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Editorial Board

Cover Photo: The entire population of Ruili City of Yunnan Province, a total of about 300,000 people, received the COVID-19 vaccination in a campaign starting on April 2, 2021 that lasted 5 days.

Preplanned Studies

Effect of Earlier Vaccination and a Two-Dose Varicella Vaccine Schedule on Varicella Incidence — Beijing Municipality, 2007–2018

Dan Zhao[1]; Luodan Suo[1]; Li Lu[1,#]; Jingbin Pan[1]; Xinghuo Pang[1]; Wei Yao[2]

Summary

What is already known about this topic?

The World Health Organization (WHO) varicella vaccines position paper states that countries where varicella is an important public health burden could consider introducing varicella vaccine (VarV) in the routine childhood immunization program (*1*). VarV has been available for many years in China but is not included in most routine immunization programs in China. As a result, substantial heterogeneity in vaccination coverage exists across regions.

What is added by this report?

In Beijing, adding a second dose of VarV for children and increasing coverage reduced the incidence of varicella. Lowering the age of the first dose of VarV to 12 months could further reduce varicella, especially among toddlers.

What are the implications for public health practice?

Governments should use economic analysis to consider inclusion of VarV into the routine children immunization program as a free vaccine and adopting a 2-dose schedule that starts at 12 months of age.

Varicella, also known as chickenpox, is a common childhood infectious disease caused by varicella-zoster virus (VZV). Varicella vaccine (VarV), with an estimated vaccine effectiveness of 94.0% (95% CI: 89.9%–98.9%) against VZV infection in a 2-dose pediatric schedule (*2*), has been available in China for many years. However, VarV has not been included in most routine immunization programs in China, including in Beijing Municipality. Considerable out-of-pocket costs are paid by parents, and coverage of VarV1 and VarV2 varies widely across the country from 20.8% to 97.8% (*3*–*5*). In October 2012, Beijing health authorities changed the VarV schedule of one dose given at 12 months or older to a 2-dose schedule with VarV1 at 18 months and VarV2 at 4 years. Since this change in the schedule, coverage levels in Beijing have been over 80.0% for VarV1 and 40.0% to 73.0% for VarV2 (*5*).

Varicella is not a nationally notifiable infectious disease in China, and therefore varicella epidemiology has not been well described in most areas of China. It is important for jurisdictions to monitor varicella incidence and VarV coverage to optimize use and impact of VarV. For example, a study that compared the annual incidence of varicella in Beijing Municipality and Ningbo City speculated that the optimal age of VarV1 administration to impact varicella epidemiology of children aged 12–24 months to be 12 months of age (*6*), but the study lacked VarV coverage data that potentially could support giving VarV at 12 months. In this study, we used 12 years of real world data to explore and quantify the impact of VarV1 and VarV2 on the incidence of varicella in Beijing.

Since 2007, clinicians in Beijing have been required to report varicella cases electronically within 24 hours to the National Notifiable Disease Reporting System (NNDRS). We systematically collated NNDRS varicella case information reported during 2007–2018 and determined overall and age-specific annual varicella incidence rates (per 100,000 population), defined as the annual number of cases divided by relevant age-appropriate population sizes obtained from the Beijing Municipal Bureau of Statistics. Data on children enrolled in Beijing's Childhood Immunization Information Management System (CIIMS) at the end of 2018 were used to assemble the 2006 to 2017 birth cohorts. VarV coverage was calculated by dividing the cumulative number of children who had received VarV in each birth cohort during each year by the total number of children in the corresponding birth cohort.

To visualize trends, we created heat maps of varicella incidence and VarV coverage by age group, geographical area, and year. Chi-squared and Cochran-

Armitage trend tests were used to evaluate trends across years. Linear regression was used to explore and quantify relationships between varicella incidence (dependent variable Y) and VarV coverage (independent variable X). Statistical analyses were performed using the Statistical Package for Social Sciences (SPSS/PASW, version 19.0, IBM, New York, USA) and R version 2.15.3 (https://www.r-project.org).

VarV1 coverage among children aged three years (the age of entering kindergarten) increased from 69.4% in 2007 to 86.0% in 2012 and stayed above 85.0% from 2012 through the end of the study period. After a 2-dose schedule was recommended in Beijing, VarV2 coverage among children aged 6 years (the age of entering primary school) increased consistently from 40.1% in 2013 to 74.5% in 2018. Varicella incidence at the age of 0–19 was approximately 300 cases per 100,000 population. In contrast with the previous 1-dose era, incidence decreased by 46.9% during 2012 to 2018 (P<0.001 for trend), varying by age group from 8.3% to 81.4%. Incidence among adults aged 20 years and older did not change (P>0.05 for trend) (Figure1).

When a single dose VarV was recommended for children aged ≥12 months, age-based coverage increased rapidly from 10.0% at 12 months to 50.0% at 14 months, then more gradually increased to 70.0% at 23 months. After the age for the first VarV dose was raised to 18 months, coverage was 10% at 18 months, increasing to 40.0% at 20 months, then further increasing to 70.0% at 22–23 months. At the same time, varicella incidence among children at 1 year of age increased 87.1%, from 366 cases per 100,000 population in 2012 to 684 cases per 100,000 population in 2018, with the most notable increase among children 13–20 months old (Figure 2).

Since 2013, VarV1 coverage has exceeded 80.0% in every Beijing county, but VarV2 coverage has varied widely (24.0%–71.6% in 2013 and 58.5%–89.3% in 2018). Linear regression showed that the incidence of varicella at 0–19 years of age (dependent variable Y) was negatively correlated with VarV2 coverage (independent variable X, with regression model, Y=456.32–3.07X; R^2=0.546; P<0.001). When VarV2 coverage increased to more than 80.0%, the model-predicted incidence at 0–19 years is 195 per 100,000 population, a 16.0% decrease compared with 2018 (with VarV2 coverage at 70.0%) and a 60.2% decrease compared with 2011 (single dose vaccination schedule; no second dose) (Figure 3).

In 2012–2018, the number of outbreaks in Beijing varied between 22 and 44 per year, 44.3% to 72.2% significant decreases compared with 79 outbreaks in 2007. The number of outbreak-related cases varied from 245 to 585 during 2012–2018, representing significant decreases of 38.9% to 74.4% compared to 958 outbreak cases in 2007.

DISCUSSION

Our analysis of 12 years of varicella surveillance data in Beijing showed that the incidence of varicella decreased significantly among people aged 0–19 years during 2007–2018 and that incidence was inversely associated with VarV2 coverage. Regression modeling showed that increasing VarV2 coverage to above 80.0% while maintaining VarV1 coverage ≥85.0% will lead to a further decrease in varicella incidence in Beijing. We found that when the recommended age for the first dose of VarV was raised from ≥12 months to 18months in Beijing in 2012, the incidence of varicella among children aged 12–20 months increased.

Based on World Health Organization (WHO) varicella vaccines position paper recommendations (*1*) and the observed benefits of VarV introduction in United States (*7*–*8*), it appears that a 2-dose VarV schedule should be introduced in China's routine immunization program in the future (*2*). Our study provides evidence to policymakers for improving varicella immunization strategies, including changing VarV reimbursement policies and vaccination scheduling.

The most commonly adopted VarV immunization schedules worldwide is administration of a first dose at 12–18 months and a second dose at 4–6 years of age (*9*). In Beijing, the age for the first dose (18 months) was slightly late, increasing the risk of varicella for children 12–17 months old due to lack of direct protection with VarV. About 90.0% of 18-month-old children were not able receive the first dose on time. There are two potential reasons for this delay. First, measles-mumps-rubella (MMR) vaccine, diphtheria-tetanus-acellular pertussis (DTaP) vaccine, and hepatitis A vaccine are administered during this age, which may make VarV a lower priority than these three Expanded Program on Immunization (EPI) vaccines. Second, healthcare workers do not strongly recommend that children receive non-EPI vaccines like VarV as soon as possible. To overcome these scheduling challenges and the increased incidence

