0·06	0·33	0·23	0·18
25–34	1·84	1·04	1·41	0·65	0·87	0·74	1·31	0·82	1·25	1·06	1·50	0·62	1·22	0·71	0·86	0·13
35–44	13·39	4·24	11·87	3·48	10·78	4·57	13·14	4·09	11·19	4·27	10·90	3·28	10·16	5·22	9·35	3·87
45–54	36·19	25·20	35·37	21·17	38·70	20·19	34·83	17·88	34·16	17·73	33·85	15·33	33·53	16·34	31·22	15·10
55–64	140·95	94·94	138·85	90·45	121·62	82·62	106·86	72·72	102·89	68·09	105·07	66·09	93·82	59·32	92·70	56·31
65–74	480·47	317·41	466·63	319·87	442·43	312·66	409·48	284·01	406·53	265·83	374·40	262·28	366·33	266·90	363·91	232·10
75+	1160·16	874·64	1207·19	893·58	1139·59	897·48	1041·93	768·40	1026·16	790·06	961·30	711·99	974·70	763·20	949·99	775·66

χ^2 test for trend for mortality rates across age groups, all years $P = 0{\cdot}000$.

Table 4 Stroke mortality rate (/100 000/year) standardized to world standard population by subtype and sex, Tianjin, 1999–2006

	CI		ICH		SAH		UND	
Year	M	F	M	F	M	F	M	F
1999	64·84	45·22	85·12	58·90	0·53	0·60	7·24	4·59
2000	66·95	47·80	83·31	54·98	0·40	0·73	7·86	5·36
2001	67·67	49·81	75·78	52·18	0·61	0·84	5·53	4·84
2002	70·32	49·10	64·05	42·48	0·65	0·98	2·26	1·72
2003	70·79	49·21	60·72	41·57	0·57	0·59	2·03	1·44
2004	64·37	46·20	59·45	38·07	0·73	0·81	1·97	1·22
2005	64·40	46·65	53·26	37·09	0·35	0·87	5·79	4·62
2006	69·70	48·87	48·63	34·50	0·59	0·51	1·24	1·00

χ^2 test for difference in mortality rates between males and females, within subtype, over the years. All subtypes $P = 0{\cdot}000$. CI, cerebral infarction; ICH, intracerebral hemorrhage; SAH, subarachnoid hemorrhage; UND, undetermined stroke.

Table 5 Proportion (%) of various stroke subtypes in total stroke mortality, Tianjin, 1999–2006

Year	CI	ICH	SAH	UND	Total
1999	40·64	54·59	0·44	4·33	100
2000	42·39	52·28	0·45	4·89	100
2001	45·17	50·22	0·61	4·00	100
2002	51·13	46·48	0·72	1·67	100
2003	52·51	45·44	0·55	1·51	100
2004	51·68	46·08	0·76	1·49	100
2005	51·92	42·64	0·59	4·84	100
2006	57·31	41·06	0·57	1·07	100

CI, cerebral infarction; ICH, intracerebral hemorrhage; SAH, subarachnoid hemorrhage; UND, undetermined stroke.

tion of stroke mortality are from European countries, America, and Japan. There are few reports from developing countries including China. The trend, mortality rate, and proportion of different subtypes of stroke mortality demonstrate different patterns by age, gender, and geographic areas (8). Because of various lifestyles, genetic, and environmental risk factors, epidemiological trends and distributions of stroke mortality show significant differences in various regions and countries.

This study was the first to use the data from the all-cause mortality surveillance system in a local CDC of China. The advantage is that the Tianjin surveillance system has now accumulated death data in a population of 10 000 000 for over 8 years. The extent of information is huge, and can allow reliable analysis in the trend, distribution, and proportion of stroke mortality by age, gender, and geographic areas. In our study, there were over 100 000 stroke death cases from both hospital and nonhospital sources.

A disadvantage of this study is that all the data were collected from the mortality surveillance system only, and there is a lack of survey data on the risk factors relating to these cases. The study therefore could not investigate the specific relationships between behavioral risk factors and stroke mortality. Another limitation of this study is that of reporting and recording bias, as well as incomplete and inaccurate case ascertainment. Our study used overlapping sources to ensure that all deaths recorded as stroke are verified, and CT scan to confirm stroke subtypes. On the other hand, although over 80% of stroke deaths in our study were confirmed by brain imaging to support the diagnosis of stroke subtypes, still, nearly 20% of the sample did not have CT scans (more likely in suburban and rural areas). As a result, there was a considerable potential misclassification bias in the pathology of stroke. This needs to be acknowledged, particularly as it has important implications for the unusual distributions of stroke subtypes in urban and rural settings.

Table 6 Proportion (%) of various stroke subtypes in total stroke mortality by geographic area, Tianjin, 1999–2006

	CI		ICH		SAH		UND		Total	
Year	Urban	Suburban	Urban	Suburban	Urban	Suburban	Urban	Suburban	Urban	Suburban
1999	48·28	32·14	47·33	62·67	0·71	0·15	3·69	5·04	100	100
2000	49·04	35·44	45·81	59·03	0·66	0·23	4·49	5·30	100	100
2001	54·20	34·79	41·03	60·78	0·85	0·33	3·92	4·11	100	100
2002	61·94	38·92	36·26	58·03	0·86	0·55	0·94	2·50	100	100
2003	62·37	40·70	35·75	57·04	0·86	0·17	1·02	2·09	100	100
2004	61·09	42·11	36·55	55·77	1·25	0·26	1·12	1·86	100	100
2005	64·89	40·10	33·17	51·28	1·08	0·15	0·86	8·47	100	100
2006	66·65	49·03	30·76	50·18	1·12	0·07	1·47	0·72	100	100
All	58·39	39·31	38·48	56·65	0·92	0·23	2·22	3·81	100	100

χ^2 test for difference in proportion of different stroke subtypes between urban and suburban, within subtype, over the years. All subtypes $P = 0·00$. CI, cerebral infarction; ICH, intracerebral hemorrhage; SAH, subarachnoid hemorrhage; UND, undetermined stroke.

