

Hypertension and Cardiac Arrest- Related Mortality in the United States: A 24-Year Epidemiological Analysis of Demographic, Geographic, and Temporal Trends (2000-2023)

Mohid Zulfiqar

Dow University of Health Sciences

Syed Ahmed Ali Shah

Dow University of Health Sciences

Muhammad Salik Uddin

Dow University of Health Sciences

Shaheer Bin Shafiq

Dow University of Health Sciences

Hassan Abdul Aziz Dhedhi

Dow University of Health Sciences

Asim Sajjad

Dow University of Health Sciences

Saad Ahmed Waqas

Dow University of Health Sciences

Hermann YOKOLO

hermannyokolo40@outlook.com

Medical Research Circle (MedReC)

Maryam Sajid

Dow University of Health Sciences

Research Article

Keywords:

Posted Date: March 3rd, 2026

DOI: <https://doi.org/10.21203/rs.3.rs-8873663/v1>

License: © ⓘ This work is licensed under a Creative Commons Attribution 4.0 International License.
[Read Full License](#)

Additional Declarations: No competing interests reported.

Abstract

Background

Hypertension (HTN) affects nearly half of U.S. adults and creates an arrhythmogenic substrate through left ventricular hypertrophy and myocardial fibrosis, increasing cardiac arrest (CA) risk. However, population-level data on HTN and CA-Related mortality trends remain limited.

Objective

This study aims to assess trends in HTN and CA-Related mortality rates and examine variations by demographics and geographic regions in the United States.

Methods

Mortality data for adults aged ≥ 25 with HTN and CA-Related conditions were extracted from the CDC WONDER database (2000–2023). Age-adjusted mortality rates (AAMRs) per 100,000 and annual percent change (APC) with 95% confidence intervals (CIs) were calculated, stratified by year, sex, race/ethnicity, age, urbanization, and Census regions using Joinpoint regression.

Results

Between 2000 and 2023, 1,603,971 HTN and CA-Related deaths were recorded. Overall AAMRs increased from 24.56 to 32.83 (AAPC: +1.09%; 95% CI: 0.39–1.79), with modest rises until 2018, a sharp surge during 2018–2021 (APC: +9.24%), and subsequent decline through 2023 (APC: -8.00%). Men consistently had higher AAMRs than women (2023: 38.87 vs 27.56). Non-Hispanic Black adults showed the highest AAMRs (58.43) but experienced slight declines, while young adults (25–44 years) had the steepest proportional increases (AAPC: +3.01%). The West recorded the highest regional AAMRs, and nonmetropolitan areas demonstrated faster growth rates (AAPC: +2.37% vs +0.81%).

Conclusions

HTN and CA-Related mortality have increased substantially over two decades, with pronounced disparities by sex, age, race, and geography. The 2018–2021 surge likely reflects COVID-19 impacts, emphasizing the urgent need for targeted HTN control strategies and interventions addressing health equity disparities.

Introduction

Cardiac arrest (CA) has globally emerged as a significant contributor to Cardiovascular disease mortality, accounting for nearly half the Cardiovascular disease deaths, with an estimated 6 million deaths occurring worldwide annually.¹ In the United States (US) alone, it is responsible for 436,000 deaths each year, a majority of whom die even before reaching the hospital.^{2,3} Additionally, out-of-hospital cardiac arrest (OHCA) also has a substantial financial burden, with cumulative average costs estimated at USD 33 billion annually in the US. This includes expenses from advanced resuscitative measures, intensive care, diagnostic testing, and interventional procedures.⁴

Hypertension (HTN) remains one of the most critical and pervasive risk factors for cardiovascular disease (CVD), affecting nearly half of all U.S. adults and contributing to substantial health and economic burdens.⁵ According to The Surgeon General's Call to Action to Control HTN (2020), nearly half of all U.S. adults—approximately 108 million people—are affected by HTN. However, only one in four individuals with the condition have their blood pressure adequately controlled ($\leq 130/80$ mmHg). Despite ongoing national efforts, HTN control rates have stagnated. Alarming, about 71% (or 61 million people) who are recommended to adopt lifestyle modifications and take antihypertensive medications still have uncontrolled blood pressure. In addition to its health burden, the report states that HTN imposes a substantial economic cost on the nation, with annual expenses for healthcare services, medications, and productivity losses due to premature death estimated between \$131 billion and \$198 billion. It is predicted that by 2030, approximately 41.4% of adults in the United States will be affected by HTN.⁶

From a pathophysiological standpoint, chronic HTN promotes left ventricular hypertrophy (LVH) through sustained pressure overload, leading to myocardial remodeling, interstitial fibrosis, and electrical conduction abnormalities. These structural and electrophysiological alterations—including QT prolongation, QRS widening, and anisotropic conduction—create a vulnerable substrate for ventricular arrhythmias and sudden cardiac death. Therefore, the aim of the present study is to assess current trends in CA-Related death among patients with HTN over the past 2 decades and determine differences by sex, age, race, ethnicity, urbanization, and census region, using data from the US Centers for Disease Control and Prevention's (CDC) Wide-Ranging Online Data for Epidemiologic Research (WONDER) database.

Methodology

2.1 Study Setting and Population

Deaths occurring within the United States related to CA and HTN were extracted from the Centers for Disease Control and Prevention's Wide-Ranging Online Data for Epidemiologic Research (CDC WONDER) database. The Multiple Cause-of-Death Public Use record death certificates were analysed to identify cases where CA and HTN both were listed as the multiple cause of death. The definitions of CA and HTN used in this study are consistent with prior publications examining these conditions in the US. Institutional review board approval was not required as CDC WONDER contains anonymized, publicly available data. We extracted CA and HTN-related death counts and population sizes from 2000 to 2023.

Deaths were identified using ICD-10 codes: I46.0, I46.1, and I46.9 for CA and I10-I15 for HTN.^{7–11} Additionally, we followed the guidelines established by the reporting standards of the Strengthening the Reporting of Observational Studies in Epidemiology.¹² Geographic data were analysed at both the state and regional levels, with all U.S. states and the District of Columbia included. States such as West Virginia, Oklahoma, Rhode Island, Tennessee, and Ohio were examined individually for mortality trends. The population was divided into urban (large metropolitan area, medium/small metropolitan area) and rural (population < 50,000) counties according to the 2013 U.S. census classification. Regions were classified as Northeast, Midwest, South, and West based on U.S. Census Bureau definitions.¹³

2.2 Data Abstraction

Specifically, data extracted for analysis included sex, race, age groups, urbanization level, state, and census region. Sex included males and females. Race groups were divided into NH White, NH Black or African American, NH American Indian or Alaska Native, and Hispanic or Latino. Age groups were categorized as adults aged (25–44) years (younger adults), 45–64 years (middle-aged adults), and 65+ (older adults). Geographic data were analysed at both the state and regional levels, with all U.S. states and the District of Columbia included. States such as West Virginia, Oklahoma, Rhode Island, Tennessee, and Ohio were examined individually for mortality trends. The population was divided into urban (large metropolitan area, medium/small metropolitan area) and rural (population < 50,000) counties according to the 2013 U.S. census classification. Regions were classified as Northeast, Midwest, South, and West based on U.S. Census Bureau definitions.¹³ For the primary cause of death, we used the rankable cause of death feature in the CDC WONDER database, which provides mortality counts and rates for the 15 leading causes of death among individuals with these conditions.

