Application and Considerations of Hypertension Control Strategies in Stroke Prevention and Management in China: Postprint

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Abstract

Hypertension is the leading cause of stroke mortality and the increasing burden of disability-adjusted life years (DALYs). As the most important modifiable risk factor, effective prevention and control of hypertension has become the core task of primary and secondary stroke prevention. The World Stroke Organization (WSO) and World Hypertension League (WHL) published the "2025 WSO/WHL Position Statement: Application of Hypertension Control Strategies in Stroke Prevention and Management" in February 2025. Based on the strategies and recommendations of this statement, this article analyzes and interprets the practical evidence from China's hypertension prevention and control efforts, while also proposing considerations for constructing a hypertension prevention and control pathway with Chinese characteristics, aiming to provide a reference for future applications and research related to stroke prevention and management in China.

Full Text

Preamble

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Practical Evidence and Reflection on Hypertension Control Strategies in Stroke Prevention and Management in China

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Abstract

Hypertension is the leading cause of stroke-related deaths and the primary contributor to the increased disability-adjusted life years (DALY) burden from stroke. As the most important modifiable risk factor, effective prevention and control of hypertension has become the core task of both primary and secondary stroke prevention. In February 2025, the World Stroke Organization (WSO) and the World Hypertension League (WHL) released the "2025 WSO/WHL Position Statement: Application of Hypertension Control Strategies in Stroke Prevention and Management." Based on the strategies and recommendations outlined in this statement, this paper analyzes and interprets practical evidence from China's hypertension prevention and control efforts, while proposing considerations for constructing a hypertension control pathway with Chinese characteristics. The aim is to provide reference for future applications and research in stroke prevention and management in China.

Keywords: Stroke; Hypertension prevention and control; Policy-driven; Digital intelligence technology; National health literacy

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1. Introduction

1.1 The "Three Highs" Characteristic of China's Stroke Burden

Stroke is an acute neurological deficit syndrome caused by cerebrovascular disease and represents one of the leading causes of disability and mortality among adults worldwide. Although stroke incidence and mortality have declined in some developed economies in recent years, many low- and middle-income countries continue to experience rising stroke incidence, imposing a heavy burden on both society and families. In China, stroke has become one of the top three causes of adult disability and death, with incidence rates ranking among the highest globally. Among cerebrovascular disease risk factors, hypertension is the foremost cause of stroke deaths and increased DALY burden, as well as the most important modifiable risk factor—a finding supported by extensive global evidence. Blood pressure levels show a continuous, independent, direct positive correlation with cardiovascular risk, including stroke. A meta-analysis of individual data from one million adults across 61 prospective cohorts demonstrated that higher systolic or diastolic blood pressure correlated with increased stroke mortality across all age groups. Consequently, effective hypertension prevention and control has become the central task in both primary and secondary stroke prevention.

Despite these known risks, China's current stroke burden exhibits typical "three highs" characteristics: high incidence, high disability, and high mortality. Data from the 2013 China National Stroke Epidemiology Survey (NESS-China) revealed that compared to three decades prior, stroke incidence and prevalence in rural areas had increased by 31.6% and 155%, respectively, while mortality decreased by 11.4%. In urban areas, incidence and mortality declined by 18.1% and 31%, respectively, though prevalence still rose. The NESS-China study's further follow-up and in-depth analysis showed that both first-ever stroke and stroke event incidence rates were increasing, while mortality was decreasing, inevitably leading to further increases in stroke prevalence and consequently greater socioeconomic burden. According to the Global Burden of Disease (GBD) 2019 study, China experienced 3.94 million new stroke cases, 28.76 million prevalent stroke cases, and 2.19 million stroke deaths in 2019. Moreover, China's stroke DALY rate increased by 36.7% between 1990 and 2019, reaching 45.9 million DALYs in 2019.

1.2 The "One High, Three Lows" Dilemma in China's Hypertension Control

China's hypertension control status can be summarized as a "one high, three lows" dilemma: high prevalence but low awareness, low treatment rates, and low control rates. Data from the China Chronic Disease and Risk Factor Surveillance showed that in 2018, the weighted prevalence of hypertension among Chinese adults aged 18 and above was 27.5%, with higher rates in men (30.8%) than women (24.2%), and in rural areas (29.4%) than urban areas (25.7%).

Age-specific prevalence increased with age for both genders. Only 41.0% of hypertensive adults were aware of their condition, 34.9% were taking antihypertensive medication, and merely 11.0% had their blood pressure under control. Among undiagnosed hypertensive patients, 50.9% had prehypertension. Awareness, treatment, and control rates were relatively higher among women and urban residents compared to men and rural residents.