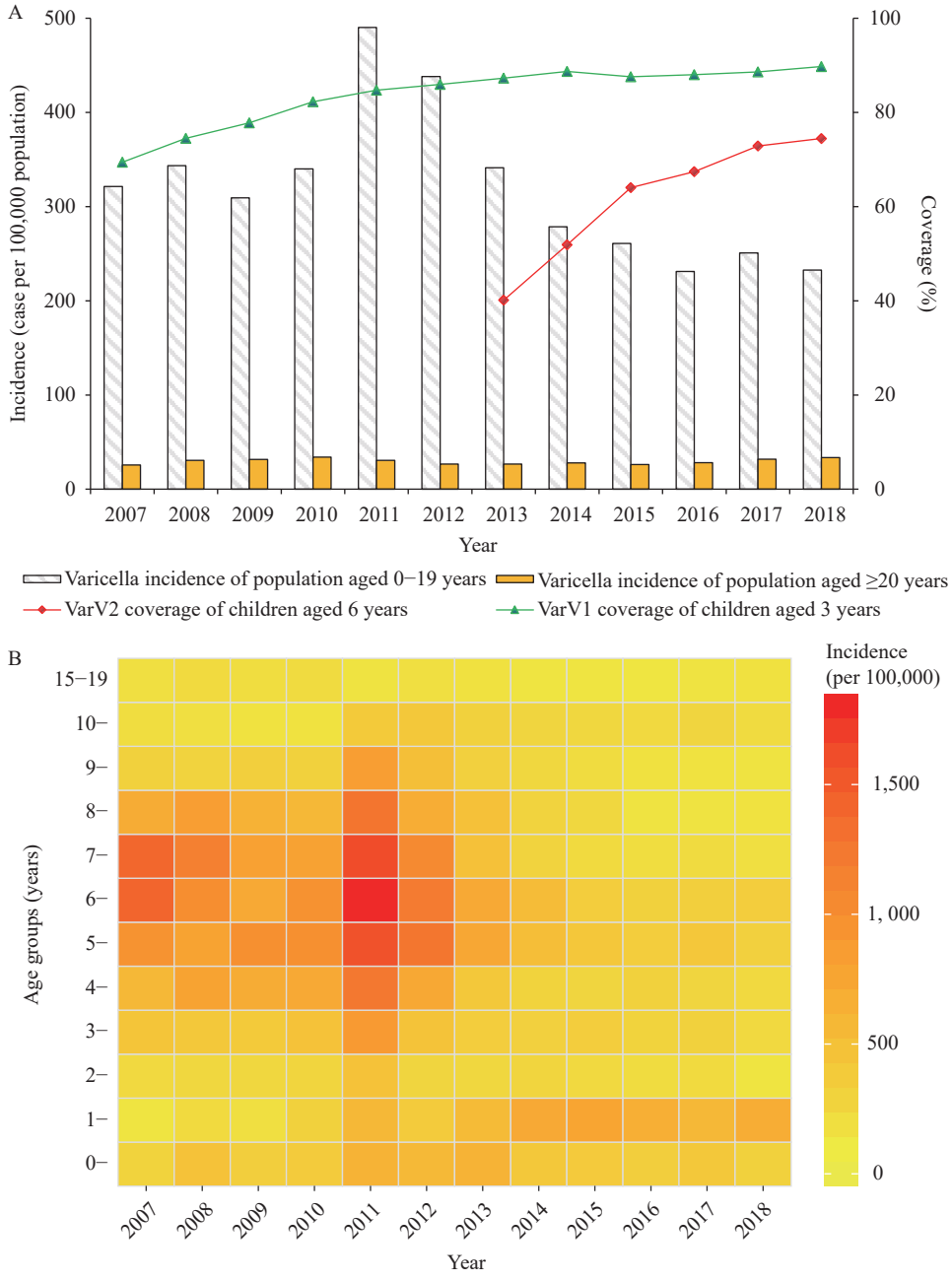

FIGURE 1. Varicella incidence (cases per 100,000 population, by year and by age group) and varicella vaccine (VarV) coverage (%) changes before and after the two-dose schedule recommendation in Beijing, 2007–2018. (A) Varicella incidence among people aged 0–19 years and ≥20 years, with superimposed varicella vaccine coverage of the first dose (VarV1) and second dose (VarV2) in Beijing, 2007–2018. (B) Heat map of varicella incidence in people aged 0–19 years during 2007–2018 in Beijing by age group.

among toddlers with an 18-month first dose, we suggest that the recommended age of the first dose should be set to 12 months.

Our study has some limitations that should be considered. First, our data were obtained from a passive surveillance system, which may be influenced by diagnostic technology, underreporting, and incomplete reporting. However, these real-world data encompass a twelve-year period with consistent reporting policies, and we believe this long and consistent reporting period can partially overcome this concern. Second, it was difficult to determine VarV coverage by month at each year of age. We therefore could not evaluate correlation between coverage and incidence among children aged 12–23 months.

In conclusion, ensuring 12-month vaccination with

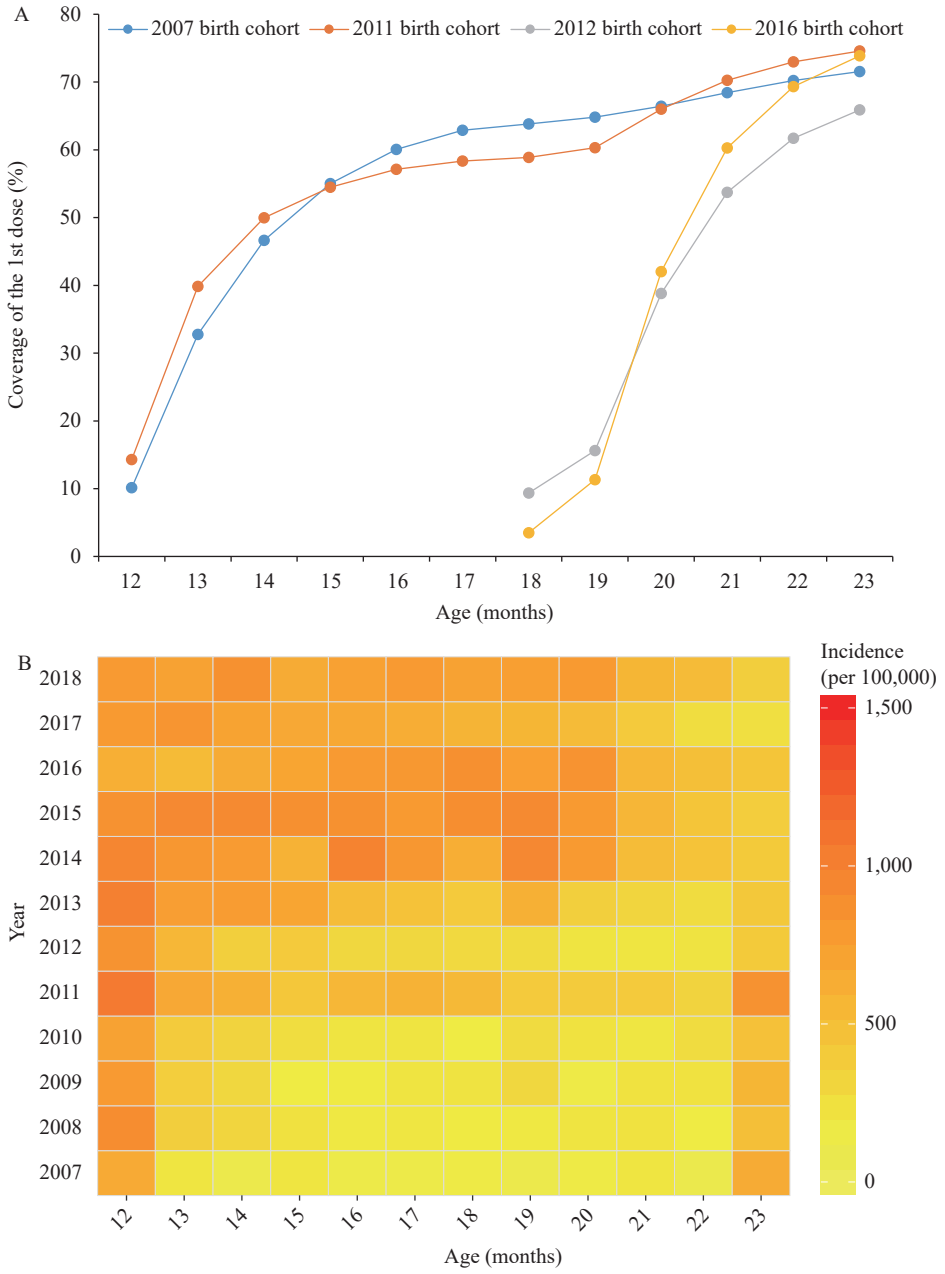

FIGURE 2. Varicella vaccine (VarV) coverage (%) and varicella incidence (cases per 100,000 population) changes in children aged 12–23 months during 2007–2018 in Beijing. (A) First dose VarV coverage among children aged 12–23 months in 2007 and 2011 birth cohorts (the age of the first dose of varicella vaccine was 12 months), and 2012 and 2016 birth cohorts (the first-dose was recommended at 18 months). (B) Heat map time series of varicella incidence per 100,000 population aged 12–23 months during 2007–2018 in Beijing by month of age.

VarV and maintaining two-dose coverage above 80.0% would be useful for varicella control. Including the varicella vaccine into EPI as a free vaccine could increase acceptance and coverage, but additional studies, especially cost-benefit studies, should be conducted to help make such a policy recommendation. Our study can provide evidence for areas with high burdens of varicella to improve disease control and prevention strategies.