2.3 Statistical Analysis

Age-adjusted mortality rates (AAMR) for CA and HTN-associated deaths were calculated. The United States population as of the year 2000 was used as the standard population for AAMR calculations.¹⁴ The Joinpoint Regression Program (Joinpoint version 5.2.0) was used to assess trends in HTN and AMI-associated mortality over the study period.¹⁴ This program identifies significant changes in annual mortality trends over time through Joinpoint regression, fitting linear segments where notable temporal variations occurred. Annual percentage change (APC) and 95% confidence intervals (CIs) for AAMRs were calculated using the Monte Carlo permutation test. The weighted average of the APCs was summarized as the average annual percent change (AAPC), with corresponding 95% CIs to capture the overall mortality trend for the 2000–2023 study period. A two-tailed *t*-test was conducted to evaluate whether APC and AAPCs indicated an increase or decrease in mortality during the study period. Statistical significance was set at $p \leq 0.05$ and is reported in the results, figures.

Results

A total of 1,603,971 HTN and CA- Related deaths occurred among adults (aged ≥ 25 years) between 2000 and 2023. **(Supplementary Table 1)** Information on the location of death was available for all 1,603,971 deaths. Of these, 44.04% occurred in medical facilities, 20.87% occurred in nursing homes/long-term care facilities, 1.09% occurred in hospices, 29.89% at the decedent's home, and 3.77% in other locations. **(Supplementary Table 2)**

Annual Stratified

The AAMR for HTN and CA-Related death in adults was 24.56 in 2000 and 32.83 in 2023 with an AAPC of + 1.09% (95% CI: 0.39 to 1.79; $p < 0.002$). The overall AAMR had a non-significant rise from 2000 to 2018 (APC: 0.84, 95% CI: 0.65 to 1.03), followed by a significant increase from 2018 to 2021 (APC: 9.24, 95% CI: 4.19 to 14.53). Lastly, trends showed a massive decline till 2023 (APC: -8.00, 95% CI: -12.11 to -3.69). A similar but less steep trend was seen on the sensitivity analysis for CA deaths related to HTN, where the underlying cause of death was restricted to CA.

Sex stratified

Men consistently had higher AAMRs than women throughout the study period. In 2000, the AAMR for men was 25.58 (95% CI: 25.20–25.96), which increased to 38.87 (95% CI: 38.51 to 39.23) in 2023 (AAPC: +1.65%; 95% CI: 0.95 to 2.35; $p < 0.001$). Similarly, the AAMR for women increased from 23.21 (95% CI: 22.93–23.50) in 2000 to 27.56 (95% CI: 27.29 to 27.82) in 2023 (AAPC: +0.55%; 95% CI: -0.18 to 1.28; $p < 0.143$). (Fig. 1, **Supplementary Table 4**)

Age Stratified

Elderly adults consistently showed higher AAMRs related to HTN and CA, compared to other age groups throughout the study period. In the young adults (25–44) age group, the AAMR increased from 0.80 (95% CI: 0.74–0.86) in 2000 to 1.80 (95% CI: 1.71–1.89) in 2023, with an average annual percent change (AAPC) of + 3.01% (95% CI: 2.39–3.49; $p < 0.001$). Similarly, in the middle-aged adults (45–64) age group, the AAMR rose from 10.14 (95% CI: 9.89–10.39) in 2000 to 16.59 (95% CI: 16.32–16.86) in 2023, with an AAPC of + 2.19% (95% CI: 1.77–2.51; $p < 0.001$). The elderly adults (65+) age group experienced the highest increase, with the AAMR rising from 105.98 (95% CI: 104.9–107.06) in 2000 to 134.6 (95% CI: 133.62–135.58) in 2023, with an AAPC of + 0.83% (95% CI: 0.51–1.06; $p < 0.001$). **(Supplementary Fig. 2, Supplementary Table 3)**

Race Stratified

The AAMRs for HTN and CA-Related deaths were highest among NH Black or African American individuals, followed by Hispanics, NH Asian or pacific islander, NH American Indian or Alaska Native,

and NH white populations. Specifically, the AAMR for NH Black or African American individuals was 58.43 (95% CI: 57.35 to 59.52), while NH Asian or Pacific Islander individuals had an AAMR at approximately 36.89 (95% CI: 35.48 to 38.3). Hispanic or Latino individuals had an AAMR of 37.88 (95% CI: 36.88 to 38.89), NH American Indian or Alaska Native individuals had an AAMR of 26.91 (95% CI: 23.78 to 30.04), and NH White individuals had the lowest AAMR of 24.69 (95% CI: 24.46 to 24.92). The data indicate that NH Black or African American adults had the highest AAMR, with a decrease observed from 2000 to 2023 with an AAPC of -0.09% (95% CI: -1.05 to 0.88; $p < 0.854$). Similarly, NH Asian or Pacific Islander experienced a decrease in AAMR with an AAPC of -1.31% (95% CI: -2.45 to -0.17, $p < 0.025$). On the other hand, NH White adults experienced a notable rise in AAMR during the same period with an AAPC of + 1.46% (95% CI: 0.92 to 1.99; $p < 0.001$). Similarly, Hispanic or Latino adults showed an upward trend in AAMR with an AAPC of + 0.16%; (95% CI: -0.95 to 1.28; $p < 0.780$), while NH American Indian or Alaska Native adults had the highest percentage increase in AAMR (AAPC: +1.73%; 95% CI: -0.20 to 3.69; $p < 0.080$). (Fig. 2, **Supplementary Table 5, Supplementary Table 10**)

Census Region Stratified

Adults in different census regions consistently showed varying AAMRs related to HTN and CA, throughout the study period. In the Northeast, the AAMR increased from 31.5 (95% CI: 30.94–32.07) in 2000 to 35.75 (95% CI: 35.23–36.27) in 2023, with an AAPC of + 0.18% (95% CI: -0.26–0.60; $p < 0.365$). Similarly, in the Midwest, the AAMR rose from 13.56 (95% CI: 13.21–13.91) in 2000 to 20.81 (95% CI: 20.43–21.19) in 2023, with an AAPC of + 1.79% (95% CI: 1.47–2.04; $p < 0.001$). In the South, the AAMR increased from 21.53 (95% CI: 21.17–21.90) in 2000 to 26.85 (95% CI: 26.53–27.17) in 2023, with an AAPC of + 0.89% (95% CI: 0.48–1.18; $p < 0.001$). The West also saw a rise in AAMR from 35.8 (95% CI: 35.18–36.43) in 2000 to 51.5 (95% CI: 50.93–52.07) in 2023, with an AAPC of + 1.34% (95% CI: 1.04–1.57; $p < 0.001$). (**Supplementary Fig. 1, Supplementary Table 8**)

State Stratified

A significant difference in AAMRs for HTN and CA-Related conditions was observed across different states, with the AAMRs ranging from 1.78 (95% CI: 1.70–1.86) in Massachusetts to 9.05 (95% CI: 8.48–9.62) in Vermont. States that fell into the top 90th percentile were Vermont, Oregon, West Virginia, North Dakota, and Ohio, which had significantly higher AAMRs compared to states in the lower 10th percentile, such as Connecticut, Alabama, Georgia, Massachusetts, and Nevada. (Fig. 3, **Supplementary Table 7**)

Urbanisation Stratified

Metropolitan areas exhibited higher HTN and CA-Related AAMRs than nonmetropolitan areas, with overall AAMRs of 28.49 (95% CI: 28.24–28.74) and 24.95 (95% CI: 24.45–25.46), respectively. The AAMRs in nonmetropolitan areas demonstrated a more pronounced increase over the study period from 2000 to 2019 in nonmetropolitan with an AAPC of + 2.37% (95% CI: 2.20–2.55; $p < 0.001$) for

nonmetropolitan and an AAPC of + 0.81% (95% CI: 0.56–1.03; $p < 0.001$) for metropolitan.