The 2019 Global Hypertension Control Report from the Non-Communicable Disease Risk Factor Collaboration (NCD-RisC) revealed that between 1990 and 2019, the number of hypertensive patients aged 30-79 worldwide doubled, increasing from 331 million to 626 million among women and from 317 million to 652 million among men. In 2019, over 1 billion hypertensive patients (82% of all hypertensive patients globally) lived in low- and middle-income regions. Hypertension control rates were highest in South Korea, Canada, and the United States (control rate >50%), while China's control rate (13.9% in men, 17.8% in women) remained far below developed countries and the global average. The situation is similarly concerning for hypertension control among stroke patients. Data from China's National Adult Chronic Disease and Nutrition Survey (2015-2017) showed that among 6,580 stroke patients, awareness, treatment, and control rates were 73.6%, 70.2%, and 17.8%, respectively. The NESS-China survey indicated that awareness of hypertension among stroke patients was 76.3%, yet the control rate was only 8%.

The "one high, three lows" status of hypertension control among the general population increases stroke risk, while the same pattern among stroke patients increases recurrence risk, thereby raising stroke disability and mortality rates. Currently, China faces a heavy stroke burden, particularly in underdeveloped rural areas, making hypertension control a formidable task. There is an urgent need to promote and implement effective, evidence-based, and locally adapted hypertension control strategies.

2. Practical Evidence of Hypertension Control Strategies in Stroke Prevention and Management

2.1 Evidence from the "Shandong Salt Reduction" Initiative and Salt Substitute Trials

Launched in 2011, the Shandong Ministry of Health Action on Salt and Hypertension (SMASH) was a government-led initiative aimed at reducing adult hypertension prevalence through salt intake control. The program employed multiple strategies, including media campaigns, distribution of calibrated salt spoons, and public education activities. The results were remarkable: within five years, sodium intake decreased significantly by 24.8%, as measured by 24-hour urinary sodium excretion, which dropped from 5,338 mg/day (13.6 g of salt) to 4,013 mg/day (10 g of salt). Potassium excretion increased by 15.1%, and the sodium-to-potassium ratio decreased by 37.7%, indicating positive dietary changes. Beyond sodium reduction, SMASH demonstrated improved blood pres-

sure levels, with adjusted mean systolic blood pressure decreasing by 1.8 mmHg (1 mmHg = 0.133 kPa) and mean diastolic pressure by 3.1 mmHg, likely attributable to reduced sodium intake. In addition to these physiological changes, systematic evaluation revealed positive impacts on participants' knowledge, attitudes, and behaviors regarding sodium reduction and hypertension. Participants showed improved awareness of recommended salt intake, paid greater attention to processed food labels, and took action to reduce dietary sodium.

Another open-label, cluster-randomized trial examined cardiovascular and safety outcomes of salt substitutes versus regular salt in high-risk adults. The trial assigned 600 villages in rural China to use either a salt substitute (75% sodium chloride, 25% potassium chloride) or continue with regular salt (100% sodium chloride) for all household cooking and food preservation. The study enrolled 20,995 adults with a history of stroke or aged $ $60 years with poorly controlled blood pressure. The primary outcome was stroke events (including first-ever and recurrent strokes), while secondary outcomes were major cardiovascular disease and all-cause death. Results showed that over an average follow-up period of 4.74 years, the salt substitute group had a 14% lower stroke event rate (RR = 0.86, 95% CI = 0.77-0.96), a 13% lower major cardiovascular disease event rate (RR = 0.87, 95% CI = 0.80-0.94), and a 12% lower all-cause mortality rate (RR = 0.88, 95% CI = 0.82-0.95) compared to the regular salt group. There was no difference in the incidence of clinical hyperkalemia between the two groups. These findings support the use of salt substitutes as a safe and effective intervention.