Conflicts of interest: The authors declared no competing interests.

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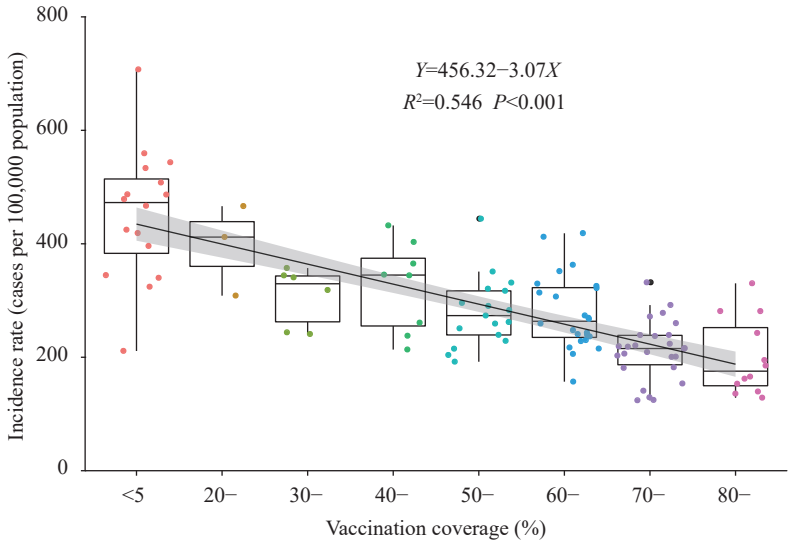

FIGURE 3. Boxplot with a scatter plot of varicella incidence of populations aged 0–19 years (cases per 100,000 population) by different varicella vaccine (VarV) coverage levels (%). The corresponding regression equation for the regression line shown is Y=α+βX (Y is varicella incidence, X is VarV coverage in children aged six years).

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Preplanned Studies

Spatial Analysis of People Living with HIV/AIDS Transmitted Through Commercial Heterosexual Contact or Non-Marital Non-Commercial Heterosexual Contact — China, 2018

Zhilong Dong[1,&]; Xiaohong Pan[2,&]; Chang Cai[3]; Qianqian Qin[3]; George F. Gao[1,#]; Fan Lyu[3,#]

Summary

What is already known about this topic?

Significant changes in human immunodeficiency virus (HIV) transmission modes have occurred in China, and the proportion of heterosexual transmission increased in recent years.

What is added by this report?

The proportions of diverse transmission routes and subgroups of heterosexual transmission were analyzed by provincial-level administrative divisions (PLADs), and nationwide spatial clustering of HIV transmission through commercial heterosexual contact (CHC) and non-marital non-commercial heterosexual contact (NMNCHC) was explored.

What are the implications for public health practice?

This report provides evidence for geographic clustering of HIV transmission through CHC and NMNCHC in China and identifies priority regions where specified research and targeted HIV prevention and control strategies should be implemented.

Over recent years, significant changes in human immunodeficiency virus (HIV) transmission modes have occurred in China, and the proportion of sexually transmitted infections has increased greatly (*1*). In addition, both the number of reported cases of people living with HIV/AIDS (PLWHA) and the distribution of diverse HIV transmission routes display regional characteristics (*2*). However, the nationwide distribution of heterosexual transmission subtypes remains unclear, including commercial heterosexual transmission, non-marital non-commercial heterosexual transmission, and marital heterosexual transmission (*3*).

Fully understanding the spatial characteristics of heterosexual transmission could establish a basis to formulate targeted regional prevention and control measures. For this purpose, this study used data from the Chinese HIV/AIDS Comprehensive Response Information Management System (CRIMS) to analyze the spatial distribution characteristics of the two main modes of heterosexual transmission, including transmission through commercial heterosexual contact (CHC) and non-marital non-commercial heterosexual contact (NMNCHC).

Newly identified cases of HIV infection were reported through the web-based CRIMS by individuals from local CDCs and medical institutions (*4*). Data usage from CRIMS was authorized by the National Center for AIDS/STD Control and Prevention of China CDC. All newly identified PLWHA in 2018 in the CRIMS were included in our study.

The frequency distribution and the constituent ratio of PLWHA infected through various transmission routes and the subgroups of those infected through heterosexual transmission were analyzed in each provincial-level administrative divisions (PLADs). Moreover, Moran's I index was utilized to explore the clustering patterns of PLWHA identified in 2018 in China, with the assumption that cities throughout the country were not significantly different from each other with respect to the spatial distribution of infection. Subsequently, Z-scores with corresponding *P*-values were presented. Statistically significant Moran's I indexes revealed the presence of overall nationwide clustering. After a national level of clustering was confirmed, local clustering analysis was required to detect specific clustering areas. Hotspot analysis (Getis-Ord Gi*) in ArcGIS (version 13.0, Esri Inc, Redlands, CA, USA) was conducted to determine areas with significantly high clusters and areas with significantly low clusters, using 3 levels of confidence intervals (*5*).

In this study, PLADs with large numbers of newly identified PLWHA normally have high proportions of heterosexual transmission. In 2018, heterosexual transmission accounted for 71.5% of all transmission. Among the top 10 PLADs with the highest numbers of

reported PLWHA, the proportions of heterosexual transmission were higher than average in 7 PLADs, including Guizhou (92.5%), Guangxi (91.2%), Yunnan (89.8%), Xinjiang (85.6%), Chongqing (83.2%), Sichuan (83.0%), and Hunan (78.6%), while those of Henan (67.3%), Guangdong (62.4%), and Zhejiang (58.9%) were below average. In addition to these top 10 PLADs, the proportions of heterosexual transmission in most other PLADs were below average, except for Xinjiang Production and Construction Corps (XPCC) (87.8%) and Jiangxi (84.4%), where the numbers of cases were relatively smaller than those of other regions (Figure 1A, Figure 1B).

In general, the proportion of newly identified PLWHA transmitted through NMNCHC (49.0%) was higher than through CHC (38.0%) in heterosexual transmission, and the proportion of NMNCHC-related transmission was higher than that of CHC in most PLADs and regions in 2018. Among the top 10 PLADs with the highest number of reported PLWHA, the ratio of NMNCHC to CHC transmission was greater than 1 in 7 PLADs, with Xinjiang having the highest ratio (5.94∶1), followed by other PLADs such as Guizhou (2.74∶1), Yunnan (2.19∶1), Henan (1.27∶1), Guangdong (1.18∶1), Sichuan (1.05∶1), and Hunan (1.03∶1). Those with a ratio less than 1 included Zhejiang (0.9∶1), Chongqing (0.87∶1), and Guangxi (0.56∶1) (Figure 1C, Figure 1D).

General spatial autocorrelation was conducted for newly identified PLWHA transmitted through CHC and NMNCHC in China in 2018. Moran's I indexes were greater than 0 and the Z-values were greater than 1.96 for both transmission routes (P<0.0001). These results confirmed the potential existence of nationwide HIV/AIDS epidemic clustering for PLWHA transmitted through CHC and NMNCHC (Table 1).

In 2018, 373 cities reported PLWHA transmitted through heterosexual contact, among which cases transmitted through NMNCHC were reported in 371 cities, while PLWHA transmitted through CHC were reported in 360 cities. Furthermore, 13 cities had identified more than 500 cases of PLWHA reported as transmitted via CHC, located in Chongqing, Sichuan, Guangxi, and Yunnan. In contrast, 20 cities had more than 500 PLWHA reported as being transmitted through NMNCHC, including Chongqing, Sichuan, Yunnan, Xinjiang, Guizhou, Guangdong, and Beijing.

The Getis-Ord Gi* statistics revealed that at the 95% confidence level, hotspots of PLWHA infected through CHC were mainly discovered in Sichuan, Chongqing, Guizhou, Guangxi, northeast Yunnan, west Guangdong, west Hunan, southwest Hubei, southeast Gansu, and southwest Shaanxi, whereas cold-spots were observed in large areas of northeastern and northern China, comprised of more than 10 PLADs such as Shandong, Hebei, Tianjin, and Beijing. Hotspots for PLWHA infected through NMNCHC were detected mainly in Sichuan, Chongqing, Yunnan, Guizhou, and the western regions of Guangxi, while cold-spots were observed in eastern Hebei, Tianjin, Shandong, Anhui, northern Jiangsu, eastern Henan, and a small part of western Jilin.

DISCUSSION

This analysis demonstrated that the overall prevalence of HIV in China follows inconsistent distribution patterns across different PLADs. In general, PLADs with higher annual frequencies of newly reported PLWHA have higher proportions of heterosexual transmission. Additionally, the distribution of PLADs and cities is unbalanced in the subclassification of heterosexual transmission. In some regions, transmission via CHC is higher than NMNCHC, while in others, the proportion of transmission through NMNCHC is higher. These findings were consistent with the results of other regional studies (*6*–*7*).