(Supplementary Fig. 3, Supplementary Table 6)

Underlying Causes of Death

We analyzed the top 3 leading underlying causes of death in CA patients with HTN. Our findings indicate that heart disease was the most prevalent cause, with an AAMR of 12.2 (95% CI: 12.2 to 12.2), followed by HTN and hypertensive renal disease at 4.1 (95% CI: 4.1 to 4.1) and Diabetes Mellitus at 2.8 (95% CI: 2.8 to 2.8). (Supplementary Table 9)

Discussion

This study analyzes HTN and CA-Related mortality among U.S. adults aged ≥ 25 from 2000 to 2023, revealing key temporal, demographic, and geographic patterns. AAMRs rose steadily from 2000 to 2018, surged sharply through 2021, then declined by 2023. Although most deaths occurred in medical settings, a substantial portion took place at home. Men consistently had higher AAMRs, despite women accounting for more total deaths. Older adults bore the highest absolute burden, but the fastest proportional increases were seen in younger adults. Regionally, the Western U.S. had the highest mortality burden, with notable state-level disparities. Nonmetropolitan areas experienced higher and more rapidly rising AAMRs than metropolitan ones. Racial and ethnic disparities were pronounced— NH Black individuals had the highest AAMRs but showed modest improvement, while rates increased significantly among NH White and NH American Indian/Alaska Native populations. (Table 1, Figure 4)

The observed temporal trends in HTN and CA-Related mortality reflect a complex interplay of evolving public health challenges and adaptations in cardiovascular care over the past two decades. The initial non-significant rise in AAMRs from 2000 to 2018 is likely attributable to the escalating prevalence of key cardiovascular risk factors, particularly the increasing rates of obesity and type 2 diabetes within the U.S. population, which exacerbate HTN's burden.^{15,16} Despite continuous public health efforts, persistent gaps in HTN control, especially among younger adults, further contributed to this upward trajectory.^{17,18} A sharp rise in AAMRs from 2018 to 2021 aligns with the COVID-19 pandemic, which directly affected cardiovascular health and disrupted healthcare access, leading to more cardiac events and increased deaths at home.¹⁹ Conversely, the massive decline in AAMRs observed from 2021 to 2023 suggests a potential post-pandemic recovery, possibly influenced by renewed public health initiatives like Million Hearts and a return to more consistent healthcare utilization, highlighting the critical role of sustained, evidence-based interventions in blood pressure control and cardiovascular health.^{20,21}

Age-stratified analysis of HTN and CA-Related mortality reveals distinct vulnerabilities across the adult lifespan. Although older adults (≥ 65 years) bear the highest absolute number of deaths, the fastest proportional increases occurred in young and middle-aged individuals. Higher death rates in the elderly reflect the cumulative effects of chronic HTN, exacerbated by age-Related physiological changes like increased arterial stiffness and cardiac remodeling.^{22–24} Furthermore, the high prevalence of

multimorbidity in this age group increases their risk for severe cardiac complications.²⁵ Conversely, the rapid rise in deaths among adults aged 25 to 64 years points to a troubling epidemiological shift.²⁶ Younger adults also tend to have poorer HTN awareness, management, and medication adherence, resulting in inadequate blood pressure control and the earlier development of cardiovascular complications.^{27–29}

The analysis of sex-specific trends in HTN and CA-related mortality reveals a consistent, yet complex, disparity throughout the study period. Men had persistently higher AAMRs than women, a result that is consistent with prior literature suggesting that men tend to experience cardiovascular events at an earlier age and with more severity.³⁰ This disparity could be the result of a combination of higher prevalence of traditional cardiovascular risk factors like smoking and poorer lifestyle choices in men, in addition to possible biological differences in disease trajectory.^{31,32} In addition, men are sometimes less apt to participate in preventive healthcare or adhere long-term to treatment plans for chronic conditions like HTN, which could contribute to less well-controlled blood pressure over time.^{33,34} This growing risk for women, especially in the later study years, could be due to the loss of hormonal protection after menopause, resulting in an accelerated increase in cardiovascular risk factors.³⁵ Additionally, women are sometimes underdiagnosed with HTN or less aggressively managed with evidence-based treatments for cardiovascular disease, perhaps related to atypical symptomatology or healthcare bias, resulting in delayed intervention and worse outcomes once HTN-related complications arise.^{36,37}

Analysis of HTN and CA-Related mortality reveals pronounced racial and ethnic disparities. NH Black adults carried the highest burden, with an earlier onset and more severe HTN linked to factors like systemic racism, economic inequity, and chronic stress that limit access to quality healthcare.^{38,39} Although this group's age-adjusted mortality rate (AAMR) slightly declined, it started from a much higher baseline. Conversely, AAMRs showed concerning upward trends for NH White and American Indian/Alaska Native populations. The increase among White adults may relate to the rising burden of obesity and suboptimal HTN management, while the significant increase for NH American Indian/Alaska Native populations is linked to health inequities, historical trauma, and underfunded healthcare systems.^{15,40} Hispanic adults also experienced an upward trend, potentially associated with acculturation to unhealthy dietary patterns and barriers to culturally competent care.⁴¹ In contrast, the NH Asian or Pacific Islander group experienced a decreased AAMR, though this aggregated category masks significant variability among sub-populations.⁴² These persistent disparities underscore the need for interventions that address the social and structural determinants of equitable care.⁴³

The differences in mortality rates due to HTN-Related CA in metropolitan and nonmetropolitan areas indicate a substantial rural-urban health divide. We report higher AAMRs and higher rates of increase in nonmetropolitan areas, which are consistent with trends in the cardiovascular health literature; higher AAMRs and associated risk factors are more prevalent in rural areas.⁴⁴ This heightened burden in rural areas results from an interplay of health care access limitations, including reduced specialist and emergency services access, along with rural hospital closures that increase time to critical

response.^{45,46} Furthermore, rural communities are also characterized by socioeconomic disadvantage markers such as increased poverty rates and educational demographics that are linked to worse cardiovascular outcomes and difficulty with proper health behaviours and medication adherence.^{47,48}

Analyzing the location of death provides crucial context for HTN and CA-Related mortality and helps identify opportunities for targeted interventions. The majority of deaths occurred in residences, suggesting they were primarily OHCA. This high proportion may be due to a lack of awareness of HTN severity, delayed symptom recognition, or delayed activation of emergency medical services (EMS). These challenges are often exacerbated in rural or underserved areas with limited pre-hospital resources and lower rates of bystander interventions like CPR and defibrillation.^{49,50} Conversely, a significant number of deaths in medical facilities indicates that many individuals were already receiving acute care for severe, often decompensated, HTN. In these instances, the underlying hypertensive heart disease likely progressed to a fatal CA despite advanced medical interventions.^{51,52} Lower proportions in nursing homes and hospices typically reflect populations with advanced chronic diseases and end-of-life care plans, where CA is an anticipated terminal event consistent with palliative care goals.⁵³ These locations highlight different clinical trajectories and underscore the need for tailored strategies for prevention, emergency response, and end-of-life care planning.

