Postprint of Key Interpretations of the China Cardiovascular Health and Disease Report 2022

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Abstract

Due to accelerated population aging and the prevalence of unhealthy lifestyles in China, the population with cardiovascular disease (CVD) risk factors is substantial, and the CVD burden continues to increase. In the composition of disease mortality among urban and rural residents in China, CVD remains the leading cause of death. In 2020, CVD accounted for 48.00% and 45.86% of deaths in rural and urban areas, respectively, with 2 out of every 5 deaths attributable to CVD. It is estimated that the current number of CVD patients in China is 330 million, including 13 million with stroke, 11.39 million with coronary heart disease, 8.9 million with heart failure, 5 million with pulmonary heart disease, 4.87 million with atrial fibrillation, 2.5 million with rheumatic heart disease, 2 million with congenital heart disease, 45.3 million with peripheral arterial disease, and 245 million with hypertension. The total hospitalization costs for cardiovascular and cerebrovascular diseases in China in 2020 amounted to 270.901 billion yuan. CVD prevention and control remains a formidable and long-term task. Overall, China should adopt a dual-pronged approach addressing both 'established disease' and 'pre-disease', improving both secondary prevention and treatment of CVD and further strengthening upstream management of modifiable risk factors such as hypertension, hyperglycemia, and hyperlipidemia, while emphasizing the allocation and prioritization of health care and public health resources, in order to reach an inflection point in CVD prevention and control at an earlier date.

Full Text

Preamble

Due to accelerated population aging and the prevalence of unhealthy lifestyles, China faces a massive population with cardiovascular disease (CVD) risk factors, leading to a continuously increasing CVD burden. CVD remains the leading cause of death among urban and rural residents in China. In 2020, CVD

accounted for 48.00% and 45.86% of deaths in rural and urban areas, respectively, meaning two out of every five deaths were attributable to CVD. The estimated number of people living with CVD in China is 330 million, including 13 million stroke cases, 11.39 million coronary heart disease cases, 8.9 million heart failure cases, 5 million pulmonary heart disease cases, 4.87 million atrial fibrillation cases, 2.5 million rheumatic heart disease cases, 2 million congenital heart disease cases, 45.3 million peripheral arterial disease cases, and 245 million hypertension cases. The total hospitalization costs for CVD in China reached 270.901 billion yuan in 2020. CVD prevention and treatment remains a formidable challenge. Overall, China should adopt a dual approach addressing both "existing disease" and "pre-disease" states, focusing on secondary prevention while strengthening upstream management of modifiable risk factors such as hypertension, hyperglycemia, and hyperlipidemia, with attention to healthcare resource allocation and prioritization to achieve an inflection point in CVD prevention and treatment as early as possible.

1.1 Tobacco Use

China is the world's largest tobacco consumer and victim. Global Burden of Disease (GBD) 2019 research shows that smoking-attributable deaths in China increased from 1.5 million to 2.4 million between 1990 and 2019, a 57.9% increase. Chinese men have consistently had the highest smoking rate globally. The 2018 China Adult Tobacco Survey revealed that the smoking rate among individuals aged $ $15 years was 26.6%, with 50.5% among men and 2.1% among women. Adolescent smoking is also concerning: the 2021 Global Youth Tobacco Survey showed a smoking rate of 4.7% among middle school students, with an experimental smoking rate of 16.7%. Vocational high school students had the highest experimental smoking rate at 28.9%, followed by regular high school students (18.9%) and junior high school students (12.9%).

The China Health Literacy Survey (CHLS), covering 84,839 participants across 31 provinces, found that in 2018, the tobacco dependence rate among Chinese adults aged 20–69 was 13.1%, with 49.7% among current smokers, translating to approximately 183.5 million smokers with tobacco dependence (177.5 million men). In 2018, 68.1% of non-smokers aged $ $15 were exposed to secondhand smoke, and 71.9% reported seeing people smoke indoors. The current e-cigarette use rate was 0.9%.

The China Kadoorie Biobank (CKB) study, following 461,047 adults aged 30–79 for a median of 11.2 years, showed that among individuals without baseline cardiometabolic disease, smokers had a 23% higher risk of first ischemic heart disease event, 14% higher risk of ischemic stroke, and 40% higher mortality risk compared to non-smokers. Among those who attempted to quit smoking in the past 12 months, over half did so for health reasons, with the top three reasons being concern about future health (38.7%), existing illness (26.6%), and family opposition (14.9%) [Figure 1: see original paper].

In July 2021, WHO's Global Tobacco Epidemic Report evaluated countries' implementation of MPOWER strategies. China received the highest rating (Level I) for monitoring (M) and warning (W) components. However, protection from tobacco smoke (P) was rated Level IV. According to the Framework Convention on Tobacco Control, China should have achieved comprehensive smoke-free policies in public transport, indoor workplaces, and public places by 2011. While 20+ cities including Beijing, Shanghai, Shenzhen, and Xi'an have implemented comprehensive smoke-free legislation covering 15.9% of the population, 134 countries and regions worldwide have implemented graphic health warnings on cigarette packages, which mainland China has not yet adopted.

1.2 Diet and Nutrition

Data from the 2015–2017 China Nutrition and Health Surveillance show that Chinese residents' average daily energy intake was 2,007.4 kcal, with adequate supply of carbohydrates, protein, and fat. Total energy intake has declined over time, with carbohydrate energy contribution decreasing significantly while fat energy contribution increased, exceeding the dietary guideline recommendation of 20–30% since 2012 [Figure 2: see original paper]. In 2015–2017, rural fat energy contribution first exceeded the 30% recommended limit, reaching 33.2%.

From 1982–2015, major changes in food intake occurred: grain and vegetable consumption decreased; animal food intake increased; fruit, egg, aquatic product, milk, and soybean intake remained low; cooking oil intake increased while household salt consumption decreased, though both remained far above recommended levels [Figure 3: see original paper]. The frequent consumption rate of sugar-sweetened beverages among children aged 6–17 was 18.9% in 2016–2017. In 2018, average annual alcohol intake among residents aged $ $18 increased by 0.4 L compared to 2012, with frequent drinking rate at 19.9% and harmful drinking rate at 8.6% (defined as $ $61 g pure alcohol daily for men, $ $41 g for women), down 0.7 percentage points from 2012.