There was a certain degree of overlap among cities with higher numbers of reported cases transmitted through CHC and NMNCHC, but CHC and NMNCHC also displayed unique characteristics with respect to the distribution of hotspots. The distribution of NMNCHC was relatively more concentrated, while that of CHC exhibited a wider pattern of distribution. This could be explained by the fact that NMNCHC was more sporadic than CHC and hence more likely to cluster within areas where there was high HIV prevalence. In addition, CHC was more frequent in eastern China, covering some parts of Guangxi and Guangdong, while NMNCHC was more prevalent in western China, mainly concentrated in the southwest. This may indicate that heterosexual commercial services were comparatively more available in some areas of Guangdong or Guangxi. Further research is essential to determine the underlying causes of CHC hotspots in these areas to develop targeted prevention and control strategies.

The hotspots of CHC and NMNCHC also overlapped to a large extent, and approximately 80% of the hotspots of NMNCHC were overlapped with those of CHC. There was likely some interweaving

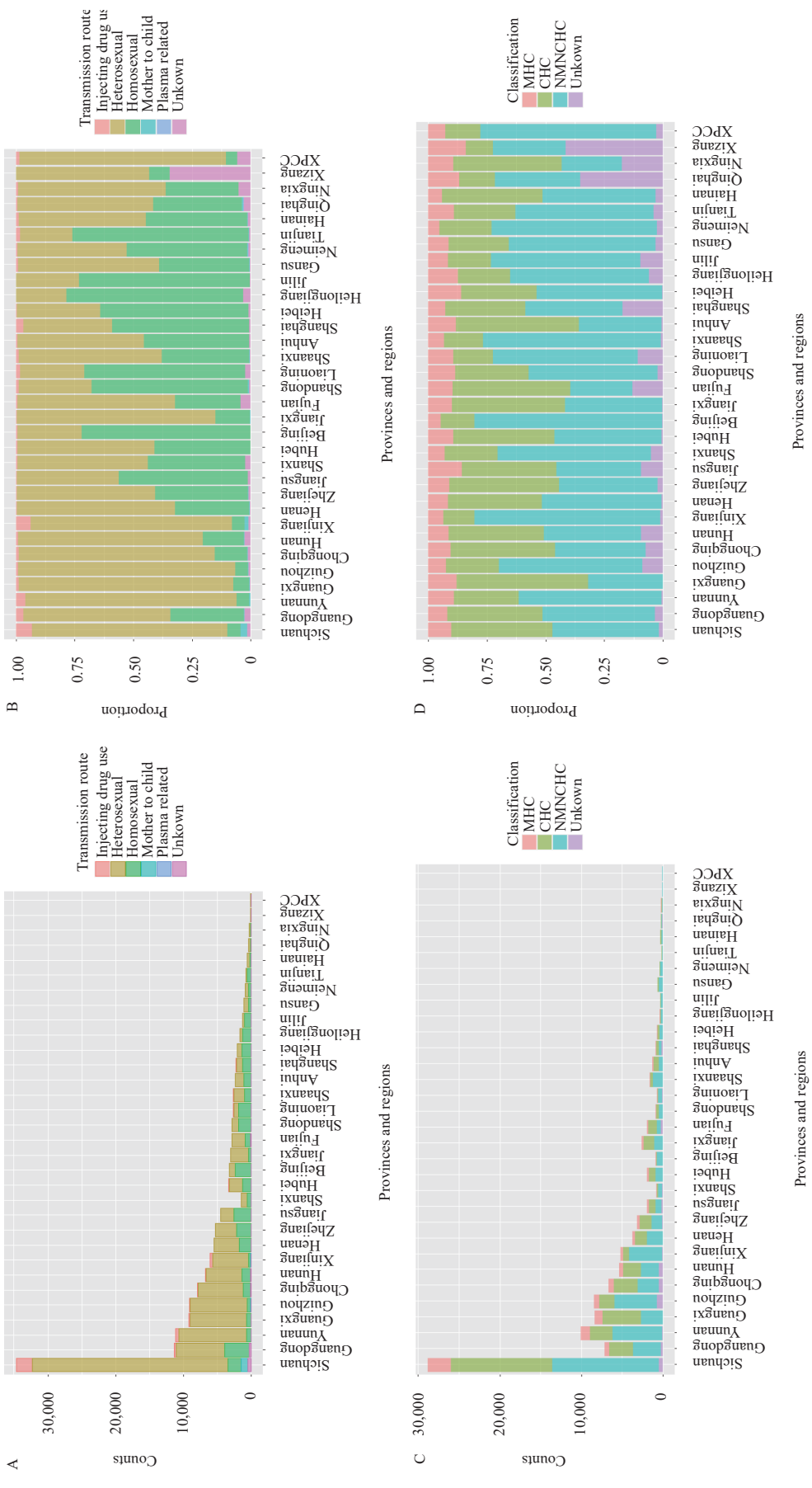

FIGURE 1. Frequency distribution and proportion of newly identified PLWHA transmitted through different transmission routes and through different types of heterosexual transmission by PLADs. (A) Frequency distribution of newly-identified PLWHA transmitted through different transmission routes by PLADs; (B) Proportion of newly-identified PLWHA transmitted through different transmission routes by PLADs; (C) Frequency distribution of newly-identified PLWHA transmitted through different types of heterosexual transmission by PLADs; (D) Proportion of newly-identified PLWHA transmitted through different types of heterosexual transmission by PLADs.

Abbreviations: PLADs=provential-level administrative divisions; MHC=marital heterosexual contact; CHC=commercial heterosexual contact; NMNCHC=non-marital non-commercial heterosexual contact; PLWHA=people living with HIV/AIDS; XPCC=Xinjiang Production and Construction Corps.

TABLE 1. Results of general spatial autocorrelation for the newly identified PLWHA reported as transmitted through CHC and NMNCHC in 2018 in China.

Transmission routes	Moran's I	Z-value	*P*-value
CHC	0.2916	22.33	<0.0001
NMNCHC	0.1847	15.32	<0.0001

Abbreviations: CHC=commercial heterosexual contact; NMNCHC=non-marital non-commercial heterosexual contact; PLWHA=people living with HIV/AIDS.

between these two populations. For example, some men might be engaged in both commercial and non-marital non-commercial heterosexual behaviors, which may transmit HIV from infected female sex workers (FSWs) to uninfected women in the general population, thereby spreading HIV from high-risk groups to the general population through heterosexual transmission (*8*).

However, in the coastal areas of China, no hotspot for CHC or NMNCHC was identified. This may be because the frequency of HIV transmission in coastal areas was relatively low, and the distribution density of the HIV epidemic was relatively small. Consequently, there were fewer sexually transmitted diseases. Nonetheless, this could also be because some large cities in areas such as Beijing or Tianjin have a high prevalence of men who have sex with men (MSM) transmission, accounting for the majority of newly identified PLWHA (*9*–*10*). Furthermore, this study discovered that although the overall proportion of heterosexual transmission in Beijing or Tianjin was comparatively small, NMNCHC remained the principal mode of transmission via heterosexual contact in these areas. Further research is necessary to evaluate the relationship between MSM groups and those cases reported as infected through CHC or NMNCHC.

This study was subject to some limitations. First, the history of sexual contact in the CRIMS is self-reported, which could lead to inaccurate reports due to social desirability, stigmatization, or recall bias. Second, different regions have inconsistent rates of identified cases, which may influence conclusions. However, a large sample size and nationwide coverage could compensate for these deficiencies to some extent.

In summary, this study provided evidence for the geographic clustering of HIV transmission through CHC and NMNCHC in China and identifies priority regions where specified research and targeted HIV prevention and control measures should be implemented.

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Preplanned Studies

Effect of Heart Rate on Major Adverse Cardiovascular Events in Hypertensive Patients with Different Ages and Genders

Yang Xi[1]; Ningling Sun[1,#]

Summary

What is already known on this topic?

The increase of heart rate will increase blood pressure, and the cardiovascular risk will increase when heart rate >80 beats/min (bpm) in patients with hypertension.

What is added by this report?

Compared with patients who were female, <65 years old, and with hypertension, patients who were male, ≥ 65 years old, and with hypertension had the lowest risk of major adverse cardiovascular events (MACE) at baseline heart rate (HR) of 70–74 bpm.

What are the implications for public health practice?

Patients with hypertension should control their blood pressure well, and the HR of male and elderly patients should be managed well at the same time.