The observed trends and disparities in hypertension highlight the need for a multi-level public health response. Among younger and middle-aged adults, annual screening in high-risk groups and validated home or ambulatory monitoring should be integrated into primary care. Patient education and adherence strategies are essential to improve long-term pharmacological and lifestyle management. Evidence-based interventions include weight reduction, the DASH diet, sodium reduction of $\geq 1,000$ mg/day, and potassium intake of 3,500–5,000 mg/day. At least 150 minutes of moderate physical activity per week is strongly recommended. Special focus is required for individuals with obesity and type 2 diabetes, who face disproportionate vulnerability. Policy-level measures such as sodium regulation in foods, active transport infrastructure, and school-based health promotion are critical to shift the overall blood pressure distribution.⁵⁴ Improving long-standing racial and ethnic disparities requires health equity interventions that are focused on social determinants of health (SDOH), including economic disadvantage and structural racism, through culturally competent community-based efforts, expanded affordable healthcare access, and policies that reduce systemic barriers.⁵⁵ The stark health disparities due to geography also require policy decisions and investments in the healthcare infrastructure of nonmetropolitan areas to bring in specialist and emergency services, and leveraging telehealth to bridge geographical care gaps.^{56,57} Lastly, state-level variations highlight the importance of implementing local specific public health policies and delivering statewide comprehensive HTN control programs with the potential to increase awareness, treatment utilization, and control rates in countries with high mortality rates, benefiting from continuous monitoring and basing their approaches on disaggregated data, all supported by continuous surveillance and granular data analysis via platforms like CDC WONDER to inform adaptive strategies.^{58,59}

Limitations

This article should be interpreted with its limitations in mind. The data used was taken from the CDC WONDER database, and its accuracy depends on how well causes of death and related health conditions are reported. Since CA can result from many different underlying problems, it is often difficult to identify HTN as the direct or primary cause, which may affect how the data is represented. Another challenge is that the information comes only from death certificates, which means a history of HTN or prior heart conditions may be underreported or overlooked. In addition, the database only includes basic demographics such as age, race, sex, geographic region, and level of urbanization. Important details like patient history, long-term blood pressure control, use of medications, and other co-morbidities are not available, making it harder to fully understand the multifactorial nature of these deaths.

Conclusion

In conclusion, our analysis of Hypertension- and Cardiac Arrest–Related mortality in U.S. adults (2000–2023) reveals an alarming trajectory: an early rise, a sharp spike in 2018–2021, and a decline by 2023. Many deaths occurred in hospitals, yet a substantial share occurred at home. Men consistently had higher age-adjusted mortality rates, while women contributed more absolute deaths. Older adults bore the greatest burden, but younger groups saw steep proportional increases. Geographically, the West and nonmetropolitan counties carried the highest rates, with wide state-level variation. Racial and ethnic disparities persisted, with NH Black adults showing the highest rates and NH White and American Indian/Alaska Native groups experiencing notable increases. These patterns reflect the combined effects of chronic hypertension remodeling, rising risk factors, poor hypertension control, COVID-19, and inequities in healthcare access.

Declarations

Data availability

The data supporting the findings of this study were obtained from the CDC WONDER online database (Centers for Disease Control and Prevention Wide-ranging Online Data for Epidemiologic Research). The datasets used and analyzed during the current study are publicly available and can be accessed at <https://wonder.cdc.gov>.

Funding statement

Not applicable.

Ethics approval statement

Not applicable.

Patient consent statement

Not applicable.

Permission to reproduce material from other sources

Not applicable

Clinical trial registration

Not applicable

Author Contribution

Author ContributionsMohid Zulfiqar: Conceptualization, study design, data interpretation, manuscript drafting, review, and editing.Syed Ahmed Ali Shah: Literature review, data interpretation, manuscript drafting, review, and editing.Muhammad Salik Uddin: Literature review, data interpretation, manuscript drafting, review, and editing.Shaheer Bin Shafiq: Literature review, data interpretation, manuscript drafting, review, and editing.Hassan Abdul Aziz Dhedhi: Methodology development, formal analysis, results interpretation, manuscript drafting (Methods and Results sections), review, and editing.Asim Sajjad: Literature review, data interpretation, manuscript drafting, review, and editing.Saad Ahmed Waqas: Literature review, data interpretation, manuscript drafting, review, and editing.Hermann YOKOLO: Critical review of the manuscript, scientific input, and editing.Maryam Sajid: Literature review, data interpretation, manuscript drafting, review, and editing.

References

1. Mehra R. Global public health problem of sudden cardiac death. J Electrocardiol. 2007;40(6):S118–22. 10.1016/j.jelectrocard.2007.06.023.
2. Facts CPR. and Stats. cpr.heart.org. Accessed February 20, 2026. <https://cpr.heart.org/en/resources/cpr-facts-and-stats>
3. Alamgir A, Mousa O, Shah Z. Artificial Intelligence in Predicting Cardiac Arrest: Scoping Review. JMIR Med Inf. 2021;9(12):e30798. 10.2196/30798.
4. Khalid N, Abdullah M, Higgins SC, et al. Cardiac Arrest Mortality Across Time and Space: A National Analysis with Forecasts to 2035. J Clin Med. 2025;14(14):4851. 10.3390/jcm14144851.
5. Benjamin EJ, Muntner P, Alonso A, et al. Heart Disease and Stroke Statistics—2019 Update: A Report From the American Heart Association. Circulation. 2019;139(10). 10.1161/CIR.0000000000000659.
6. Heidenreich PA, Trogdon JG, Khavjou OA, et al. Forecasting the Future of Cardiovascular Disease in the United States: A Policy Statement From the American Heart Association. Circulation. 2011;123(8):933–44. 10.1161/CIR.0b013e31820a55f5.
7. Khalid N, Afzal MA, Abdullah M, et al. Trends in cardiac arrest related mortality in the united states from 1999–2020 - a cdc wonder database analysis. JACC. 2024;83(13Supplement):2368–2368.