The China Heart Healthy Diet study, a multicenter, single-blind, randomized trial, found that a 28-day cuisine-based heart-healthy diet (including Shandong, Huaiyang, Cantonese, and Sichuan cuisines) reduced systolic and diastolic blood pressure by -10.0 [95%CI (-12.1, -7.9)] mmHg and -3.8 [95%CI (-5.0, -2.5)] mmHg, respectively. The diet reduced fat energy by 5–8%, increased protein energy by 3.5–5.5%, maintained carbohydrate energy, reduced sodium from nearly 6,000 mg/d to 3,000 mg/d, increased dietary fiber from 11 g/d to 30 g/d, and increased potassium from <1,700 mg/d to 3,700 mg/d. The incremental cost-effectiveness ratio was 0.4 yuan per day per 1 mmHg systolic BP reduction, demonstrating cost-effective blood pressure control.

The Salt Substitute and Stroke Study (SSaSS) health economics evaluation showed that replacing regular salt with salt substitutes reduced stroke risk by 14%. The salt substitute group gained 0.054 quality-adjusted life years (QALYs) per person at a cost savings of 110 yuan, with average costs of 1,538 yuan in

the intervention group versus 1,649 yuan in the control group, demonstrating dominance (better outcomes at lower cost).

1.3 Physical Activity

Physical inactivity has become a major health risk factor. The Chinese School-aged Children Physical Activity and Fitness Study, covering 120,000–130,000 primary and secondary students nationwide, found that in 2017, physical activity 达标率 (meeting guidelines) was 38.5% for grades 4–6 primary students and 35.3% for junior high students, both higher than 2016 (33.5% and 32.5%, respectively). Senior high school 达标率 remained unchanged (24.4% vs. 24.2%). Only 5.12% of primary and secondary students met the 24-hour movement guidelines ($ $60 min/d moderate-to-vigorous activity, $ $2 h/d screen time, adequate sleep) in 2017. Screen time $ $2 h on weekdays was 8.7%, 11.5%, and 9.0% for TV, mobile phone, and computer use, respectively, rising to 23.7%, 27.7%, and 17.5% on weekends.

National student health surveys from 1985–2014 (738,523 Han students aged 13–18) showed declining excellent health status rates ($P<0.001$) [Figure 4: see original paper]. China Health and Nutrition Survey (CHNS) data on 4,341 children aged 6–17 found that from 2004–2015, physical inactivity rates increased by 5.5%, activity volume decreased by 5.8 MET · h/7 days, and sedentary time increased by 1.8 h/7 days.

The 2015 China Chronic Disease and Nutrition Surveillance (CCDNS) found that only 12.5% of adults aged $ $18 regularly participated in physical activity, up from 11.9% in 2010 but still low, with only 8.6% among those aged 25–34. CHNS data showed total physical activity among Chinese adults decreased from 399 MET · h/week in 1991 to 213 MET · h/week in 2009. Occupational activity decreased by 31% for men from 1991–2011, with similar trends for women. CCDNS data showed average leisure sedentary time was 3.2 h/d in 2018, similar to 2013 (3.3 h/d) but higher than 2010 (2.7 h/d).

A study of 40–74 year-olds in 168 countries found that meeting physical activity recommendations could prevent 18.3% of premature deaths in China, equivalent to avoiding 1.0165 million premature deaths annually. CKB data on 487,000 CVD-free individuals followed for 7.5 years showed total physical activity was inversely associated with CVD mortality. Compared with the lowest activity group ($ $9.1 MET \cdot h/d), the highest quintile ($ $33.8 MET · h/d) had 41% lower CVD mortality risk. Each 4 MET · h/d increase reduced CVD mortality risk by 12%.

The economic burden of physical inactivity in 2007 was $6.7 billion, accounting for 15.2% of major chronic disease expenditures.

1.4 Overweight and Obesity

Analysis of three nationally representative datasets from 2002–2017 shows continuously rising overweight and obesity rates [Figure 5: see original paper]. The 2015–2017 China Nutrition and Health Surveillance reported overweight rates of 6.8% and obesity rates of 3.6% in children under 6; 11.1% and 7.9% in children aged 6–17; and 33.3% and 14.1% in adults aged 18, respectively. Projections suggest that by 2030, overweight/obesity rates could reach 65.3% in adults (Chinese criteria), 31.8% in children aged 7–17, and 15.6% in children 6, affecting 789.95 million, 58.92 million, and 18.19 million people, respectively.

GBD 2019 estimated that in 2019, high BMI accounted for 549,500 CVD deaths in China, with an age-standardized mortality rate of 38.64/100,000, representing 11.98% of all CVD deaths. The Guangzhou Biobank Cohort study of 19,405 Chinese aged >50 followed for 11.5 years found that among those with BMI 22.5 kg/m^{2}, each 5 kg/m^{2} increase raised CVD mortality by 37%. Analysis of Shanghai Women's and Men's Health Studies (48,377 women and 35,989 men aged 40–59) showed that among those with BMI 23 kg/m^{2}, each 5 kg weight gain from adulthood to middle age increased later CVD death risk by over 20% [men HR=1.26, 95%CI (1.16, 1.38); women HR=1.23, 95%CI (1.14, 1.33)].

A childhood obesity prevention program randomized 1,641 children from 40 schools to comprehensive intervention (diet and physical activity) or control groups. The 12-month health economics evaluation showed public sector intervention costs of 35.53 yuan per child and social sector costs of 536.95 yuan per child. The intervention group had favorable cost-effectiveness ratios of 8,888 yuan/QALY from the public sector perspective and 73,831 yuan/QALY from the societal perspective.

1.5 Psychological Factors

A hospital-based meta-analysis of 23 studies found that 51% [95%CI (0.43, 0.58)] of Chinese hospitalized coronary heart disease patients had depression, with 0.5–25.44% being severe. The Guidelines for Primary Care of Depression (2021) report that 15–30% of acute coronary syndrome patients, 20% of coronary heart disease patients, and 20% of congestive heart failure patients have depressive disorders. Follow-up of 190 newly diagnosed coronary disease patients over 36 months showed anxiety and depression rates increased from 42.6% to 51.1% and 33.3% to 43.7%, respectively.