The previous follow-up study of the Kailuan cohort in Tangshan City, Hebei Province found that resting heart rate (HR) was associated with all-cause death; the risk of all-cause death was the lowest when heart rate was 68–72 beats/min (bpm) and was the highest when heart rate exceeded 82 bpm (*1*). Compared with the normal population, the related risk was higher in hypertensive population when heart rate was > 80 bpm (*2*). The gender and age of patients with hypertension affected the prognosis of cardiovascular events (*3*), but whether it was related to heart rate was not clear. This study conducted cohort follow-up of patients with hypertension and analyzed the impact of baseline heart rate level on major adverse cardiovascular events (MACE) in patients with different ages and genders.

The HR, blood pressure (BP), systolic blood pressure (SBP), and diastolic blood pressure (DBP) of the patients were measured by Omron medical automatic electronic sphygmomanometers (model: hem-8102a). According to the baseline HR, patients were divided into 4 groups: <70 bpm, 70–74 bpm, 75–79 bpm, and ≥80 bpm. All patients with hypertension were treated with calcium antagonist (amlodipine). If the target BP was not met, other antihypertensive drugs would be added until the target BP was <140/90 mmHg. After 24 months of follow-up, the effects of baseline HR on MACE were analyzed in hypertensive patients of different ages (<65 years old/≥65 years old) and genders (male/female). The definition of MACE includes death, non-fatal stroke, non-fatal myocardial infarction, unstable angina pectoris, coronary intervention, coronary artery bypass grafting, newly onset atrial fibrillation, heart failure, and aortic dissection aneurysm, one of which criteria is enough for patient to be defined as MACE. All statistical analysis was performed by SAS (version 9.4, SAS Institute Inc., Cary, USA).

A total of 9,991 patients with hypertension from 110 hospitals in 21 cities* were enrolled in this study, including 5,045 males, 4,946 females, 5,400 patients aged <65 years, and 4,591 patients aged ≥65 years. The mean age was 64.46±10.65 years. The results showed that faster HR, younger age, and higher baseline SBP and DBP were all significant (all $P<0.001$) (Supplementary Table S1, available in http://weekly.chinacdc.cn/). After 24 months of antihypertensive drug treatment, SBP, DBP of hypertensive patients with different ages and genders were significantly lower than those at baseline ($P<0.001$). HR of female patients after treatment was significantly lower than that of baseline ($P<0.001$), but there was no significant difference in HR of male patients before and after treatment (Table 1).

The results showed that after adjusting for baseline BP, smoking, drinking, hyperlipidemia, diabetes, coronary heart disease, cerebrovascular disease, and taking beta blockers, the relative risk of MACE at baseline HR of 70–74 bpm in male and ≥65 years old patients decreased by 41% and 40% [HR=0.593 (95%CI: 0.401–0.876), $P=0.009$; HR=0.603 (95%CI: 0.422–0.861), $P=0.005$] (Table 2).

* 21 cities: Beijing, Hangzhou, Shanghai, Xuzhou, Nanjing, Guangzhou, Shenzhen, Changsha, Yinchuan, Jilin, Xi'an, Wuhan, Shenyang, Dalian, Tianjin, Zhengzhou, Chongqing, Chengdu, Jinan, Shijiazhuang, Handan.

TABLE 1. Blood pressure and heart rate at baseline and 24 months follow-up in hypertensive patients with different ages and genders.

Item	Systolic blood pressure (mmHg)		Diastolic blood pressure (mmHg)		Heart rate (bpm)	
	Baseline	24 months follow-up	Baseline	24 months follow-up	Baseline	24 months follow-up
≥65 years old (n=4,591)	145.03±17.27	130.97±7.28	82.41±10.31	77.00±6.19	72.90±8.67	71.52±5.81
<65 years old (n=5,400)	145.78±17.52*	130.27±6.99†	87.21±10.52†	78.21±5.75†	74.08±7.93†	71.81±5.42†
Male (n=5,045)	145.40±17.09	130.67±7.09	85.52±10.74	77.86±6.04	71.73±8.28	71.72±5.57
Female (n=4,946)	145.47±17.73	130.51±7.18	84.27±10.57§	77.45±5.94§	73.33±8.32§	71.63±8.32

Abbreviation: bpm=beats/min.

Note: Compared before and after 24 months treatment, except heart rate of male patients, *P* values were <0.001; compared with ≥65 years old, *P<0.05, †P<0.01; compared with male patients, §P <0.01.

TABLE 2. Effects of different baseline heart rate levels on MACE in hypertensive patients with different ages and genders.

Item	Baseline heart rate (bpm)	Hazard ratio (95%CI)	*P*	Hazard ratio (95%CI)*	*P*
Male					
	<70	0.996 (0.685−1.447)	0.981	0.871 (0.593−1.279)	0.480†
	70−74	0.639 (0.436−0.935)	0.021	0.593 (0.401−0.876)	0.009†
	75−79	0.756 (0.506−1.130)	0.173	0.751 (0.500−1.127)	0.167†
	≥80	Ref		Ref	
Female					
	<70	1.063 (0.719−1.570)	0.760	1.007 (0.676−1.501)	0.973†
	70−74	0.860 (0.584−1.266)	0.445	0.891 (0.601−1.321)	0.567†
	75−79	0.713 (0.461−1.104)	0.130	0.791 (0.509−1.230)	0.298†
	≥80	Ref		Ref	
<65 years old					
	<70	1.094 (0.696−1.720)	0.697	1.028 (0.644−1.641)	0.909§
	70−74	0.941 (0.611−1.450)	0.784	0.963 (0.620−1.496)	0.866§
	75−79	0.741 (0.458−1.199)	0.222	0.769 (0.473−1.249)	0.288§
	≥80	Ref		Ref	
≥65 years old					
	<70	0.892 (0.637−1.248)	0.505	0.853 (0.604−1.205)	0.369§
	70−74	0.612 (0.432−0.867)	0.006	0.603 (0.422−0.861)	0.005§
	75−79	0.751 (0.516−1.092)	0.134	0.784 (0.537−1.146)	0.209§
	≥80	Ref		Ref	

Abbreviation: MACE=major adverse cardiovascular events.

* Adjusted for age/gender, baseline blood pressure, smoking, drinking, hyperlipidemia, diabetes, coronary heart disease, cerebrovascular disease, taking beta blockers.

† Adjusted for age, baseline blood pressure, smoking, drinking, hyperlipidemia, diabetes, coronary heart disease, cerebrovascular disease, and taking beta blockers.

§ Adjusted for gender, baseline blood pressure, smoking, drinking, hyperlipidemia, diabetes, coronary heart disease, cerebrovascular disease, and taking beta blockers.

DISCUSSION

The increase of HR is a common clinical phenotype of hypertension. A cross-sectional survey of 115,229 patients with hypertension in 21 cities in China showed that 38.2% of the patients with hypertension had a HR of ≥80 bpm (*4*). In European systolic hypertension trial, compared with patients with baseline HR <80 bpm, patients with baseline HR ≥80 bpm had an 89% increase in all-cause mortality risk after an average follow-up of 24 months (*5*). The previous studies in Chinese and Swedish suggested that there were age and gender differences in the prevalence, awareness, treatment, and control of

hypertension (*6*). However, there are few studies on the optimal HR range of hypertensive patients of different ages and genders (*7*).

The study compared baseline HR of patients with hypertension before treatment. The results showed that patients with faster baseline HR had higher baseline blood pressure and lower age. Previous studies have shown that increased HR is a biomarker of increased sympathetic activity (*8*). This study further suggested that the sympathetic activity was higher in younger patients with hypertension.

Previous studies have shown that estrogen affects the cardiovascular system, including inducing vasodilation, inhibiting vascular remodeling, regulating renin-angiotensin-aldosterone system, and sympathetic nervous system. However, these protective effects can be significantly reversed in postmenopausal women (*9*). The mean age of hypertensive patients in this study was 64.46±10.65 years old, and the female patients at this age were lacking estrogen. The disappearance of estrogen's protective effect in postmenopausal elderly women, which is closely related to increases in blood pressure variability, nocturnal blood pressure load, and cardiovascular events, is likely not related to MACE decreases in hypertensive patients with HR of 70–74 bpm. In addition, previous studies have suggested that elderly age is closely related to the occurrence of MACE, especially in patients with stage 2 hypertension, and the increased risk of MACE was only observed in ≥70 years old patients (*10*). The study showed that the relative risk of MACE was lower when HR was 70–74 bpm in hypertensive patients ≥65 years. Strengthening the management of HR may reduce risk of MACE.

Furthermore, enrolled patients had been treated with standard antihypertensive drugs, which probably was one of the reasons that there was not much difference in systolic blood pressure between men and women and between younger and older people at baseline.

This study was subjected to some limitations. First, 24-hour Holter was not used to evaluate HR variability, which was the deficiency of heart rate analysis in this study. Second, this study was not a prospective study, further studies were needed to confirm the relationship between HR and MACE.