2.2 Evidence from Urban Community Practice

Between 1991 and 2000, the Beijing Neurosurgical Institute established intervention and control communities in Beijing, Shanghai, and Changsha, each with approximately 50,000 participants. The study implemented multifactor interventions targeting high-risk populations (including stroke survivors returning to the community) with a focus on hypertension, while simultaneously conducting population-wide health education and health promotion. After three years of observation, the study assessed changes in key indicators, first-ever stroke incidence and mortality outcomes, and stroke recurrence outcomes. The results showed that first-ever stroke incidence risk decreased by 11.4% (RR = 0.8959, 95% CI = 0.8483-0.9460, P < 0.001), with ischemic stroke incidence risk decreasing by 13.2% (OR = 0.868, 95% CI = 0.805-0.934, P < 0.001) and hemorrhagic stroke risk decreasing by 7.2% (OR = 0.928, 95% CI = 0.852-1.012, P = 0.0899), though the latter difference was not statistically significant. In the Beijing area, population monitoring revealed a 26% reduction in 3-year mortality risk after first-ever stroke (RR = 0.74, 95% CI = 0.61-0.89, P = 0.002). The 3-year cumulative recurrence rates in intervention and control communities were 11.7% versus 20.8% (P = 0.029), respectively. In the intervention communities, the 3-year recurrence risk after first-ever stroke decreased by 42% (RR = 0.58; 95% CI = 0.34-1.00, P = 0.048), with a 39% reduction in mortality risk

after first-ever hemorrhagic stroke (RR = 0.61, 95% CI = 0.46-0.81, P = 0.001). Additionally, a comprehensive intervention study targeting hypertension, diabetes, and smoking control in urban communities showed that after four years of follow-up, major risk factor levels decreased in the intervention population, with stroke incidence declining by 41.4% in men and 46.3% in women. Comparing pre- and post-intervention periods, stroke mortality decreased by 31.8% in men and 19.0% in women. The differences in 5-year average incidence and mortality rates between intervention and control communities were statistically significant ($P < 0.01$).

2.3 Evidence from Rural Community Practice

In 2022, Phase I results of the China Rural Hypertension Control Project (CRHCP study) were published in *The Lancet*, confirming that after 18 months of treatment, the intervention group achieved significantly greater reductions in mean systolic and diastolic blood pressure (14.5 mmHg and 7.1 mmHg, respectively) compared to the control group. In 2023, *The Lancet* published Phase II results of the CRHCP study: 36-month follow-up data first confirmed that implementing a comprehensive protocol including intensive blood pressure control in the entire population reduced systolic blood pressure by >21 mmHg, cardiovascular disease risk by 30%, stroke risk by 23%, and all-cause mortality risk by 15%. These findings provide an actionable solution for hypertension control in rural China and similar regions worldwide. In 2024, research first confirmed that when trained village doctors implemented multifaceted interventions, blood pressure in hypertensive patients aged 60 and older could be controlled below 130/80 mmHg, safely and effectively reducing cardiovascular disease risk by 25%, stroke risk by 26%, and total mortality risk by 10%.

2.4 Evidence from Compound Preparation Strategies

2.4.1 The SECURE Trial: The SECURE trial was a 4-year Phase III randomized controlled clinical trial enrolling post-myocardial infarction patients within 6 months. The trial included 1,237 patients in the polypill group and 1,229 in the control group. The polypill treatment included aspirin (100 mg), ramipril (2.5, 5.0, or 10.0 mg), and atorvastatin (20.0 or 40.0 mg). The primary composite endpoint included cardiovascular death, non-fatal type 1 myocardial infarction, non-fatal ischemic stroke, or urgent revascularization. Results showed that 118 patients (9.5%) in the polypill group versus 156 patients (12.7%) in the conventional treatment group experienced primary outcome events (RR = 0.76, 95% CI = 0.60-0.96, P = 0.02). For secondary endpoints (cardiovascular death, non-fatal type 1 myocardial infarction, or non-fatal ischemic stroke), 101 patients (8.2%) in the polypill group versus 144 patients (11.7%) in the conventional treatment group experienced events (RR = 0.70, 95% CI = 0.54-0.90, P = 0.005). Medication adherence was higher in the polypill group, with similar adverse events between groups. This study demonstrated that polypill therapy within 6 months post-myocardial infarction significantly reduced the risk of

major adverse cardiovascular events.

2.4.2 Effectiveness of Polypill for Primary and Secondary Prevention of Cardiovascular Disease (PolyIran Trial): The PolyIran trial was a 5-year pragmatic cluster-randomized trial conducted in Iran, with 3,421 participants in the polypill group and 3,417 in the control group. The polypill included hydrochlorothiazide (12.5 mg), aspirin (81 mg), atorvastatin (20 mg), and enalapril (5 mg), with 5 mg enalapril replaced by 40 mg valsartan if cough developed during follow-up. Results showed that in real-world settings, polypill use significantly reduced the risk of major adverse cardiovascular events (including acute coronary syndrome hospitalization, fatal myocardial infarction, sudden death, heart failure, coronary revascularization surgery, and non-fatal and fatal stroke) among individuals aged 50-75. The trial confirmed that polypill therapy effectively prevented major adverse cardiovascular events, with high patient adherence, few adverse reactions, and cost-effectiveness. Therefore, the polypill strategy is particularly suitable for promotion as a prevention program to reduce cardiovascular disease burden in low- and middle-income countries.