The INTERHEART study found that 21.66% of Chinese acute myocardial infarction (AMI) patients had depression, significantly higher than controls without CVD (10.36%). Although China's depression prevalence is lower than 51 other countries, its association with AMI is stronger (China OR=2.27 vs. other countries OR=1.37). A meta-analysis of 41 hypertension-depression studies reported a 26.8% overall depression prevalence among hypertensive patients, with 28.5% in China versus 22.1% in other countries.

The China Health and Retirement Longitudinal Study (CHARLS) assessed depressive symptoms in 6,810 CVD-free residents and found that persistent depressive symptoms were significantly associated with increased CVD and mortality risk. CKB analysis of 486,541 Chinese aged 30–79 found a 0.61% major depression prevalence. After median follow-up of 7.2 years, major depression increased ischemic heart disease risk by 32% overall and by 72% in urban residents.

2. CVD Risk Factors

2.1 Hypertension

National hypertension surveys conducted in 1959, 1980, 1991, and 2002 found crude prevalence rates of 5.1%, 7.7%, 13.6%, and 17.6% among residents aged 15, showing an upward trend. The China Hypertension Survey (CHS) found that in 2012–2015, crude hypertension prevalence was 27.9% (weighted rate 23.2%) among adults aged 18, estimating 245 million hypertensive adults. The crude rate for high-normal blood pressure was 39.1% (weighted 41.3%), affecting 435 million people. The 2018 CCDRFS survey of 179,873 adults aged 18 in 298 counties across 31 provinces found a weighted hypertension prevalence of 27.5%.

CKB cohort data showed hypertension age-standardized incidence increased from 40.8/1,000 person-years in 1993–1997 to 48.6/1,000 person-years in 2011–2015. In 2015, hypertension awareness, treatment, and control rates among adults aged 18 were 51.6%, 45.8%, and 16.8%, respectively, all showing significant improvement [Figure 6: see original paper].

A 2016–2019 study across 23 provinces and 130 hospitals found that each 1-unit increase in sodium/potassium ratio raised blood pressure by 0.46/0.24 mmHg. Another study of 20,995 high CVD-risk individuals (72.6% with stroke history, 88.4% with hypertension) followed for 4.74 years found that compared to regular salt, salt substitutes reduced stroke risk by 14%, major cardiovascular events by 13%, all-cause mortality by 12%, and acute coronary syndrome events.

The STEP study of 8,511 elderly hypertensive patients followed for 3.34 years found that intensive treatment (systolic BP target 110–<130 mmHg) reduced major outcome events to 3.5% compared to 4.6% in standard treatment (target 130–<150 mmHg), an absolute difference of 1.1%. The Rural Hypertension Control Project demonstrated that village doctor-led comprehensive interventions significantly improved control rates; at 18 months, 57.0% of intervention group patients had BP <130/80 mmHg versus 19.9% in controls, with average BP reductions of 26.3/14.6 mmHg versus 11.8/7.5 mmHg.

By 2019, 109 million hypertensive patients were registered in management programs, with standardized management rates increasing 29.28% since 2009 and control rates rising from 50.88% to 67.72%. A health economics evaluation based on SPRINT data showed that intensive BP treatment increased QALYs from 9.51 to 9.87 over a lifetime, with an incremental cost of $10,997 per QALY gained, and an 82.8\times$ China's per capita GDP.

Three-time-point screening strategies help accurately assess hypertension prevalence in those under 18. The 2012–2015 Chinese Children and Adolescents Cardiovascular Health study and 2018–2019 six-province survey showed that while single-visit prevalence differed using Chinese versus US criteria, three consecutive non-same-day measurements yielded similar final prevalence rates (3.7% vs. 3.3% and 8.4% vs. 5.9%, respectively). CHNS data from nine surveys (1991–2015) showed school-age children's hypertension prevalence increased from 8.5% to 19.2%, with isolated diastolic hypertension being the predominant phenotype (accounting for >2/3 of cases), rising from 6.2% to 14.1%. Obesity is the most important risk factor for childhood hypertension, with overweight/obesity's population attributable risk percentage (PAR%) for hypertension increasing from 6.3% in 1995 to 19.2% in 2014, twice the increase in PAR% for diastolic hypertension.

2.2 Dyslipidemia

Adult dyslipidemia prevalence increased dramatically from 18.6% in 2002 to 40.4% in 2012. The 2010–2013 China Nutrition and Chronic Disease Surveillance found total cholesterol (TC), LDL-C, non-HDL-C, and triglycerides (TG) increased by 0.70, 0.75, 0.74, and 0.35 mmol/L, respectively, compared to 2002. The NCD Risk Factor Collaboration found that China's average non-HDL-C level, the lowest globally in 1980, reached ~4 mmol/L by 2018, comparable to many high-income Western countries.

The Beijing Child and Adolescent Metabolic Syndrome Study comparing 1,660 children in 2004 and 1,649 in 2014 found TC, LDL-C, non-HDL-C, and TG increased by 0.21, 0.12, 0.27, and 0.07 mmol/L, respectively, while HDL-C decreased by 0.07 mmol/L. The main dyslipidemia types in Chinese adults are low HDL-C and high TG [Figure 7: see original paper].

Among 236,579 individuals in China-PEACE MPP (10.2% of the total), 42.9% of high 10-year ASCVD risk patients achieved LDL-C <2.6 mmol/L, with only 4.5% of those not at target receiving treatment. Among 71,785 very high-risk patients (3.2% of total), 26.6% achieved LDL-C <1.8 mmol/L, with a treatment rate of 7.3% and treatment 达标率 of 14.5%. Among 40,875 ACS patients with discharge prescriptions, 95.1% remained on statin monotherapy. The DYSIS II-China study of 752 ACS patients on lipid-lowering therapy found 58.8% did not achieve LDL-C targets, with average shortfall of (0.7$±$0.7) mmol/L, and 91.4% on statin monotherapy, indicating underutilization of combination therapy.

GBD 2019 data show that 61% of China's CVD disease burden in 2019 was due to atherosclerotic CVD (ASCVD), with elevated LDL-C being the second-largest attributable risk factor, yet control rates remain low among high/very-high risk populations.

2.3 Diabetes

Diabetes prevalence in China has increased significantly [Figure 8: see original paper]. The 1980 survey of 300,000 people found 0.67% prevalence. The 2015–2017 survey of 75,880 adults aged $ $18 across 31 provinces found 12.8% diabetes prevalence and 35.2% prediabetes using ADA criteria; using WHO criteria, prevalence was 11.2%, estimating 129.8 million adults with diabetes (70.4 million men, 59.4 million women).