In summary, major adverse cardiovascular events increased when HR was ≥80 bpm in patients with hypertension. To better control the cardiovascular risk of male and elderly hypertensive patients over 65 years old, the HR should be controlled in the range of 70–74 bpm while the blood pressure is properly managed.

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SUPPLEMENTARY TABLE S1. Baseline characteristics of hypertensive patients with different baseline heart rates [($\bar{x}$±s), n (%)].

Baseline HR (bpm)	Age (years)	BMI (kg/m^2)	SBP (mmHg)	DBP (mmHg)	Diabetes (%)	Hyperlipidemia (%)
Total (n=9,991)	64.46±10.65	24.61±2.82	145.43±17.41	84.90±10.67	1,477(14.78)	858(8.59)
<70 (n=2,655)	65.74±10.73	24.59±2.81	143.23±17.07	82.75±10.87	422(15.89)	250(9.42)
70–74 (n=3,589)	64.47±10.47 *	24.53±2.78	143.59±16.65	84.13±10.16 *	507(14.13)	294(8.19)
75–79 (n=2,305)	63.28±10.37 *, †	24.72±2.78	146.35±16.83*, †	85.99±10.10*, †	320(13.88)	188(8.16)
≥80 (n=1,442)	63.94±11.17 *	24.66±2.99	152.62±18.73*, †, §	89.04±11.10 *, †, §	228(15.81)	126(8.74)
	F=23.409	*F*=2.355	*F*=115.527	*F*=126.957	χ^2=6.525	χ^2=3.627
P value	<0.001	0.070	<0.001	<0.001	0.089	0.305

Abbreviation: SBP=systolic blood pressure; DBP=diastolic blood pressure; HR=heart rate; bpm=beats/min.
* compared with <70 bpm, *P*<0.05.
† compared with 70–74 bpm, *P*<0.05.
§ compared with 75–79 bmp, *P*<0.05.

Vital Surveillances

Cardiovascular Disease Mortality — China, 2019

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ABSTRACT

Introduction: Cardiovascular disease (CVD) is the leading cause of death and has caused a heavy burden in China. China has about 106 million CVD patients, including 33 million with stroke. This study presents the latest cardiovascular mortality in China in 2019 to provide evidence for disease control and prevention.

Methods: Mortality data from the China Death Surveillance Point System (DSP System) was used for CVD mortality estimation. A descriptive analysis was conducted to demonstrate the results.

Results: A total of 5.09 million CVD deaths were estimated in China in 2019, with a mortality rate and age-standardized mortality rate of 364.5 per 100,000 population and 276.0 per 100,000, respectively. Stroke is the leading cause of death, and the mortality rate and age-standardized mortality rate (ASMR) were 171.6 per 100,000 and 130.0 per 100,000, respectively. The second major cause was ischemic heart diseases, and the mortality rate and ASMR were 147.3 per 100,000 and 142.1 per 100,000, respectively. Stroke and ischemic heart diseases were the two major causes of CVD deaths, which accounted for over 87% of all CVD deaths.

Conclusions: Although age-standardized mortality of CVD continues to decline in China, the number of deaths is still increasing. Therefore, prevention and control efforts for CVD should be maintained. In order to achieve the "Healthy China 2030" goal of reducing the mortality rate of CVD in China, it is necessary to further strengthen the prevention, control, and treatment capacity of stroke. Meanwhile, increases in ischemic heart disease deaths in highly developed areas should be monitored.

INTRODUCTIONS

With socioeconomic development, the lifestyle of the general public in China has shifted significantly. Especially with the acceleration of population aging and urbanization in China, people are increasingly exposed to cardiovascular-related risk factors, and the incidence and prevalence of cardiovascular disease (CVD) has increased in the past 10 years (*1*). According to the 2018 report on CVDs in China, the report estimated that the number of cardiovascular patients in China was about 290 million, among which approximately 13 million had stroke and approximately 11 million had coronary heart disease. CVD remains the top cause of death and it accounted for over 40% of deaths in China in 2016. Stroke was ranked as the first cause of death among CVDs (*2*–*3*).

The Chinese government pays a lot of attention to the prevention and control of CVDs. In the past five years, the Chinese government has issued several important policy documents, including "China's medium-to-long term plan for the prevention and treatment of chronic diseases (2017–2025)" (*4*), "Healthy China 2030" (*5*), and "Healthy China Action (2019–2030)" (*6*), all of which set the reduction of cardiovascular deaths as the priority goal for prevention and control. This report provides a detailed picture about the level and distribution of CVD mortality nationwide in 2019, which will be useful for evaluating CVD prevention and control efforts in the future.

METHODS

The data analyzed in this study came from the National Disease Surveillance Point (DSP) system of China, which covered 24% of the population (over 300 million) and collected all causes of death in 605 surveillance points. Previous work has demonstrated its national and provincial representativeness (*7*). A DSP surveillance point represents a rural county or an urban district, which is an administration unit in China.

In 2019, a total of 1,867,524 deaths were reported to the DSP system. International Classification of Diseases 10th revision (ICD-10) was used to identify CVD deaths (I00-I99). The mortality data was obtained and stratified by causes of CVD, sex, age group, area type (urban/rural), and region (eastern/central/western). National population data was obtained from the National Bureau of Statistics in 2019 with identical stratification as the mortality data.

The crude mortality rate (CMR) of CVD was calculated by using the number of deaths and associated populations. The mortality rate was adjusted through a formula to prevent underreporting of data: adjusted mortality rate (AMR) = crude morality rate/(1–underreporting rate). The overall underreporting rate of CVD (12.9%) was based on propensity score weighting established in a previous study (*8*). By multiplying the mortality rate in specific populations for each stratum and calculating the sum, CVD deaths were estimated by using scaled-up aggregation data in each stratum. The Sixth National Population Census in 2010 was used for age-standardized mortality rate (ASMR) estimation. SAS software (version 9.4, SAS Institute Inc., Cary, USA) was applied for statistical analysis.

RESULTS

The statistics regarding adjusted mortality rates, ASMR, and estimated CVD deaths nationwide in 2019 were shown in Table 1. The mortality rate for all CVD deaths were 364.5 per 100,000 population, 387.6 per 100,000 for males, and 340.9 per 100,000 for females. An estimated of 5.09 million people died because of CVD in 2019, of whom 2.76 million were male and 2.33 million were female. Stroke was the leading cause of death, and the mortality rate and ASMR were 171.6 per 100,000 and 130.0 per 100,000, respectively. The second major cause was ischemic heart diseases, and the mortality rate and ASMR were 147.3 per 100,000 and 142.1 per 100,000, respectively. Stroke and ischemic heart diseases were the two major causes of CVD deaths for both genders. The number of deaths caused by the 2 diseases was estimated to be over 4.45 million and accounted for over 87% deaths of all CVD deaths.

The mortality rate and ASMR of CVD in different areas and regions were demonstrated in Table 2. In 2019, the ASMR of CVD in rural areas was 294.8 per 100,000, which was higher than that in urban areas (241.7/100,000). For different regions, the ASMR was the lowest in the eastern region, followed by the western region, and was the highest in the central region, with 242.6/100,000, 286.0/100,000, and 313.0/100,000, respectively. Stroke was still the most common cause of deaths in different areas and regions, and ASMR was the highest in western rural areas, reaching 154.0/100,000. In eastern urban areas, ischemic heart disease surpassed stroke and became the leading cause of death among CVD, with the ASMR reaching 95.1/100,000.

DISCUSSION

This article provided the latest information on CVD deaths in China and displayed regional differences of type-specific CVDs.

China's cardiovascular mortality rate was 364.5 per 100,000 population in 2019 with males higher than females, which was consistent with other previous studies (*2*–*3*). Compared with the surveillance results published by China CDC in 2015, the CVD mortality rate increased 7.4% and ASMR decreased 4.7% (*9*). The results indicated that the increase in the number of deaths from CVD was closely related to population aging. In 2019, CVD accounted for 47% of all deaths in China, suggested that two out of every five deaths were CVD patients.

The mortality rate of CVD was higher in central and western regions than in the eastern region, and higher in rural areas than in urban areas. The results can be explained by the high-salt diet in northern and northeastern areas of China, as well as the high

TABLE 1. Mortality rate, age-standardized mortality rate (ASMR), and estimated deaths of cardiovascular diseases categorized by sex in China, 2019.