2.6 WHO HEARTS Program Implementation in China

The WHO-developed HEARTS technical package provides tools for governments and professional organizations to support primary care services (PCS) in applying evidence-based strategies for cardiovascular disease control and prevention. The HEARTS modules include healthy lifestyle counseling, evidence-based treatment protocols, access to essential medicines and technology, cardiovascular disease risk management, team-based care, monitoring systems, and implementation guidelines. The HEARTS China Hypertension Control Project was launched in Henan Province in 2017. By December 2021, 894 PCS had participated, screening over 620,000 individuals, registering 268,000 patients, and treating 190,000 hypertensive patients. At the last follow-up visit, 86,523 patients had achieved blood pressure control targets, and all-cause hospitalizations for cardiovascular disease decreased by 13%. However, data recorded in the monitoring system indicated serious clinical inertia in implementing the HEARTS protocol, suggesting that additional training courses and incentive mechanisms might help PCS improve care quality.

3. Building a "Chinese Path" for Hypertension and Stroke Control

The "2025 WSO/WHL Position Statement: Application of Hypertension Control Strategies in Stroke Prevention and Management" emphasizes the importance of stroke community control from the perspective of health service equity and accessibility. The statement identifies several key community-based hypertension control strategies: opportunistic screening, lifestyle modification, public awareness enhancement/salt reduction, task shifting/task sharing, polypill/digital technology, national hypertension control planning, and the

WHO HEARTS program. These six strategies provide important inspiration for China's prevention and control system innovation. Building a prevention and control path with Chinese characteristics requires adapting these international experiences to China's unique healthcare system, cultural traditions, and technological development level.

3.1 Policy-Driven Systematic Reform

The "Healthy China 2030 Action Plan" has established specific targets for hypertension and cardiovascular disease prevention and control, including expected reductions in cardiovascular disease mortality by 2030, as well as targets for hypertension awareness, standardized management, treatment, and control rates. These policies aim to further promote the implementation of effective evidence-based strategies. In recent years, with improved living standards and intensive salt reduction advocacy, public awareness of salt reduction has gradually increased. The "Xinhua · China Salt Reduction Health Index Report (2024)" showed that the 2024 salt reduction health index reached 76.98 points, up 1.23 points year-on-year, remaining in the 60-80 point "good" range, indicating sustained improvement in residents' salt reduction health levels, though there remains considerable room for improvement. In 2024, Xinhua News Agency and China Salt Group jointly launched the 2024 "Healthy China Salt Reduction Action" campaign in central and state-owned enterprises, effectively promoting salt reduction knowledge dissemination and enhancing public health awareness. Based on the effectiveness of polypill therapy in hypertension control, corresponding policies are needed to facilitate its promotion, including accelerating polypill review and approval processes and addressing issues related to national medical insurance directory inclusion. On March 1, 2023, the new edition of the "National Basic Medical Insurance, Work Injury Insurance, and Maternity Insurance Drug Catalog (2022)" was officially implemented, with the clopidogrel-aspirin polypill included among the newly added drugs. It is expected that more polypills will be included in the medical insurance directory in the future, allowing patients to benefit from innovative medications.

Since 2009, hypertension management has been a core component of the National Essential Public Health Services Program. The continuously updated "National Guidelines for Primary Hypertension Prevention and Management" provide comprehensive guidance for primary healthcare workers in hypertension management. The program aims to gradually achieve homogenization of hypertension management standards between primary care institutions and hospitals, while progressively improving the first-visit rate and control rate at primary care institutions. The current primary hypertension management program has gradually formed a systematic and standardized prevention and control system with expanding service coverage and remarkable management effectiveness. By 2019, approximately 109 million hypertensive patients were registered nationwide, with the standardized management rate increasing by 29.28% over ten years and the blood pressure control rate among managed populations increas-

ing by 16.84% over the same period, representing average annual growth rates of 3.28%. Moreover, the gaps in various indicators between eastern, central, and western regions have been gradually narrowing. Given that 245 million people currently have hypertension in China, hypertension control remains a formidable task. The breakthrough requires multi-dimensional collaborative efforts to build a Chinese-characteristic hypertension control system, focusing on three key dimensions: integrating traditional medical wisdom with modern technology in technical pathways, combining top-level design with grassroots innovation in implementation strategies, and balancing health equity with efficiency improvement in value orientation.