A hospital-based study using the Hospital Quality Monitoring System (HQMS) database assessed complications in 92,413 type 1 diabetes (T1DM) and 6,094,038 type 2 diabetes (T2DM) inpatients. Major vascular complications increased from 14.1% and 14.5% in 2013 to 13.2% and 18.4% in 2017 for T1DM and T2DM, respectively. Microvascular complications increased from 29.9% and 19.0% to 31.6% and 21.0%.

The Da Qing Diabetes Prevention Study randomized 577 adults with impaired glucose tolerance to control or lifestyle intervention groups (diet, exercise, or combined). After 30 years of follow-up, the intervention group had 3.96-year delay in diabetes onset, 39% reduced diabetes risk, and 26%, 35%, 33%, and 26% reductions in cardiovascular events, composite microvascular events, cardiovascular death, and all-cause death, respectively. Stroke and severe retinopathy rates were also lower, with average life expectancy increased by 2.4 years.

2.4 Chronic Kidney Disease

A national CKD prevalence survey (September 2009–September 2010) covering 13 provinces found 10.8% prevalence among adults aged >18, estimating 120 million CKD patients. Abnormal kidney function (eGFR $<60\ \mathrm{ml \cdot min^{-1} \cdot (1.73\ m^2)^{-1}}$) prevalence was 1.7%, and albuminuria (urine albumin-to-creatinine ratio >30 mg/g) was 9.4%. CHARLS data show renal function decline prevalence increases with age: 10.3% overall among those $ $60, ranging from 3.3% in 60–64 year-olds to 33.9% in those $ $80.

The China Kidney Disease Network (CK-NET) 2016 report found that hospitalized patients with CKD accounted for 4.86% of total hospitalizations, with CKD prevalence of 13.90% in diabetes patients, 11.41% in hypertension patients, and 7.96% in CVD patients.

2.5 Metabolic Syndrome

The 2002 and 2010–2012 China Nutrition and Health Surveys (48,556 and 104,098 adults aged $ $18) found metabolic syndrome prevalence increased from 6.6% (2002) to 15.4% (2012) using Chinese Diabetes Society criteria. Among 16,872 children aged 10–17 surveyed in 2010–2012, prevalence was 2.4% using pediatric criteria and 4.3% using Cook criteria.

2.6 Air Pollution

Ambient and indoor air pollution rank 3rd and 13th among factors affecting disability-adjusted life years (DALYs) and mortality in China. Compared with 1990, indoor air pollution-related deaths decreased 72.7% and DALY losses decreased 80.2% by 2019. In 2021, 218 of 339 prefecture-level cities met outdoor air quality standards (64.3%), up 3.5% from 2020, with all six major pollutants (PM2.5, PM10, SO2, NO2, CO, O3) decreasing.

Studies using 2013–2015 data from 272 Chinese cities found that increased exposure to PM2.5, coarse particles (2.5–10.0 m), O3, SO2, NO2, and CO increased mortality risks from CVD, coronary heart disease, and hypertension. A 2013–2018 time-series study in 250 counties found PM2.5 heavy pollution events increased CVD death risk by 1.09%. From 2000–2016, PM2.5-attributable deaths increased to 3.08 million, though annual deaths have declined since 2013.

Research on carbon reduction pathways found that emission reductions could avoid approximately 118,000 and 614,000 PM2.5-attributable deaths by 2030 and 2050, respectively. Analysis of Beijing's air pollution control plan (2013–2017) showed air quality improvements generated economic benefits of -19.82, -18.93, 157.07, 152.64, and 223.30 billion yuan annually, representing -0.85‰, -0.81‰, 6.68‰, 6.16‰, and 8.77‰ of annual GDP, respectively, with total five-year profits of 49.426 billion yuan (4.11‰ of five-year GDP total).

A study using medical insurance reimbursement data from a sample city found that each 10 g/m^3 reduction in PM2.5 decreased average medical costs by 1,699 yuan and reduced work time loss by 1.24 days. Reducing annual PM2.5 concentration to the national standard of 35 g/m^3 would generate health benefits exceeding 1.28 billion yuan, representing 18% of annual environmental protection investment.

3. CVD Community Prevention

The "Healthy China 2030" plan mandates implementing comprehensive chronic disease prevention strategies and strengthening national demonstration areas for chronic disease prevention and control. By 2020, 488 national demonstration areas had been established across 31 provinces, covering 17.1% of counties (districts, cities), exceeding the 15% target set in the 2017–2025 chronic disease prevention plan. These demonstration areas are driving a fundamental shift from high-risk population strategies to whole-population strategies.

In Anshan's Lishan District, demonstration area construction launched in 2013 increased health units (health trails, cabins, communities) from 73 to 116 (59% increase). Over seven years, overweight rates decreased 15.00% (36.79% to 31.27%), obesity rates decreased 40.30% (16.90% to 10.09%), smoking rates decreased 36.27% (30.63% to 19.52%), secondhand smoke exposure decreased 50.95% (75.12% to 36.85%), and drinking rates decreased 53.13% (32.73% to 15.34%). Healthy behaviors improved: salt-limiting spoon use increased from

3.22% to 15.34%, oil-control pot use from 1.26% to 12.95%, and demand for chronic disease knowledge from 48.65% to 65.74%. Hypertension and diabetes prevalence significantly decreased (34.69% to 23.51% and 16.76% to 8.96%, respectively), and average life expectancy increased by 1.57 years (78.00 to 79.57 years).

Qiaokou District in Wuhan, designated a third-batch national demonstration area in 2014, established a collaborative disease prevention and control mechanism among CDCs, hospitals, and primary care institutions. Ten community health centers established hypertension intervention clinics. A 2017 survey showed self-reported hypertension increased from 16.88% (2013) to 23.71% (2017) (actual prevalence: 33.71% and 33.54%), while hypertension treatment control rates increased from 22.22% to 51.09%.

4.1 CVD Prevalence Trends

China's CVD prevalence continues to rise, with an estimated 330 million current patients: 13 million stroke, 11.39 million coronary heart disease, 8.9 million heart failure, 5 million pulmonary heart disease, 4.87 million atrial fibrillation, 2.5 million rheumatic heart disease, 2 million congenital heart disease, 45.3 million peripheral arterial disease, and 245 million hypertension cases.