ICD-10	Cause	Mortality rate (per 100,000)			ASMR (per 100,000)			Estimated number of deaths		
		Both	Male	Female	Both	Male	Female	Both	Male	Female
I00–I99	Cardiovascular diseases	364.5	387.6	340.9	276.0	325.7	229.0	5,090,379	2,763,498	2,326,881
I01–I09	Rheumatic heart diseases	4.7	4.0	5.4	3.6	3.3	3.7	65,637	28,632	37,005
I10–I13	Hypertensive heart diseases	26.4	25.3	27.6	19.9	21.4	18.1	368,686	180,341	188,345
I20–I25	Ischemic heart diseases	147.3	152.1	142.1	111.4	128.6	94.7	2,057,100	1,085,879	971,221
I60–I69	Stroke	171.6	189.7	153.3	130.0	158.1	103.8	2,396,458	1,351,142	1,045,316
I40–I42, I51.4–I51.6	Cardiomyopathy and myocarditis	1.9	2.1	1.6	1.5	1.9	1.2	26,534	15,343	11,191

Abbreviation: ICD-10=International Classification of Diseases 10th revision.

TABLE 2. Mortality rate (per 100,000) and age-standardized mortality rate (per 100,000) of cardiovascular diseases categorized by area and region in China, 2019.

Item	Total		East			Central			West		
	Urban	Rural	Total	Urban	Rural	Total	Urban	Rural	Total	Urban	Rural
Mortality rate											
Cardiovascular diseases	331.0	382.0	358.7	324.3	378.8	393.1	351.2	410.4	336.1	320.2	345.1
Rheumatic heart diseases	4.1	5.1	3.4	3.2	3.6	4.7	3.2	5.3	6.5	6.2	6.9
Hypertensive heart diseases	21.9	28.8	24.6	19.4	27.6	30.8	24.9	33.3	23.3	22.5	23.8
Ischemic heart diseases	141.0	150.5	149.8	146.0	152.0	164.5	150.6	170.3	120.8	123.0	119.4
Stroke	149.3	183.2	164.9	137.8	180.6	183.0	162.8	191.3	167.4	152.8	175.7
Cardiomyopathy and myocarditis	1.7	2.0	1.1	1.2	1.1	1.2	1.4	1.2	3.8	2.7	4.5
Age-standardized mortality rate											
Cardiovascular diseases	241.7	294.8	242.6	212.7	260.6	313.0	274.9	329.2	286.0	257.6	303.8
Rheumatic heart diseases	3.0	3.9	2.3	2.2	2.4	3.7	2.5	4.2	5.7	5.1	6.1
Hypertensive heart diseases	15.8	22.0	16.3	12.5	18.6	24.5	19.3	26.8	19.9	18.0	20.9
Ischemic heart diseases	102.5	116.1	100.9	95.1	104.5	131.1	118.1	136.7	103.1	99.3	105.4
Stroke	109.1	141.2	111.8	90.7	124.3	145.2	127.1	152.9	141.8	122.3	154.0
Cardiomyopathy and myocarditis	1.3	1.6	0.9	0.9	0.9	1.1	1.2	1.0	3.3	2.2	4.0

prevalence of hypertension, high total cholesterol, blood glucose level, and high smoking rate in the central and western regions (*10*). It is necessary to strengthen the interventions of these risk factors in the central and western regions.

Stroke is still the most important cause of death of CVD in China. Compared with surveillance results in 2015 (*9*), ASMR decreased by 8.4%. A nationwide retrospective survey of cerebrovascular disease confirmed the reported trend of declining stroke mortality (*11*). Reasons for declining stroke mortality mainly include the improvement of access to healthcare, the progress of medical technology, and the improvement of public health conditions (*12*). Meanwhile, ASMR of ischemic heart disease continued to increase by 3.6% compared with 2015 (*9*), and in highly developed areas (eastern urban areas), the burden of ischemic heart disease has surpassed that of stroke.

The findings were subject to some limitations. The reporting of underlying cause-of-death has flaws and data underreporting was inevitable. Although we had adjusted the underreporting rate in the study, the underreporting rate is not the latest one corresponding to 2019. Therefore, the reported results may underestimate the current level of CVD and cerebrovascular disease deaths.

Although age-standardized mortality of CVD continues to decline in China, the number of deaths is still increasing. Prevention and control efforts for CVD should be maintained in the future. To achieve the "Healthy China 2030" goal of reducing the mortality rate of CVD in China, it is necessary to further strengthen the prevention, control, and treatment capacity of stroke, while the increase of ischemic heart disease deaths in developed regions should be closely monitored.

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Recollections

Development and Impacts of the Sierra Leone-China Laboratory for Parasitic Diseases Testing and Surveillance

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BACKGROUND

The Republic of Sierra Leone is located on the west coast of Africa, bordering Guinea and Liberia, with a population of 7.8 million in 2019 (*1*). It has a tropical monsoon climate, with high temperatures and plentiful precipitation. As one of the least developed countries in the world (*2*), Sierra Leone has long struggled with poor health outcomes with a life expectancy at birth of 59 for male and 61 for female, and high maternal and neonatal mortality, threatened by infectious diseases such as malaria, tuberculosis, typhoid fever, cholera, and Lassa fever (*3*).

Since March 2014, the 3 West African countries of Sierra Leone, Guinea, and Liberia have been hit by the worst outbreak of Ebola virus disease (EVD) in history. A total of 28,610 cases and 11,308 deaths were reported (*4*). As requested, the Chinese government has rapidly sent 1,200 medical staff to these countries to fight against Ebola (*5*). In a bid to conduct testing for Ebola and other viral hemorrhagic fevers (VHF), China CDC established the Sierra Leone-China Friendship Fixed Biological Safety Laboratory Level 3 (BSL-3 Laboratory) in Sierra Leone, which was officially put in operation in March 2015. It now serves as the national reference laboratory for VHF in Sierra Leone and the national training center for virus testing and biosafety. Since then, China and Sierra Leone have implemented 2 technical cooperation projects (Phase 1 and Phase 2) based on the BSL-3 Laboratory to provide technical support to Sierra Leone in terms of VHF testing capacity and surveillance capacity of key infectious diseases.

Sierra Leone also suffers from a heavy burden of parasitic diseases, including malaria, schistosomiasis, lymphatic filariasis, onchocerciasis, soil-transmitted helminth diseases, and African trypanosomiasis (*6*). The Global Burden of Disease Study 2019 showed that the malaria burden in Sierra Leone in 2019 was 824,000 (355,000–1,400,000) disability-adjusted life years (DALYs) per 100,000 individuals, and the onchocerciasis burden was 23,000(9,750–40,000) DALYs per 100,000 individuals (*7*). According to the *World Malaria Report 2020*, Sierra Leone reported 2,615,850 malaria cases in 2019 with an average incidence rate of 33.5% (2,615,850/7,813,207), and 6,824 malaria deaths with a case fatality rate of 0.3% (6,824/2,615,850). It is estimated that 2.24 million outpatient visits each year were due to malaria, of which about 1 million were children under 5 years old (*8*). Parasitic diseases, especially malaria, have posed great threats to health and socioeconomic development in Sierra Leone.

At present, Sierra Leone faces huge challenges in the prevention and control of parasitic diseases. First, many weaknesses exist in its public health system, including laboratory testing capacity, implementation of prevention and control measures, prevention and control personnel, and data quality. Second, prevention and control efforts fall short of strong fundamentals with few national epidemiological data and incomplete vector monitoring data. Third, the parasitic disease control program is unsustainable and needs more investment as it is largely dependent on international aid projects.

To understand the disease spectrum and infection status of parasitic diseases in Sierra Leone, the Sierra Leone-China BSL-3 laboratory for parasitic disease testing and surveillance (parasitic disease laboratory) was jointly established by China CDC and Ministry of Health and Sanitation of the Republic of Sierra Leone. This paper reviews the establishment, development, and impacts of the BSL-3 laboratory.

ESTABLISHMENT PROCESS AND WORK CONTENT

When the BSL-3 Laboratory Technical Cooperation Project Phase 1 (July 2015–June 2017) was underway, China CDC had realized the importance of malaria infection and planned to build the laboratory's testing capacity for malaria. To promote the convenience and

efficiency of testing, a special laboratory for parasitic diseases was set up in the Sierra Leone-China Friendship Hospital in July 2017 during the implementation of BSL-3 Laboratory Technical Cooperation Project Phase 2, in which febrile patients were tested for malaria.

The parasitic disease laboratory is designed in accordance with the standards of a Biosafety Level 2 Laboratory. With one year's efforts, the laboratory has established basic conditions for malaria detection and mosquito vector identification. The development history of the laboratory was shown in Figure 1.

ACHIEVEMENTS AND EXPERIENCES

Supported by the BSL-3 Laboratory Technical Cooperation Project Phase 2, 10 general hospitals were selected as sentinel hospitals in 3 regions of Sierra Leone (later expanded to 13 sentinel hospitals in 6 regions).

During June 2017 to June 2020, relying on the BSL-3 Laboratory, the parasitic disease laboratory has detected 14,444 blood samples of febrile patients from sentinel hospitals by rapid diagnostic tests (RDTs) for malaria, of which 2,918 were positive with a positivity rate of 20.2% (2,918/14,444) (Figure 2).