- 10.1016/S0735-1097(24)04358-4.
8. Sajid M, Ali D, Qureshi S, et al. Trends and Disparities in Acute Myocardial Infarction-Related Mortality Among U.S. Adults With Hypertension, 2000–2023. *Clin Cardiol.* 2025;48(4):e70129. 10.1002/clc.70129.
 9. Shaukat MT, Mohsin A, Nadeem ZA et al. Trends in hypertensive disease related deaths in the United States from 1999 to 2020: a retrospective analysis. *Minerva Cardiol Angiol.* Published online June 2025. 10.23736/S2724-5683.25.06713-4
 10. Nabi R, Zanub A, Akhtar M, et al. Concomitant mortality trends due to obesity and hypertension in the U.S.: a 20-year retrospective analysis of the CDC WONDER database. *BMC Cardiovasc Disord.* 2025;25(1):496. 10.1186/s12872-025-04909-z.
 11. Hashmi S, Safdar I, Kazmi MH, et al. Rising Mortality Related to Diabetes Mellitus and Hypertension: Trends and Disparities in the United States (1999 – 2023). *Clin Cardiol.* 2025;48(4):e70132. 10.1002/clc.70132.
 12. Elm EV, Altman DG, Egger M, Pocock SJ, Gøtzsche PC, Vandenbroucke JP. Strengthening the reporting of observational studies in epidemiology (STROBE) statement: guidelines for reporting observational studies. *BMJ.* 2007;335(7624):806–8. 10.1136/bmj.39335.541782.ad.
 13. Issa R, Nazir S, Khan Minhas AM, et al. Demographic and regional trends of peripheral artery disease-related mortality in the United States, 2000 to 2019. *Vasc Med.* 2023;28(3):205–13. 10.1177/1358863x221140151.
 14. Anderson RN, Rosenberg HM. Age standardization of death rates: implementation of the year 2000 standard. *Natl Vital Stat Rep Cent Dis Control Prev Natl Cent Health Stat Natl Vital Stat Syst.* 1998;47(3):1–16.
 15. Trends in Obesity Prevalence Among Adults With Hypertension in the United States, 2001 to 2023 | Hypertension. Accessed August 16. 2025.
<https://www.ahajournals.org/doi/10.1161/HYPERTENSIONAHA.124.24123>
 16. Powell-Wiley TM, Poirier P, Burke LE, et al. Obesity and Cardiovascular Disease: A Scientific Statement From the American Heart Association. *Circulation.* 2021;143(21):e984–1010. 10.1161/CIR.0000000000000973.
 17. Fryar CD. Hypertension Prevalence, Awareness, Treatment, and Control Among Adults Age 18 and Older: United States, August 2021–August 2023. 2024;(511).
 18. Tang R, An J, Bellows BK, Moran AE, Zhang Y. Trends in Hypertension Prevalence, Awareness, Treatment, and Control Among US Young Adults, 2003–2023. *Am J Hypertens.* 2025;38(8):551–9. 10.1093/ajh/hpaf044.
 19. Heart Disease Mortality in the United States, 1970 to 2022 | Journal of the American Heart Association. Accessed August 16. 2025.
<https://www.ahajournals.org/doi/10.1161/JAHA.124.038644>
 20. Wall HK, Wright JS, Fleisher LA, Sperling LS. Improving Blood Pressure Control in the United States: At the Heart of Million Hearts 2027. *Am J Hypertens.* 2023;36(8):462–5. 10.1093/ajh/hpad029.

21. Mensah GA, Wei GS, Sorlie PD, et al. Decline in Cardiovascular Mortality. *Circ Res*. 2017;120(2):366–80. 10.1161/CIRCRESAHA.116.309115.
22. Hypertensive Heart Disease: Symptoms, Causes & Treatment. Cleveland Clinic. Accessed August 16. 2025. <https://my.clevelandclinic.org/health/diseases/21840-hypertensive-heart-disease>
23. Sun Z, Aging. Arterial Stiffness, and Hypertension. *Hypertension*. 2015;65(2):252–6. 10.1161/HYPERTENSIONAHA.114.03617.
24. Tomek J, Bub G. Hypertension-induced remodelling: on the interactions of cardiac risk factors. *J Physiol*. 2017;595(12):4027–36. 10.1113/JP273043.
25. Aggarwal P, Woolford SJ, Patel HP. Multi-Morbidity and Polypharmacy in Older People: Challenges and Opportunities for Clinical Practice. *Geriatrics*. 2020;5(4):85. 10.3390/geriatrics5040085.
26. Scott J, Agarwala A, Baker-Smith CM, et al. Cardiovascular Health in the Transition From Adolescence to Emerging Adulthood: A Scientific Statement From the American Heart Association. *J Am Heart Assoc*. 2025;14(9):e039239. 10.1161/JAHA.124.039239.
27. Gooding HC, McGinty S, Richmond TK, Gillman MW, Field AE. Hypertension Awareness and Control Among Young Adults in the National Longitudinal Study of Adolescent Health. *J Gen Intern Med*. 2014;29(8):1098–104. 10.1007/s11606-014-2809-x.
28. Lee H, Yano Y, Cho SMJ, et al. Adherence to Antihypertensive Medication and Incident Cardiovascular Events in Young Adults With Hypertension. *Hypertension*. 2021;77(4):1341–9. 10.1161/HYPERTENSIONAHA.120.16784.
29. Yano Y. Blood Pressure in Young Adults and Cardiovascular Disease Later in Life. *Am J Hypertens*. 2021;34(3):250–7. 10.1093/ajh/hpab005.
30. Heart disease - Symptoms and causes. Mayo Clinic. Accessed August 16. 2025. <https://www.mayoclinic.org/diseases-conditions/heart-disease/symptoms-causes/syc-20353118>
31. Peters SAE, Muntner P, Woodward M. Sex Differences in the Prevalence of, and Trends in, Cardiovascular Risk Factors, Treatment, and Control in the United States, 2001 to 2016. *Circulation*. 2019;139(8):1025–35. 10.1161/CIRCULATIONAHA.118.035550.
32. Lv Y, Cao X, Yu K, et al. Gender differences in all-cause and cardiovascular mortality among US adults: from NHANES 2005–2018. *Front Cardiovasc Med*. 2024;11. 10.3389/fcvm.2024.1283132.
33. Men's Health: Breaking Down Barriers to Healthcare Engagement -. Accessed August 16. 2025. <https://azprimaryclinic.com/mens-health-breaking-down-barriers-to-healthcare-engagement/>
34. Lefort M, Neufcourt L, Pannier B, et al. Sex differences in adherence to antihypertensive treatment in patients aged above 55: The French League Against Hypertension Survey (FLAHS). *J Clin Hypertens*. 2018;20(10):1496–503. 10.1111/jch.13387.
35. Fasero M, Coronado PJ. Cardiovascular Disease Risk in Women with Menopause. *J Clin Med*. 2025;14(11):3663. 10.3390/jcm14113663.
36. 2019 ACC/AHA Guideline on the Primary Prevention of Cardiovascular Disease: A Report of the American College of Cardiology/American Heart Association Task Force on Clinical Practice