CVD remains the leading cause of death, accounting for 48.00% and 45.86% of deaths in rural and urban areas in 2020 [Figure 9: see original paper]. Rural CVD mortality has exceeded urban levels since 2009 [Figure 10: see original paper]. In 2020, rural CVD mortality was 336.13/100,000 (heart disease 171.36/100,000, cerebrovascular disease 164.77/100,000), while urban mortality was 291.04/100,000 (heart disease 155.86/100,000, cerebrovascular disease 135.18/100,000). CVD deaths increased from 3.09 million in 2005 to 4.58 million in 2020, while age-standardized mortality rates decreased from 286.85 to 245.39/100,000. Premature CVD mortality burden decreased 19.27% from 2005. Ischemic heart disease, hemorrhagic stroke, and ischemic stroke were the three leading CVD causes of death in 2020.

4.2 Coronary Heart Disease

In 2020, urban coronary heart disease mortality was 126.91/100,000 and rural was 135.88/100,000, continuing an upward trend since 2012, with rural areas surpassing urban levels after 2016 [Figure 11: see original paper]. AMI mortality showed an overall upward trend from 2002–2020, with rapid increases from 2005. Rural AMI mortality exceeded urban levels in 2007, 2009, 2010, and 2011, and has been consistently higher since 2013 [Figure 12: see original paper].

The 2013 Fifth National Health Services Survey found coronary heart disease prevalence of 10.2‰ in those aged $ $15 (27.8‰ in those $ $60), up from 7.7‰ in 2008, with 11.396 million cases nationwide—an increase of about 1.08 million from 2008. The China PEACE AMI study of 162 hospitals across 31

provinces showed STEMI hospitalizations increased from 3.7/100,000 in 2001 to 8.1/100,000 in 2006 and 15.8/100,000 in 2011.

The China Acute Myocardial Infarction (CAMI) registry showed significant variation in AMI in-hospital mortality across hospital levels (3.1% provincial, 5.3% municipal, 10.2% county) in 2013–2014. Analysis of 29,581 STEMI patients from 80 hospitals with PCI capability found overall in-hospital mortality of 6.3%. Quality scores based on guidelines showed mortality rates of 7.2%, 6.6%, and 5.4% in low (<71.1%), medium (71.1–76.5%), and high (>76.5%) performing hospitals, respectively.

A study of 57,560 STEMI patients from 143 tertiary hospitals (2014–2019) found only one-fifth received all nine class I recommended management strategies, with substantial quality variation across hospitals. CAMI data analysis of late PCI (>12 hours after symptom onset) showed PCI significantly reduced 2-year MACCE, all-cause death, myocardial infarction, stroke, and revascularization compared to medical therapy, with improved left ventricular ejection fraction.

AI-assisted coronary CT angiography in 165 patients (680 vessels, 1,505 segments) reduced post-processing time by 69–76% compared to human readers. AI diagnostic sensitivity/specificity for obstructive coronary disease was 90.5%/82.3% per patient, 81.4%/93.9% per vessel, and 72.9%/95.0% per segment, outperforming less experienced readers. AI+human reading improved diagnostic performance over human reading alone.

Analysis of 66,971 isolated CABG patients from 74 tertiary hospitals (2013–2018) showed in-hospital mortality decreased from 0.9% to 0.6%, with reduced inter-hospital variation and increased adherence to guideline-recommended surgical processes and secondary prevention.

PCI cases increased from 227,965 in 2009 to 1,164,117 in 2021 [Figure 13: see original paper], with average 1.48 stents/drug balloons per patient. Drug-coated balloon use increased from 6.4% (2019) to 15.0% (2021). In-hospital mortality remained low at 0.38% in 2021.

4.3 Cerebrovascular Disease

Cerebrovascular disease mortality showed an overall increasing trend from 2003–2020 [Figure 14: see original paper]. In 2020, urban mortality was 135.18/100,000 (21.30% of total deaths, ranking third), while rural mortality was 164.77/100,000 (23.53% of total deaths, ranking second), with higher rates in males and rural areas.

GBD 2019 data show China's age-standardized stroke incidence was 200/100,000 in 2019 (ischemic 144/100,000, hemorrhagic 44/100,000, subarachnoid hemorrhage 11/100,000). Compared with 1990, age-standardized incidence decreased 9.0%, with ischemic stroke increasing 35.0% and hemorrhagic stroke decreasing 53.0%. Age-standardized prevalence was 1,468.9/100,000, up 13.2% from 1990.

Age-standardized DALY rates decreased 41.6%, YLL rates decreased 45.7%, but YLD rates increased 15.9%.

The China Stroke Center Alliance analysis of 1,006,798 stroke/TIA admissions from 1,476 hospitals (2015–2019) showed improved management: IV thrombolysis increased 60.3%, dysphagia screening 14.7%, anticoagulation for atrial fibrillation 31.4%, while in-hospital death/unauthorized discharge decreased 9.7% and complications decreased 27.1%.

A health economics evaluation of delayed endovascular therapy (EVT) for acute ischemic stroke found EVT at 61–120 minutes post-onset was most cost-effective compared to later time windows. Each hour of EVT delay resulted in 0.45 QALY loss and 165.02 healthy days lost, with net economic loss of 15,105 yuan.

4.4 Arrhythmia

In 2021, 99,306 pacemakers were implanted nationwide, up 15.2% from 2020. His-Purkinje system pacing (His bundle or left bundle branch pacing) has progressed rapidly, with left bundle branch pacing originating in China and generating >70 international publications since 2019. Leadless pacemakers, first implanted in China on February 10, 2015, reduce lead- and pocket-related complications and are now performed at >10 centers.

A 2020–2021 stratified multi-stage sampling study of 114,039 residents aged $ 18*across*22*provinces**found**atrial**fibrillation**prevalence**of*1.6*{2}**DS*\{2\}$-VASc scores $ $2, 1, and 0, respectively, with wide variation between tertiary (9.6–68.4%) and non-tertiary (4.0–28.2%) hospitals. A study of patients diagnosed with atrial fibrillation at three tertiary hospitals found only 24.41% received guideline-concordant anticoagulation pre-admission.