A total of 413 RDT-test-positive blood samples were applied for species identification by microscopy, in which the *Plasmodium. falciparum* infection accounted for 56.2% (232/413), other *Plasmodium* excluded *P. falciparum* (PAN) infection accounted for 4.3% (18/413), mixed infection with *P. falciparum* and other *Plasmodium* accounted for 39.5% (163/413). The results demonstrated that *P. falciparum* was a dominant pathogen of malaria in Sierra Leone.

The Kato-Katz technique was deployed to test the stool samples for soil-transmitted helminth infections, with the equipment and expertise of the parasitic disease laboratory in collaboration with the Chinese medical team. The results indicated that the ascaris and

FIGURE 1. Milestones of Sierra Leone-China laboratory for parasitic diseases testing and surveillance.

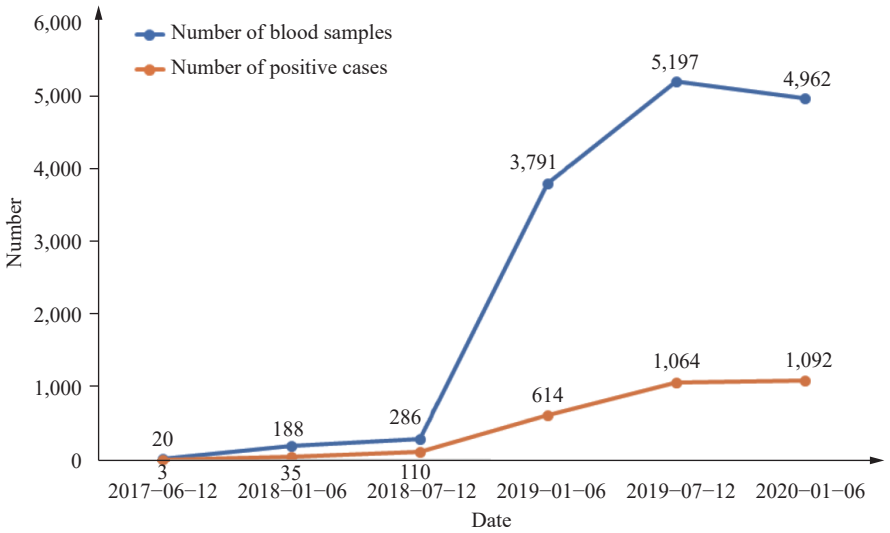

FIGURE 2. Number of blood samples and malaria-positive cases tested by the Sierra Leone-China laboratory for parasitic disease testing and surveillance from 2017 to 2020.

hookworm eggs positive rate was 40.0% (5/20). At the same time, the laboratory carried out a 3-year plan for monitoring *Anopheles* mosquitoes at 10 field sites in the western urban areas and suburban areas of Sierra Leone's capital. According to morphological identification, out of 22,947 mosquito samples, *Anopheles* (*An. gambiae* s.s., *An. funestus*, and *An. melas*) accounted for 15.3% (Figure 3).

The parasitic disease laboratory serves as a reference laboratory for parasite identification in Sierra Leone. It provides timely technical support for patient treatment. The laboratory once carried out a molecular analysis of a blood sample from a Chinese patient with severe artesunate hemolysis who was later confirmed with *P. falciparum* infection. In 2017, when a mudslide hit Freetown, the capital city of Sierra Leone, the experts from the laboratory played a crucial role in diseases and vectors surveillance, evaluation, and disinfection. Moreover, the laboratory also works on mosquito vector monitoring in many high-risk communities of Sierra Leone and Chinese-funded enterprises.

The parasitic disease laboratory is dedicated to the detection and monitoring of parasites and tropical diseases, which further enhances work efficiency and resource allocation of the BSL-3 laboratory. In Sierra Leone, a country with a high burden of parasitic diseases accompanied by VHF such as Ebola and Lassa fever, establishing a specialized laboratory for parasitic disease detection based on the BSL-3 laboratory model is crucial to strengthening the public health systems. From the perspective of biosafety, the nucleic acid extraction of samples from the Lassa fever epidemic area could be completed in a P3 laboratory and then transferred to the parasitic disease laboratory for testing. Samples of suspected cases from other areas can be directly tested in the parasitic disease laboratory. In terms of technology and talents, the technical staff were recruited from medical colleges and universities in Sierra Leone or recommended by the Ministry of Health and Sanitation of Sierra Leone. These staff were first dispatched to parasitic disease laboratories at a lower biosafety level, and later some high-achieving individuals ones were selected to work in the BSL-3 laboratory. This upward movement of personnel fits the present status of their public health capacity in Sierra Leone.

The laboratory has laid a solid foundation for bilateral and multilateral cooperation projects in public health, as it is a platform for Sierra Leone and other international organizations to learn more about China's products and experience in the prevention and control of parasitic diseases. Based on previous achievements, the Bill and Melinda Gates Foundation has decided to support China CDC to implement molecular epidemiological research on malaria in Sierra Leone.

CHALLENGES AND PERSPECTIVE

In 2005, the World Health Organization (WHO) recommended artemisinin-based combination

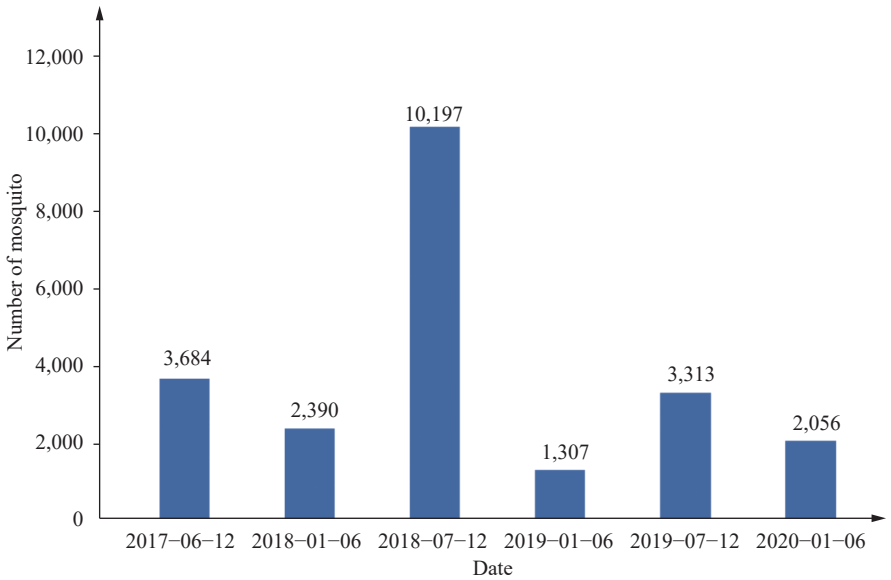

FIGURE 3. Identification number of mosquito vectors by the Sierra Leone-China laboratory for parasitic disease testing and surveillance from 2017 to 2020.

therapies as first-line treatments for falciparum malaria in endemic areas (*9*). However, artemisinin resistance has been reported in Rwanda and other countries (*10*). If resistant strains continue to spread, the lives of tens of thousands of African patients could be at risk. Hence, it is an urgent task to monitor the *Plasmodium*-resistance to artemisinin, which remains a huge challenge for Sierra Leone.

According to the WHO's evaluation of Sierra Leone's National Malaria Control Program, Sierra Leone still encounters significant challenges in malaria control. For instance, most laboratories in Sierra Leone have weak testing capacities and inadequate personnel for parasitic diseases and other neglected tropical diseases because of underinvestment. Although technical personnel have been trained in recent years, the overall technical capacity of the country is still inadequate.

The parasitic disease laboratory could be one of the cornerstones for this capacity. Since its establishment in 2017, the parasitic disease laboratory has done field tests for malaria and soil-transmitted helminth diseases as well as vector monitoring. Meanwhile, it is also an important and successful platform in Sierra Leone for training personnel in parasitic disease testing. Laboratory testing capacity of the parasitic diseases should be further enhanced in the future, not only covering malaria control and mosquito vector identification, but expanding to other neglected tropical diseases such as schistosomiasis and filariasis. The laboratory aims to serve as a training and health education base and parasite resource bank in support of parasitic disease control and research in Sierra Leone.

To implement the commitment of China-Africa health cooperation, more effort must be made to explore a model of establishing parasitic disease testing laboratories in countries with high parasitic disease burdens based on public health foreign-aid teams or hospitals where Chinese medical teams work. With the help of the epidemiological knowledge and field work experience from public health foreign aid teams and the clinical resources from medical teams, the Sierra Leone-China laboratory for parasitic disease testing and surveillance could work on multicenter clinical trials for parasite testing and antimalarial drugs and vaccines, which provide technical support for the China-Africa cooperation project on malaria and schistosomiasis control and help spread and share China's experience and products in parasitic disease control and prevention.

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