An exploratory study of the use of the electronic health records of hypertensive patients to support the primary prevention of stroke in Shanghai

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Research article

Keywords: An exploratory study of the use of the electronic health records, hypertensive patients, Shanghai

Posted Date: November 12th, 2019

DOI: https://doi.org/10.21203/rs.2.17138/v1
Abstract

Background The value of targeting people with a high risk of stroke based on electronic health records (EHRs) in Shanghai is largely undiscovered. Aim To test the hypothesis that EHRs might be developed into an evidence-based support system to identify people who are at high risk of stroke.

Methods We performed a screen analysis utilizing EHRs to target the population with stroke risk factors, such as hypertension, diabetes mellitus, obesity, smoking and physical inactivity. We calculated the distribution of each risk factor and the combinations of risk factors.

Results In the Jiading District of Shanghai, 46,580 hypertensive patients with complete baseline information joined the hypertensive patient management system from 2014 to 2017. The majority of the patients were older than 60 years. Physical inactivity (83.24%), smoking (24.07%), diabetes (16.87%), and obesity (12.23%) were highly prevalent in hypertension participants. Approximately 4377 patients had hypertension only, accounting for 9.70% of the total patients in this study. Approximately 52.47% of the patients had two risk factors at the same time, and 38.13% of the patients had hypertension, which means that 17,762 patients could be identified as a high-risk population for stroke according to the criteria established by the National Stroke Screening Survey.

Conclusion Our exploratory findings suggest the feasibility of targeting populations with a high risk of stroke using the EHRs of hypertensive patients.

Background

With over 2 million new cases annually, stroke is associated with the highest disability-adjusted life years lost of any disease in China[1]. The burden is expected to increase further as a result of population aging, an ongoing high prevalence of risk factors (e.g., hypertension), and inadequate management[1]. Stroke is the second-leading cause of death in the world and the leading cause of death in China[1]. Up to 80% of strokes could be prevented through healthy lifestyle changes and control of health conditions that raise the risk of stroke[1].

From 2013 to 2014, the National Project Office of Stroke Prevention and Control organized a screening survey of 633,859 residents older than 40 years in 31 provinces of China. Following a random cluster sampling framework, structured questionnaires were used to collect information on risk factors, diagnosis history, treatment, and sociodemographic characteristics and were administered by community health workers trained by national and provincial specialists[1]. Hypertension, dyslipidaemia, diabetes, obesity, physical inactivity, smoking, and atrial fibrillation are the most common and modifiable risk factors for stroke in China[1].

The traditional way of identifying patient populations at high risk of stroke in China is using questionnaires to collect information for certain populations, and the sample size can vary in different research settings. Usually, a large-scale survey takes substantial time and manpower. We are currently
living in a fast-changing world of information and communications technology. As a result of the continuous construction of electronic health record databases, local electronic health record (EHR) data can now allow researchers to capture, aggregate, access, and analyse more data than ever before, as well as new and different identified sources of data, such as data on hypertension, diabetes, overweight or obesity. Real-world evidence-based stroke prevention should be given more attention. A regional model of screening a high-risk stroke population supported by an EHR database in China is needed, which would help to investigate the distribution of stroke risk factors, identify more populations with a high risk of stroke, and develop a public health action plan to prevent stroke.

Jiading is a suburban district in Shanghai and is located in the north-western part of Shanghai. It had a population of 624.1 thousand in 2018, and 32.59% of the population are older than 60 years. Hypertension, diabetes mellitus, smoking, obesity, and physical inactivity are investigated in the Stroke Prevention and Control Project in China as stroke risk factors. Additionally, hypertension is a particularly important risk factor for haemorrhagic stroke, although it contributes to atherosclerotic disease, which can lead to ischaemic stroke as well. Thus, we conducted an exploratory study of stroke risk factor analysis based on the hypertensive patient management system in Jiading, which aimed to estimate the distribution of the major risk factors for stroke prior to a formal survey or door-to-door investigation. Using electronic health records may contribute to providing appropriate data analysis and consistent recommendations for the primary prevention of stroke.

**Methods**

**Database source**

Two databases were chosen in this study that included information on topics such as hypertension, diabetes, smoking, physical activity, height, and weight: the Hypertension Patients Management Database and the Diabetes Mellitus Patients Management Database. Both databases cover the Shanghai Jiading District household registration population only. The Hypertension Patients Management Database is used to record hypertensive patients’ information on height, weight, smoking, alcohol consumption, physical activity, systolic blood pressure, diastolic blood pressure and medication of hypertension patients. The Diabetes Mellitus Patients Management Database is used to record information on the type of diabetes mellitus, systolic blood pressure, diastolic blood pressure and fasting blood sugar value.