Radiofrequency catheter ablation (RFCA) is performed at >600 hospitals nationwide. RFCA cases grew from 15,107 in 2009 to 210,609 in 2021 [Figure 15: see original paper], a 13.2–17.5% annual growth rate. Atrial fibrillation RFCA proportion increased from 31.9% (2018) to 46.4% (2021), with pulmonary vein isolation remaining the main approach (60.2% of total RFCA). Perioperative ischemic stroke rate was 0.4% and hemorrhagic stroke 0.1%.

A Xinjiang study of 3,224,103 residents identified 1,244 sudden cardiac death (SCD) cases, with an overall incidence of 38.6/100,000 and higher risk in men. In 2021, 6,547 implantable cardioverter-defibrillators (ICDs) were implanted, up 36% from 2020 (4 per million population), with 44% being dual-chamber devices. Cardiac contractility modulation (CCM), first implanted in mainland China on December 30, 2014, has been performed at 5 centers with 8 devices implanted by May 2016, showing reliable safety and significant improvements in NYHA class, 6-minute walk test, and quality of life at 6 months.

A discrete event simulation model found that for paroxysmal atrial fibrillation, antiarrhythmic drugs yielded 4.98 QALYs at $15,374 cost, while second-generation cryoballoon ablation yielded 5.92 QALYs at $26,811, and

steerable ablation catheter yielded 6.55 QALYs at $24,722. The incremental cost-effectiveness ratios (ICERs) were $5,927/QALY and $12,167/QALY, respectively, with both ablation strategies being cost-effective at China's $30,390/QALY threshold.

4.5 Valvular Heart Disease

A stratified multi-stage sampling study of 31,499 residents aged $ $35 using echocardiography (October 2012–December 2015) identified 1,309 valvular heart disease cases, with a weighted prevalence of 3.8%, estimating 25 million patients nationwide. While rheumatic valve disease remains the leading cause (55.1%), degenerative valve disease is increasing (21.3%) due to aging and improved living standards. Analysis of 325,910 patients who underwent transthoracic echocardiography at Zhongshan Hospital (2011–2015) identified 3,673 (1.13%) with bicuspid aortic valve, predominantly male (69.1%), with 58.4% having significant aortic insufficiency, 52.5% ascending aortic dilation, and 19.2% aortic root dilation.

4.6 Congenital Heart Disease

Congenital heart disease is China's most common birth defect, with detection rates increasing over time and varying regionally (2.9–16‰). A meta-analysis of 617 studies (1980–2019) covering 76,961,354 newborns found detection rates increased from 0.201‰ (1980–1984) to 4.905‰ (2015–2019), with higher rates from west to east and lower rates from south to north. According to the 2021 China Health Statistics Yearbook, congenital heart disease mortality was 0.61/100,000 in urban and 0.76/100,000 in rural areas in 2020.

A survey by the Chinese Pediatric Society found that from July 2006–December 2018, 4,981 pediatric cardiomyopathy cases were admitted to 33 hospitals, accounting for 0.079% of pediatric inpatients. Dilated cardiomyopathy (DCM) was most common (1,641 cases, 32.95%), followed by endocardial fibroelastosis (1,283 cases, 25.76%) and left ventricular non-compaction (635 cases, 12.75%). In 2021, congenital heart disease surgeries accounted for 25.8% of all cardiac and aortic surgeries (71,693 cases), the lowest proportion historically, likely due to declining birth rates and improved prenatal screening. Adult congenital heart disease surgeries represent an increasing proportion.

National Quality Control Information Platform data show 36,528 congenital heart disease interventional procedures in 2020 [Figure 16: see original paper], with 97.1% medical discharge rate, 0.5% in-hospital mortality, 0.8% unauthorized discharge rate, and 1.1% 30-day readmission rate. Average total costs were 68,601 yuan, up from 49,779.8 yuan in 2018 and 57,943.1 yuan in 2019.

4.7 Cardiomyopathy

A stratified cluster sampling survey of 8,080 residents (4,064 men, 4,016 women) in nine provinces (October 2001–February 2002) found hypertrophic cardiomyopathy (HCM) crude prevalence of 0.16% (0.22% men, 0.10% women), with age- and sex-adjusted prevalence of 80/100,000, estimating >1 million adult HCM patients in China. The same survey found dilated cardiomyopathy (DCM) prevalence of 19/100,000. A DCM prevalence survey in non-Keshan disease areas of northern China (July–December 2011) identified 6 cases among 49,751 people, estimating prevalence of 1.2/10,000.

Analysis of 10,714 heart failure patients from 42 hospitals in 1980, 1990, and 2000 found DCM proportions of 6.4%, 7.4%, and 7.6%, respectively. A pediatric cardiomyopathy study (2006–2018) of 4,981 cases found DCM most common (1,641 cases, 32.95%), with increasing hospitalizations.

Genetic testing in 529 HCM patients found pathogenic mutations in 43.9%, most commonly MYH7 and MYBPC3 genes. A 2020 Fuwai Hospital study found common genetic variants also contribute to HCM, suggesting non-Mendelian inheritance patterns with ethnic specificity. Arrhythmogenic cardiomyopathy (ACM) is mainly caused by desmosomal gene mutations, with 63.3% of Chinese patients having detectable pathogenic mutations, most commonly PKP2. The homozygous DSG2 founder variant p.Phe531Cys is a Chinese ACM susceptibility factor (8.47% prevalence, high penetrance), and homozygous PNPLA2 variant c.245G>A/p.G82D is associated with ACM phenotype expression.

A 2022 Nature Cardiovascular Research article used metabolomics and lipidomics to identify metabolic profiles in HCM patients, developing machine learning algorithms for precise diagnosis and prognosis prediction, identifying three metabolic subtypes with different cardiac function and outcomes, and proposing the pentose phosphate and redox pathways as potential therapeutic targets.

4.8 Heart Failure

Heart failure prevalence in China is rising, with mortality rates comparable to cancer. The 2012–2015 CHS analysis of 22,158 residents found heart failure prevalence of 1.3% in those aged $ $35, left ventricular systolic dysfunction (LVEF<50%) of 1.4%, and moderate/severe diastolic dysfunction of 2.7%.

The China-HF registry analysis of 13,687 heart failure patients from 132 hospitals (2012–2015) found in-hospital mortality of 4.1%. The 2020 China Heart Failure Quality Control Report analysis of 33,413 patients from 113 hospitals (2017–2020) found in-hospital mortality of 2.8%. A 5-year follow-up of 3,335 acute heart failure patients in Beijing found 5-year all-cause mortality of 55.4% and CVD mortality of 49.6%, with median survival of 34 months.