- Guidelines | Circulation. Accessed August 16. 2025.
<https://www.ahajournals.org/doi/10.1161/CIR.0000000000000678>
37. EVERETT B. Gender Differences in Hypertension and Hypertension Awareness Among Young Adults. *Biodemography Soc Biol*. 2015;61(1):1–17. 10.1080/19485565.2014.929488.
 38. Heart Disease and Black/African Americans | Office of Minority Health. Accessed August 16. 2025.
<https://minorityhealth.hhs.gov/heart-disease-and-blackafrican-americans>
 39. CDCMMWR, QuickStats. Age-Adjusted Percentage of Adults Aged ≥ 18 Years with Hypertension, by Sex and Race and Ethnicity – United States, August 2021–August 2023. *MMWR Morb Mortal Wkly Rep*. 2024;73. 10.15585/mmwr.mm7348a5.
 40. Heart Disease and American Indians/Alaska Natives | Office of Minority Health. Accessed August 16. 2025. <https://minorityhealth.hhs.gov/heart-disease-and-american-indiansalaska-natives>
 41. 2025 Heart Disease and Stroke Statistical Update Fact Sheet: Hispanics/Latinos & Cardiovascular Diseases. Accessed August 16. 2025. <https://professional.heart.org/-/media/phd-files-2/science-news/2/2025-heart-and-stroke-stat-update/factsheets/2025-stats-update-fact-sheet-hispanic-latino-and-cvd.pdf>
 42. Big differences found in heart and stroke risks among Asian American, Native Hawaiian and Pacific Islander groups. *www.heart.org*. Accessed August 16. 2025.
<https://www.heart.org/en/news/2025/03/10/big-differences-found-in-heart-and-stroke-risks-among-asian-american>
 43. Impact of Social Determinants of Health on Cardiovascular Disease | Journal of the American Heart Association. Accessed August 16. 2025.
<https://www.ahajournals.org/doi/10.1161/JAHA.124.039031>
 44. Biondi-Zoccai 'Giuseppe, ' '. When rural is worse for cardiovascular care. Accessed August 16. 2025.
[https://www.escardio.org/Sub-specialty-communities/European-Association-of-Preventive-Cardiology-\(EAPC\)/News/when-rural-is-worse-for-cardiovascular-care](https://www.escardio.org/Sub-specialty-communities/European-Association-of-Preventive-Cardiology-(EAPC)/News/when-rural-is-worse-for-cardiovascular-care)
 45. Rural-Urban Temporal Trends for Sudden Cardiac Death in the United States, 1999–2019 | *JACC: Clinical Electrophysiology*. Accessed August 16. 2025.
<https://www.jacc.org/doi/10.1016/j.jacep.2021.12.006>
 46. Miller KEM, James HJ, Holmes GM, Van Houtven CH. The effect of rural hospital closures on emergency medical service response and transport times. *Health Serv Res*. 2020;55(2):288–300. 10.1111/1475-6773.13254.
 47. SDH CVD Evidence Report.pdf. Accessed August 16. 2025.
<https://www.healthdata.org/sites/default/files/2024-08/SDH%20CVD%20Evidence%20Report.pdf>
 48. Social factors help explain worse cardiovascular health among adults in rural vs. urban communities | National Institutes of Health (NIH). Accessed August 16. 2025.
<https://www.nih.gov/news-events/news-releases/social-factors-help-explain-worse-cardiovascular-health-among-adults-rural-vs-urban-communities>

49. FACTS, Accessed. August 16, 2025. <https://www.heart.org/-/media/Files/About-Us/Policy-Research/Fact-Sheets/Acute-Care/Out-of-Hospital-Cardiac-Arrest.pdf>
50. Evaluation of Glomerular Hemodynamic Function by Empagliflozin in Diabetic Mice Using In Vivo Imaging | Circulation. Accessed August 16. 2025. <https://www.ahajournals.org/doi/10.1161/CIRCULATIONAHA.118.037418>
51. Clinical Outcomes in Hypertensive Emergency: A Systematic Review and Meta-Analysis | Journal of the American Heart Association. Accessed August 16. 2025. <https://www.ahajournals.org/doi/10.1161/JAHA.122.029355>
52. Guiga H, Decroux C, Michelet P, et al. Hospital and out-of-hospital mortality in 670 hypertensive emergencies and urgencies. *J Clin Hypertens*. 2017;19(11):1137–42. 10.1111/jch.13083.
53. Wiese CHR, Bartels UE, Zausig YA, Pfisteringer J, Graf BM, Hanekop GG. Prehospital emergency treatment of palliative care patients with cardiac arrest: a retrospective investigation. *Support Care Cancer*. 2010;18(10):1287–92. 10.1007/s00520-009-0746-8.
54. Saudi, HTN HP P guideline v1 (1). pdf. Accessed August 16, 2025. [https://www.pha.gov.sa/ar-sa/EvidenceAndProcedures/Documents/Saudi%20HTN%20HP%20P%20guideline%20v1%20\(1\).pdf](https://www.pha.gov.sa/ar-sa/EvidenceAndProcedures/Documents/Saudi%20HTN%20HP%20P%20guideline%20v1%20(1).pdf)
55. Williams DR, Mohammed SA, Racism, Health I. Pathways and Scientific Evidence. *Am Behav Sci*. 2013;57(8). 10.1177/0002764213487340.
56. About Rural Health Care | National Rural Health Association - NRHA | NRHA. National Rural Health. Accessed August 16. 2025. <https://www.ruralhealth.us/about-us/about-rural-health-care>
57. Hayden EM, Davis C, Clark S, TELEHEALTH IN EMERGENCY MEDICINE: A CONSENSUS CONFERENCE TO MAP THE INTERSECTION OF TELEHEALTH AND EMERGENCY MEDICINE. *Acad Emerg Med Off J Soc Acad Emerg Med*. 2021;28(12):1452–1474. 10.1111/acem.14330
58. Go AS, Bauman MA, Coleman King SM, et al. An Effective Approach to High Blood Pressure Control. *Hypertension*. 2014;63(4):878–85. 10.1161/HYP.0000000000000003.
59. CDC WONDER, Accessed. August 16, 2025. <https://wonder.cdc.gov/>

Table

Table 1 is available in the Supplementary Files section.