**Data extraction**

We used a standardized data collection form (available on request). All patients from the Hypertension Patients Management Database had hypertension, and all patients from the Diabetes Mellitus Patients Management Database had diabetes. After merging these two databases into a data source, we kept the hypertension patients with or without diabetes. We extracted the identity card number and information on
sex, age, height, weight, smoking, alcohol consumption, physical activity, and diabetes. We used the data from those aged 40 years and older. The patients joined the Hypertensive Patient Management System from 2014 to 2017.

**Data synthesis and analysis**

In this article, the analyses focused on characterizing five risk factors for stroke, namely, hypertension, diabetes, obesity, smoking and physical inactivity. Proportions were used for categorical variables, and means with standard deviations were used for continuous variables. Body mass index (BMI) was calculated as weight in kilograms divided by the square of height in metres. BMI was categorized into four groups: underweight (BMI <18.5kg/m$^2$), normal weight (18.5 kg/m$^2$ ≤ BMI <24kg/m$^2$), overweight (24 kg/m$^2$ ≤ BMI <28), and obesity (BMI ≥28kg/m$^2$). Physical activity less than seven days per week was considered physical inactivity.

**Statistical methods**

Descriptive statistics were calculated for all variables. Continuous data are presented as the means±SDs and were compared using Student's t-test. Categorical variables are displayed as frequencies and percentages and were analysed using chi-square ($\chi^2$) tests. A two-tailed $p<0.05$ was considered statistically significant. All analyses were conducted using Stata 13.0.

**Results**

In this exploratory study, we selected two databases for research. We initially screened 49,516 persons who were entered into the Hypertensive Patient Management System from 2014 to 2017, and 2936 persons were excluded based on our inclusion criteria. The detailed patient recruitment flow chart is illustrated in Figure 1. Overall, this study contained 46,580 persons with at least one risk factor for stroke who had complete information at baseline.

An introduction of the database is summarized in Tables 1; in each year from 2014 to 2017, respectively, 10,595, 20,077, 12,876, and 3,032 patients were entered into the system. A detailed description of the participants’ follow-up duration is presented in Figure 2 for hypertensive patients.

Patient demographic characteristics are listed in Table 2. The proportion of males was 48.43%, and 51.57% of these patients were female. The majority of the patients (79.12%) were older than 60 years. The average age was 67.82 years. Approximately half of the patients (42.49%) had normal BMIs. Compared with women, men had a higher BMI (24.69 vs 24.48kg/m$^2$), smoking rate (48.90% vs 0.76%), alcohol consumption rate (46.44% vs 2.07%), SBP (130.60 vs 130.07 mm Hg), and DBP (79.69 vs 79.04 mm Hg) (all $p<0.05$).
Risk factors varied by gender and age and are shown in Table 3. Compared with men, women were more likely to have obesity ($p < 0.05$), diabetes and physical inactivity, but no significant gender differences were detected for diabetes or physical inactivity ($p > 0.05$). Men were far more likely to drink and smoke than women were ($p < 0.05$). The rates of diabetes among hypertensive patients aged 70–79 were higher than the rates among patients in other age groups. The rates of smoking, obesity and physical inactivity among hypertensive patients aged 40–49 were higher than the rates among patients in other age groups. The rates of diabetes, smoking, obesity and physical inactivity differed among age groups (all $p<0.05$).

Approximately 9.40% of patients had hypertension only. Compared with women, men had a lower rate of one risk factor (7.03% vs 11.62%) and two risk factors (38.59% vs 65.51%); however, men had a higher rate of three risk factors (42.67% vs 20.06%), four risk factors (10.58% vs 2.79%), and five risk factors (1.13% vs 0.01%) (Figure 3). The distribution between males and females was different, possibly because only a few women smoked.

For men, the combination of hypertension + smoking + physical inactivity covered most patients (31.35%), followed by hypertension + physical inactivity (31.19%) and hypertension only (7.03%). For women, hypertension + physical inactivity was the top category (61.08%), followed by hypertension only (11.62%) and hypertension + diabetes + physical inactivity (11.06%) (Figure 4).

Discussion

Main findings

Our study provided the astonishing rate of several modifiable stroke risk factors from hypertensive patients with EHRs in Shanghai based on a large contemporary population. The increasing burden of stroke has become a serious public problem and a great economic burden in Shanghai. Therefore, before the qualified primary prevention of stroke is addressed, strategies focusing on deeper data analysis should be emphasized in the available health monitoring data area.