The 2020 quality control report found heart failure patients averaged 67$±$14 years, 60.8% male, with declining valvular disease proportion and hypertension

(56.3%) and coronary disease (48.3%) as main etiologies. Infection was the leading precipitating factor, followed by myocardial ischemia and exertion. Heart failure with reduced, mid-range, and preserved ejection fraction accounted for 40.2%, 21.8%, and 38.0%, respectively. Diuretic use remained stable, digoxin use declined, and mineralocorticoid receptor antagonist and β-blocker use increased. Renin-angiotensin system blocker use increased overall but ACEI/ARB use declined with ARNI availability.

In 2021, 5,333 cardiac resynchronization therapy (CRT) devices were implanted, up 37% from 2020 (3.6 per million population), with CRT-D proportion increasing to 66%. The China Heart Transplant Registry shows 66 qualified institutions by 2021. From 2015–2021, 2,794 heart transplants were performed, with 279, 368, 446, 490, 679, 557, and 738 cases annually. In 2021, non-ischemic cardiomyopathy accounted for 75.2% of recipients (80.3% in pediatric recipients). In-hospital survival was 91.0%, with multi-organ failure and graft failure accounting for ~40% of early deaths. One-year and three-year survival rates were 85.4% and 79.9% overall (85.1% and 79.5% in adults; 89.7% and 84.8% in children).

4.9 Pulmonary Vascular Disease and Venous Thromboembolism

4.9.1 Pulmonary Arterial Hypertension

China's largest multicenter prospective PAH registry (August 2009–December 2019) included 2,031 patients from 34 tertiary centers. Mean age was 35$±$12 years, 76.2% female. Congenital heart disease was the most common cause (45.2% PAH-CHD), followed by idiopathic PAH (38.8%), connective tissue disease-associated PAH (13.1%), and other subtypes (3.0%). In systemic lupus erythematosus patients, PAH prevalence was 3.8% (74/1,934). One-year, three-year, and five-year survival rates were 68.0%, 38.9%, and 20.8%, respectively, improving to 92.1% and 75.1% in the targeted therapy era.

A national observational study of 140 Takayasu's arteritis-PAH patients (2007–2019) found mean diagnosis age of 41.4 years, 81% female, with one-year, three-year, and five-year survival rates of 94.0%, 83.2%, and 77.2%. Percutaneous pulmonary angioplasty reduced mortality [HR=0.18, 95%CI (0.05, 0.73)] in anatomically suitable patients.

4.9.2 Venous Thromboembolism

A Hong Kong registry (2004–2016) of 2,214 VTE patients (65.2% deep vein thrombosis, 34.8% pulmonary embolism) found VTE incidence increased from 28.1 to 48.3/100,000 person-years. The China VTE Hospitalization and Mortality Study (2007–2016) of 105,723 patients from 90 hospitals found age- and sex-adjusted hospitalization rates increased from 3.2 to 17.5/100,000, while in-hospital mortality decreased from 4.7% to 2.1% and hospital stay shortened

from 14 to 11 days.

The China Pulmonary Embolism Registry (CURES, 2009–2015) included 7,438 acute symptomatic PE patients from 31 provinces. High-risk (hemodynamically unstable), intermediate-risk (sPESI$ $1), and low-risk (sPESI=0) patients accounted for 4.2%, 67.1%, and 28.7%, respectively. CT pulmonary angiography was the most common diagnostic method (87.6%) and anticoagulation the most common initial treatment (83.7%). Systemic thrombolysis decreased from 14.8% to 5.0%, and acute PE mortality decreased from 3.1% to 1.3%.

The DissolVE-2 study (March–September 2016) of 13,609 hospitalized patients (6,623 medical, 6,986 surgical) at 60 tertiary hospitals found 36.6% of medical and 53.4% of surgical patients were at high VTE risk, yet only 14.3% received any VTE prophylaxis (9.3% medical, 19.0% surgical), and only 10.3% received guideline-recommended prophylaxis (6.0% medical, 11.8% surgical).

4.10 Aortic and Peripheral Arterial Disease

4.10.1 Aortic Disease

Acute aortic dissection is a critical condition with male predominance. Analysis of >300 million urban residents' medical insurance data (2015–2016) estimated annual incidence of 2.78/100,000 person-years (3.96 men, 1.59 women). The Sino-RAD registry showed Chinese patients are ~10 years younger than Western counterparts (mean 51.8 years). For type A dissection, open surgery accounted for 89.6% of treatments (5.5% mortality), while type B dissection was treated with medication (21.3%, 9.8% mortality), surgery (4.4%, 8.0% mortality), or endovascular therapy (69.6%, 2.5% mortality).

Low temperatures and temperature drops are significantly associated with dissection onset. Compared with 28°C, the odds ratio for aortic dissection was 2.84 [95%CI (1.69, 4.75)] at -10°C and 2.36 [95%CI (1.61, 3.47)] at 1°C. A 7°C temperature drop increased 6-day cumulative OR to 2.66 [95%CI (1.76, 4.02)].

Thoracic endovascular aortic repair (TEVAR) in-hospital mortality decreased from 2.0% (2017) to 1.3% (2021), with death/unauthorized discharge decreasing from 4.9% to 4.0%. Endovascular abdominal aortic repair (EVAR) mortality decreased from 1.7% to 1.3%, with death/unauthorized discharge stable at 3.7–3.9%. Bentall procedure mortality was 1.5–1.9%, with death/unauthorized discharge decreasing from 4.4% to 2.5%. Total arch replacement mortality was 5.9–7.4%, with death/unauthorized discharge of 11.2–14.6%.

4.10.2 Peripheral Arterial Disease

4.10.2.1 Lower Extremity Arterial Disease (LEAD) A stratified random sampling survey found 6.6% prevalence in those aged $ $35, estimating 45.3 million LEAD patients nationwide, with 1.9% (860,000) receiving revascularization. Prevalence in T2DM patients reaches 21.2%.