Our study found that the stroke mortality rate in Tianjin declined from 133·52/100 000/year in 1999 to 102·52/100 000/year in 2006, showing a 23% reduction. The standardized mortality rate on average decreased by 3·88% per year: this may be due to the increasing efforts in health care and disease prevention. The distributions of stroke mortality in males and females are statistically different in Tianjin, with male mortality being higher than female mortality. For the two main stroke subtypes CI and ICH, the mortality rate for males was also higher than that for females.

Our results show that stroke is still the main threat to the health of the population in Tianjin. Stroke is now the leading number one or number two cause of death. Moreover, the proportion of different subtypes of stroke death has changed; ICH was the predominant subtype in stroke death between 1999 and 2001, but CI has become the primary subtype in recent years (2002–2006). This might be related to the changing lifestyles, which included:

- unhealthy diet,
- physical inactivity, and
- tobacco use.

The fat energy proportion of total diet is up to 35% in the urban area; the prevalence of adult obesity and abnormal blood lipid levels in Tianjin was 26·8% and 32·2%, respectively, both above the national average; daily per capita sodium intake exceeded 10 g; adult male smoking prevalence reached 51·5%, three times that for female; and the prevalence of adult (18 years plus) hypertension was 30·7% (9). The prevalence of diabetes was 6·2%, twice that of 1995. Research studies have demonstrated that all of the above factors increase the risk of an ischemic stroke (10). A meta-analysis of hypertension and risk of stroke showed that the overall relative risk of stroke associated with hypertension was 5·43 (95% CI 4·62–6·39). The relative risks were similar for hemorrhagic (5·44, 3·99–7·40) and ischemic (5·25, 3·95–6·98) stroke (11). The estimated 1·8-fold increase in stroke risk associated with smoking (after control of other stroke risk factors) from the Framingham Heart Study confirms this substantial increase in risk. The adjusted risk ratio was 1·8 for those with serum cholesterol 240–279 mg/dL and 2·6 for those with cholesterol levels 280 mg/dL and above (10).

In our study, the proportion of CI in Tianjin ranged from 32·12% to 66·65% and presented an increasing trend in urban areas. The upper limit of the range in Tianjin was only slightly lower than the range in developed countries, that is, from 67·3% to 80·5%. The proportion of ICH in Tianjin ranged from 30·76% to 62·67% which was much higher than the range of 6·5–19·6% in western counties (1, 12). Our study showed that SAH accounted for 0·07–1·25%, and undetermined type accounted for 0·72–8·27%. This is slightly different from the results of other Chinese research studies that found SAH around 2·0–3·9%, and undetermined type around 2·8–3·0% (13–16). In western countries, about 0·8–7·0% are SAH, and 2·0–14·5% are of an undefined type (12). There is a tendency toward a higher proportion of hemorrhagic strokes in East Asian countries, as studies have suggested; the proportion of ICH is significantly higher (up to 35% of the total) than in individuals of European descent (4).

Our study finding is important in that both ICH and CI are major subtypes of stroke in Tianjin, with a huge gap in urban and rural distributions. ICH is still the leading cause of stroke death (up to 60% of total) in the rural/suburban population. Further investigation will be needed to determine the differences in lifestyle and other risk factors in urban and suburban areas that might explain the urban/rural difference in stroke subtypes in causing mortality. For example, there may be health care and cultural factors. Peasants who live in rural areas usually do not receive treatment due to lack of hospital access. Peasants in China also have a mindset that they should not go to the hospital until they have a life-threatening disease. The control rate of hypertension is lower in rural areas; this may be one reason for the different proportions of stroke subtypes between rural and urban settings. The rural–urban split in access to stroke treatment is also reflected in studies from Taiwan and Bolivia, which show that 10% and 50%, respectively, of patients with stroke in rural settings do not go to a hospital or see a doctor (17, 18).

Stroke is a preventable disease. The different distributions of stroke subtypes in Tianjin suggest that the measures for the control and prevention of stroke should focus on the risk factors related to the two major subtypes, and should be tailored for different populations and regions. Specific focus on the primary prevention and control strategies needs to be highlighted in developing countries, so that the global burden of stroke can be reduced. It would be logical to place emphasis on effective population-wide interventions to control or reduce exposure to leading risk factors, such as raised blood pressure, smoking, high cholesterol, low fruit and vegetable intake, physical inactivity, and alcohol excess (19–23). Japan sets a good example for considerably reducing stroke mortality by controlling the risk factors in the last century (24–29). The stroke morality had decreased 7% annually in Japan (24, 30). In Tianjin, intervention programs are being developed. These include healthy lifestyle education and the Maintain Normal Blood Pressure and Bodyweight project. Those aged 35 and over receive free measurement of blood pressure in hospitals and clinics. Village doctors and community doctors are trained periodically to apply the National Guidelines for Treatment and Prevention of Hypertension to prevent stroke occurrence. However, the system of primary health care is still not perfect in China, particularly in rural areas. Prevention and control programs are not implemented extensively and effectively. There is a lack of regulations for food labeling. By-laws for prohibiting smoking in public areas are not effectively enforced. Preventive services, such as cessation of smoking and alcohol abuse, are not yet covered by health insurance policies. It is hoped that this study will lead to increased awareness and prevention and control activities for stroke in China.

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