Figures

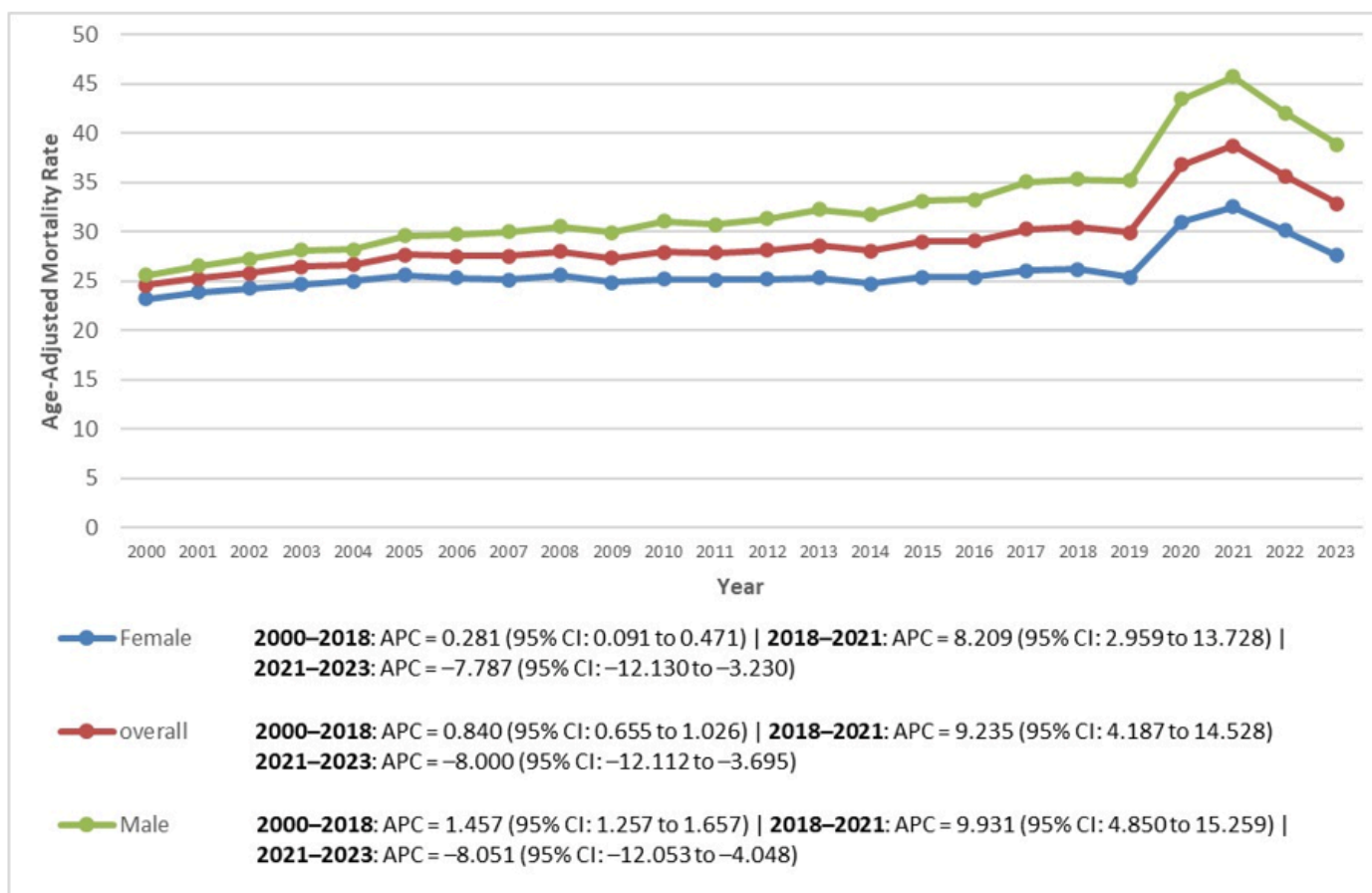


Figure 1

Figure 1

Hypertension and Cardiac Arrest- related AAMRs per 100,000 in adults in the United States from 2000 to 2023 stratified by sex. APC, annual percent change; CI, confidence intervals.

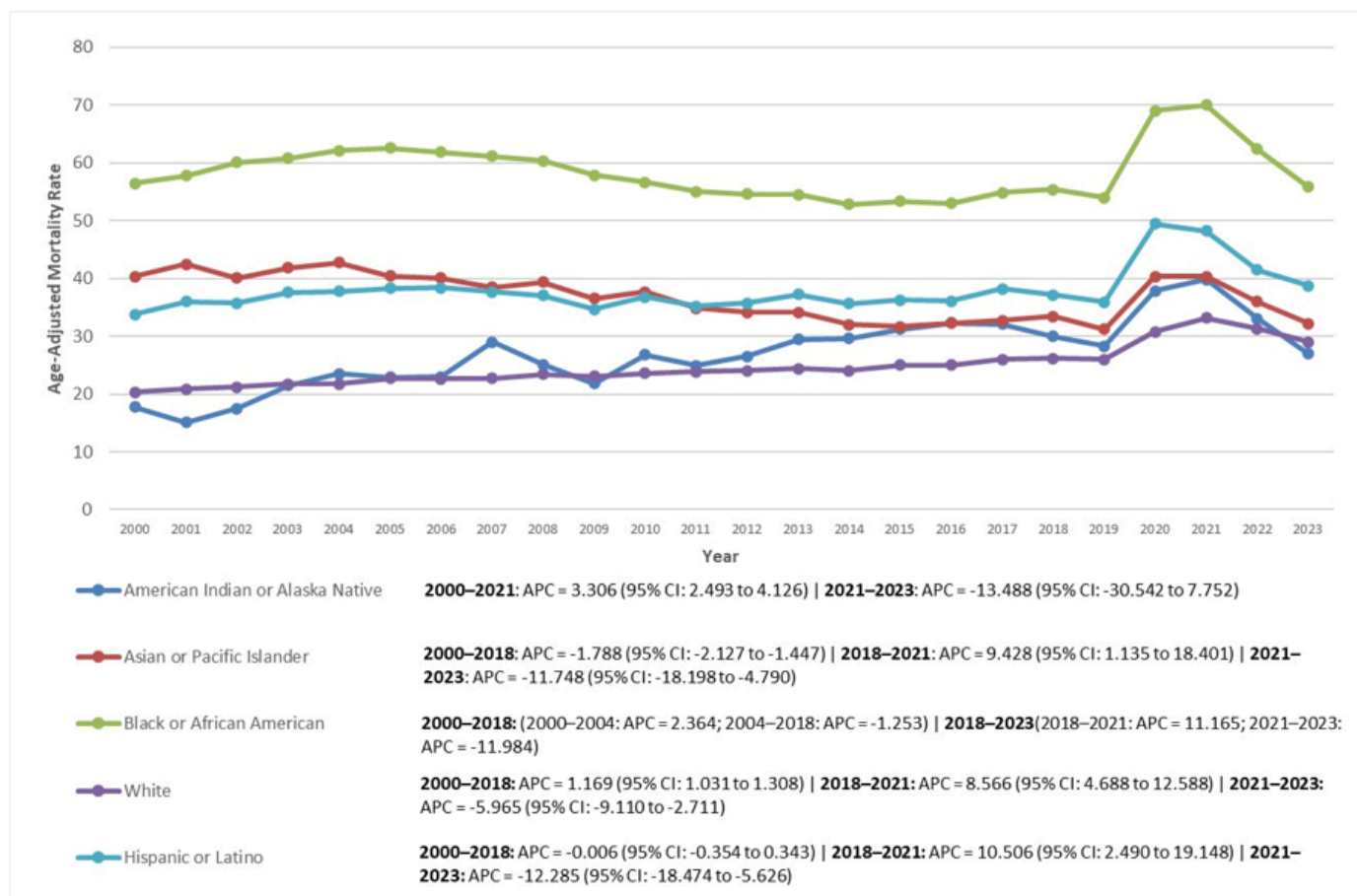


Figure 2

Figure 2

Hypertension and Cardiac Arrest-Related AAMRs per 100,000 in adults the United States from 2000 to 2023 stratified by race. APC, annual percent change; CI, confidence intervals.