4.10.2.2 Carotid Atherosclerotic Disease (CASD) Screening of 106,918 community residents aged $ $40 found 0.5% prevalence of moderate-to-severe carotid stenosis. A cross-sectional study of 38,642 health center participants (median age 46) found 30.0% CASD prevalence. Screening of 9,215 high stroke-risk individuals in Beijing community hospitals found 74.7% CASD prevalence. In 2019, 6,600 carotid endarterectomies and 18,649 carotid stenting procedures were reported.

4.10.2.3 Subclavian Artery Stenosis (SCAS) An inter-arm systolic blood pressure difference $ $15 mmHg predicts >50% SCAS. A Shanghai community study of 3,133 residents aged $ $60 found 1.8% with this finding. Etiology analysis showed atherosclerosis accounted for 95.9% in those >40 years and Takayasu's arteritis for 90.5% in those $ $40 years.

4.10.2.4 Mesenteric Artery Disease (MAD) MAD lacks epidemiological data but is underdiagnosed with high misdiagnosis and mortality rates. A meta-analysis of case reports (1994–2006) found 61.3% misdiagnosis and 60.6% mortality among 111 confirmed mesenteric artery embolism/thrombosis cases. Another meta-analysis of ischemic bowel disease misdiagnosis literature (1998–2008) found 63.4% misdiagnosis rate.

4.10.2.5 Renal Artery Stenosis (RAS) An 18-year single-center study of 2,905 RAS patients found main causes were atherosclerosis (82.4%, increasing from 50% in 1999–2000 to 85% in 2015–2016), Takayasu's arteritis (11.9%), and fibromuscular dysplasia (4.3%). Non-atherosclerotic causes were more common in patients $ $40 years.

4.11 Cardio-Oncology

A large cohort study of 710,000 cancer patients found 18% had CVD risk factors or established CVD (13% with risk factors, 5% with CVD). After adjusting for age, sex, cancer stage, and treatment, heart failure conferred the worst prognosis (79% increased all-cause mortality), followed by myocardial infarction (50% increased mortality).

5.1 Cardiac Rehabilitation

China's cardiac rehabilitation has developed rapidly, with growing evidence of clinical benefits and advancing center construction and standards. However, participation remains low. A 2016 survey of 124 tertiary hospitals across seven geographic regions found only 30 (24%) offered cardiac rehabilitation services (2.2 hospitals per 100 million population). Among 13 hospitals completing detailed surveys, 3 (23%) offered Phase I rehabilitation, 3 (23%) Phase II, and 7 (54%) both phases.

5.2 Stroke Rehabilitation

Rehabilitation department bed numbers continue growing, reaching 246,907 in 2020. Rehabilitation professionals increased from 16,000 physicians, 14,000 therapists, and 12,000 nurses in 2009 to 38,000 physicians and 15,000 nurses in 2018. Early rehabilitation improves neurological function in acute ischemic stroke patients. Ultra-early rehabilitation (within 72 hours) showed greater improvements in NIHSS and Fugl-Meyer scores at 1 and 3 months compared to early rehabilitation (72 hours–7 days). Starting rehabilitation at 24–48 hours versus 72–96 hours post-stroke resulted in lower modified Rankin scores at 90 days and significantly improved lower extremity Fugl-Meyer scores in the first week.

6.1 Cardiovascular Basic Research

High-impact cardiovascular basic research from mainland China began accelerating after 2005, with influential publications mainly in Circulation and Circulation Research. Analysis of Cell, Nature Medicine, Circulation, JACC, European Heart Journal, Circulation Research, and Nature Communications shows rapid recent development [Figure 17: see original paper]. From 2005–2020, 74 basic research articles from mainland China addressed cardiac/vascular anatomy, development, function, and pathogenesis, covering AMI, heart failure, ischemia-reperfusion injury, cardiomyopathy, cardiac remodeling, arrhythmia, aneurysm/dissection, atherosclerosis, and vascular remodeling, with hot topics including cardioprotection/regeneration, single-cell sequencing, and gene therapy.

6.2 Cardiovascular Medical Device Development

From September 1, 2021–August 5, 2022, the National Medical Products Administration approved 59 innovative medical devices, including 26 cardiovascular products (44.1%), demonstrating cardiovascular innovation's dominance. Of these, 52 (88.1%) were domestic original products. During the same period, 189 Class III cardiovascular devices received approval, including 130 domestic products (4 previously in innovation channel), compared to 142 approvals (101 domestic, 11 innovation channel) in the previous year, showing accelerated approval and rapid industrial development. Of 130 domestic products, 115 were interventional, 3 imaging, 7 hemodynamic monitoring, 2 open surgery, 1 AI software, and 2 diagnostic.

7. CVD Economic Burden

Since 1980, CVD and diabetes hospital discharges have increased continuously, especially after 2000. Correspondingly, total CVD hospitalization costs have risen rapidly, with average annual growth rates exceeding GDP growth since 2004, driven by growing service demand and recent price inflation.

In 2020, total hospitalization costs for CVD and cerebrovascular disease were

270.901 billion yuan, including 165.222 billion for CVD (ischemic heart disease 116.959 billion, hypertension 13.260 billion, pulmonary embolism 1.849 billion, chronic rheumatic heart disease 1.520 billion) and 105.679 billion for cerebrovascular disease (cerebral infarction 74.770 billion, cerebral hemorrhage 30.909 billion). Diabetes hospitalization costs were 31.641 billion.

Average per-hospitalization costs in 2020 were: ischemic heart disease 14,638.22 yuan (angina 15,369.94 yuan, AMI 30,159.06 yuan), cerebral infarction 9,824.93 yuan, cerebral hemorrhage 20,397.61 yuan, hypertension 6,235.41 yuan, pulmonary embolism 17,528.28 yuan, arrhythmia 17,587.40 yuan, heart failure 9,416.21 yuan, chronic rheumatic heart disease 9,806.14 yuan, and diabetes 7,766.69 yuan.

After adjusting for price factors, average annual growth rates (2004–2020) for total hospitalization costs were 24.65% for AMI, 16.81% for cerebral infarction, and 12.79% for cerebral hemorrhage. Since 2018, heart failure costs grew 16.14% annually, angina 6.45%, pulmonary embolism 5.82%, arrhythmia 3.52%, and ischemic heart disease 0.10%. Average per-hospitalization cost growth rates were 5.32% for AMI, 4.36% for cerebral hemorrhage, and 1.11% for cerebral infarction.

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References: [1]–[178] (as listed in original text)

Note: Figure translations are in progress. See original paper for figures.