3.2 Digital Intelligence Technology-Enabled Precision Prevention and Control

We are currently in an era of rapid technological development. In recent years, digital intelligence technologies such as wearable devices and machine learning hold promise for providing effective technological support for screening, monitoring, and precision prevention and control of hypertension and high-risk stroke populations. First, the vigorous development of non-invasive, portable, and cuffless sensor technologies enables long-term continuous blood pressure monitoring and facilitates home blood pressure monitoring. Studies have shown that home-measured blood pressure values correlate more significantly with cerebrovascular events than office blood pressure measurements. Additionally, wearable devices can effectively identify nocturnal or sleep-time hypertension, which has greater predictive value for stroke risk than daytime blood pressure. Based on the promotion and application of wearable devices, real-time monitoring of blood pressure fluctuations can be achieved, with data synchronized to the cloud. AI algorithms can identify morning surge hypertension or abnormal fluctuations, automatically sending alerts to doctors and patients to enable timely attention and intervention. Beyond blood pressure, wearable devices have made significant progress in ECG monitoring, diabetes, sleep apnea, lifestyle monitoring, hemodynamics and plaque monitoring, and gait and exercise monitoring, providing new solutions for stroke risk assessment and prevention.

Second, high-risk population prediction based on multi-source data and AI algorithms, as well as intelligent risk factor management platforms based on large models, can already be used for accurate dynamic prediction of stroke risk, enabling early identification of high-risk populations and intensive interventions to reduce stroke risk. Third, health lifestyle interventions, emotional regulation, and medication adjustments delivered through internet-based medical care, smartphone apps, and mobile health education can improve patient medication adherence, enhance treatment confidence, and strengthen self-management capabilities. Remote medical collaboration can also guide grassroots adjustments to personalized intervention and prevention plans, achieving better blood pressure control. These digital intelligence technologies are no longer just prospects; many regions domestically and internationally have taken the lead in exploration

and practice, achieving favorable results. Studies have shown that village doctor-led mobile health interventions can significantly reduce cardiovascular disease risk and improve risk factors and behaviors. During the 12-month follow-up period, the 10-year risk of atherosclerotic cardiovascular disease (ASCVD) decreased from 18% to 11.7% in the intervention group and from 17.8% to 13.6% in the control group, with an absolute difference of -1.88%. Average systolic blood pressure decreased by 23.2 mmHg in the intervention group versus 15.2 mmHg in the control group ($P < 0.001$), while average diastolic blood pressure decreased by 10.9 mmHg versus 6.9 mmHg ($P < 0.001$). The study also observed gradually improving medication adherence and stronger awareness of daily health behaviors among intervention group participants—improvements more gratifying than mere numerical reductions. It is hoped that digital intelligence technology will mature further for early promotion and widespread application, benefiting the public.

3.3 Improvement of National Health Literacy

The 55th "Statistical Report on China's Internet Development" shows that as of December 2024, China had 1.108 billion internet users, with an internet penetration rate of 78.6% and mobile phone usage reaching 99.7%. Currently, platforms like Weibo and WeChat have become the fastest-growing and most active internet applications. With their integrated audio-visual-text capabilities, strong timeliness, broad coverage, and interactive features, they offer tremendous advantages for medical science education. It is necessary to leverage this innovative health education model to better disseminate knowledge about hypertension hazards and prevention, improving awareness rates. Concurrently, attention should be paid to establishing authoritative health education platforms, combating pseudoscience, providing guidance on scientific medication use, reducing misconceptions about "health supplements replacing medications," and improving public information discrimination capabilities. Training in home blood pressure monitoring skills and promoting smart device applications, with data synchronized to family doctors, can enable early screening and intervention. Improving national health literacy can help form a "knowledge-attitude-practice" closed loop, facilitating a shift from passive treatment to active prevention in hypertension control, and enabling better coordination between non-professionals and medical personnel in hypertension and stroke prevention and management.

4. Conclusion: Optimizing Hypertension Control Strategies in Stroke Prevention

Although China's standardized stroke mortality rate has begun to decline, stroke-related risk factors—particularly the continuously rising prevalence of hypertension, coupled with still-unoptimistic awareness, treatment, and control rates—remain concerning. As the foremost modifiable factor, optimizing locally adapted hypertension control strategies in stroke prevention and improving population-level hypertension control is particularly urgent. China's

breakthrough in hypertension control requires multi-dimensional collaborative efforts to build a Chinese-characteristic hypertension control system. Establishing a government-led, multi-stakeholder, technology-supported collaborative governance mechanism will contribute Chinese solutions and strength to global hypertension and stroke prevention and control, transforming the "Healthy China 2030" vision into tangible benefits for hundreds of millions of people.

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