Hypertension has been documented as the most important risk factor for stroke in China\[1\]. For that reason, in our study design, all of the subjects had hypertension. The second-most common risk factor in our study population was physical inactivity; the rate of physical inactivity was quite high because the categories of physical activity from the original data were exercising every day, exercising one or more days per week, exercising once per month, and not exercising. We considered exercising every day to count as physical activity, and the other categories were classified as physical inactivity. The definition of physical inactivity from the China National Stroke Screening Survey was physical activity performed less than 3 times a week for 30 minutes. We may have overestimated the rate of physical inactivity. One large study showed 50.01% survival among stroke patients with physical inactivity\[2\].

When biological sex was considered, this study found that women were more likely than men to have diabetes and obesity. Similar results were found in a study of stroke patients aged 60 years or above in
northern China\textsuperscript{11} and in another study of stroke patients aged 75 years or above in China\textsuperscript{10}. In our study, alcohol overuse and smoking were more common among males, which is consistent with several previous findings\textsuperscript{11,11}.

We found that the risk factors among hypertension patients also varied by age. A higher proportion of hypertension patients aged 70–79 years had diabetes. The rates of smoking, obesity and physical inactivity among hypertensive patients aged 40–49 were higher than the rates in other age groups, but the number of patients aged 40–49 was small. One possible explanation is that the distribution of age groups in Shanghai was unequal. Another possible explanation is that compared with their parents’ generation, patients aged 40–49 years may live a completely different way of life with more energy intake and less physical activity, thus increasing their chances of exposure to risk factors for obesity.

The China National Stroke Screening Survey defined people with a high risk of stroke as those with TIA, stroke, or three risk factors (hypertension, atrial fibrillation or valve heart disease, smoking, dyslipidaemia, diabetes, physical inactivity, obesity, family history of stroke). In our research, it was easy to target hypertensive patients who did or did not smoke and who had or did not have diabetes, physical inactivity, and obesity. We observed a high rate of those risk factors in hypertension populations in the present study, and poor management of the risk factors may cause the high prevalence of stroke. Compared with other traditional population-based surveys, the present study provided a comprehensive and accurate estimation of the rate of risk factors with a more representative population. Therefore, the primary prevention and management of related risk factors based on EHR data insight might be of great importance.

**Limitations**

This study also had several limitations. First, no patients with hypertension or diabetes were included in the EHR database. Second, the structural database was designed before the China National Stroke Screening Survey began, and some information was not covered or was inconsistent with the survey details.

**Conclusions**

We provided a large population and accurate estimation of the current rate of stroke risk factors in Shanghai’s Jiading District. Patients with three or more risk factors accounted for 38.13% of the sample, which means that 17,762 patients could be identified as a high-risk population for stroke according to the criteria established by the National Stroke Screening Survey. These patients may cause great economic and societal burdens. Moreover, the considerable rate of stroke risk factors was likely related to the poor management of risk factors, particularly smoking and physical inactivity. Therefore, strategies of long-term data mining from EHRs could contribute to the primary prevention of stroke in Shanghai.
Declarations

Acknowledgments

We thank JiaDing Health Information Center for supporting the study. We are grateful to staff members of JiaDing Health Information Center, data collectors and study participants for their cooperation in the success of this study.

Authors’ contributions

Tingting Yang, Fen Li contributed in the design of the study and write up of the manuscript. Bifan Zhu, Yuqian Chen and Duo Chen made the data analysis, drafting, interpretation and edition of the data. Shuwei Gu, Jiefen Liu checked the data and compared the inconsistencies. Changying Wang, Zhiying Hou and Jiajie Xu checked the manuscript, tables and figures. Chunlin Jin and Ying Wang contributed to the design of the study, monitoring the study and edition of the manuscript. All authors critically revised the manuscript and have approved the final manuscript.

Funding

This work was support by two grants ShanghaiMunicipal Health Commission 2018YQ51, the National Natural Science Foundation of China (71673055). The funder had no role in study design, data collection and analysis, decision to publish or preparation of the manuscript.

Availability of data and materials

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

Ethics approval and consent to participate

Ethical clearance was obtained from Shanghai Health Development Research Center, Shanghai Medical Information Center. Neither the case records nor the data extracted was used for any other purpose.

Consent for publication

Not applicable

Competing interests

The authors declare that they have no competing interests.
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Tables

Due to technical limitations, full-text HTML conversion of this manuscript could not be completed. However, the manuscript can be downloaded and accessed as a PDF.

Figures
49,516 patients screened

47,473 patients enrolled

46,940 patients enrolled

46,580 patients with complete information at baseline

2,043 patients died before 2019

533 patients with stroke

360 patients without baseline

Figure 1

Figure 2
Figure 3

Figure 4

Supplementary Files

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- table2.png