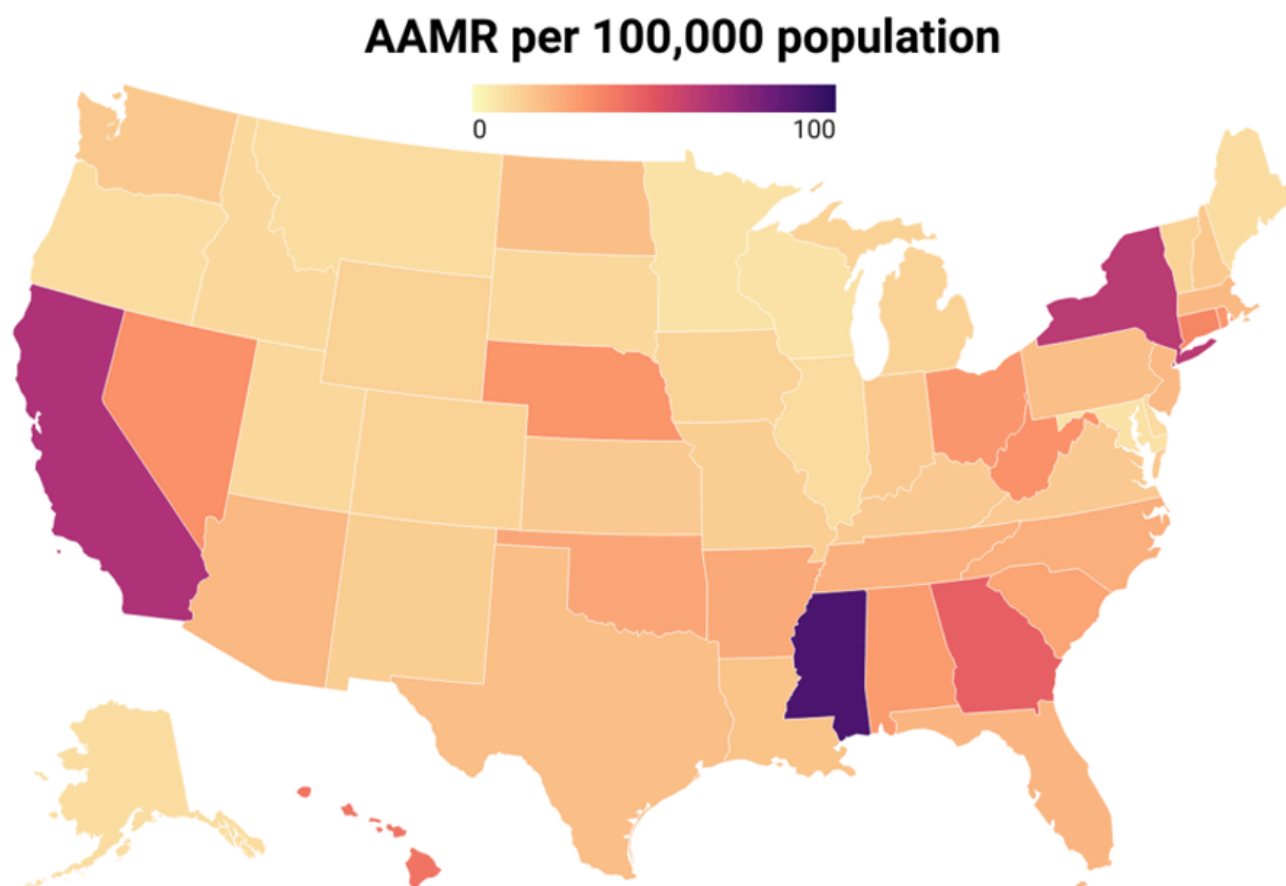


Figure 3

Figure 3

Hypertension and Cardiac Arrest-Related mortality in adults in the United States stratified by state, 2000-2020

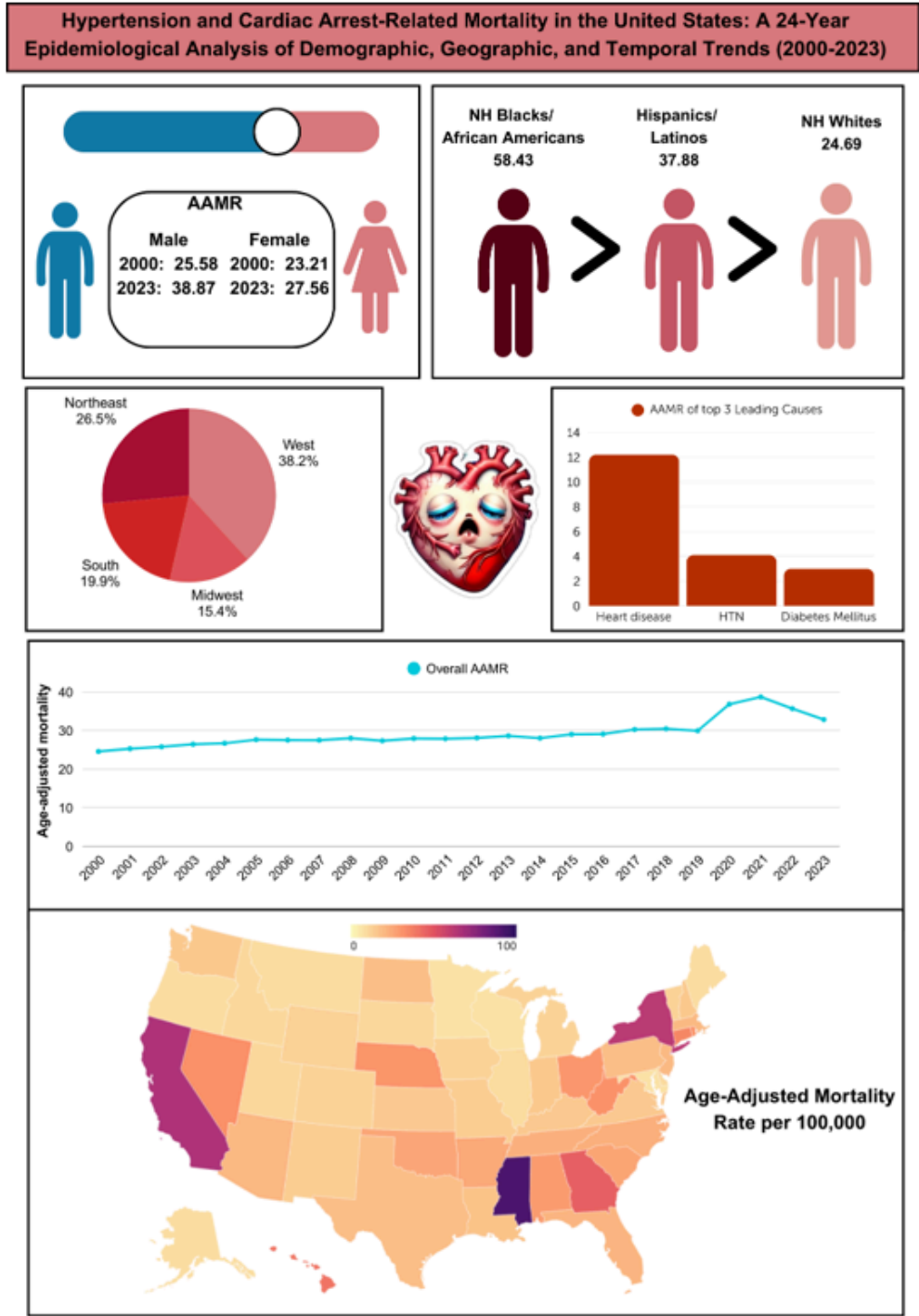


Figure 4

Figure 4

central illustration

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- [CAandHTNsupplementarytablesandfigures.docx](#)
- [Table1.docx](#)