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**Original Research Article**

# Temporal trends in mortality from 1999 to 2020 in patients aged over 25 years with heart failure and cardiogenic shock

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## ABSTRACT

**Background:** Heart failure (HF) is a major cause of mortality and its association with cardiogenic shock (CS) remains underexplored. Understanding this relationship is essential to identify high-risk populations and develop targeted public health interventions. Aim was to evaluate mortality trends in HF, where CS is a contributing cause of death by using the Centers for Diseases Control and Prevention (CDC) multiple causes of death by (MCD) database.
**Methods:** A retrospective original research study was conducted using the CDC MCD database to assess mortality trends between 1999 and 2020 in individuals >25 years in the United States. Deaths from congestive HF (ICD-10, I50.0), left ventricular failure (i50.1) and HF, unspecified (ICD-10, I50.9) as underlying cause and CS (ICD-10, R57.0) as contributor cause were selected. Data were stratified by gender, race, geographic region and place of death. Age-adjusted mortality rates (AAMR) and annual percentage change (APC) were calculated.
**Results:** A total of 14901 deaths were recorded. The AAMR for HF with CS showed a decline from 1999 to 2009 (APC- -4.84%), an increase, 2009 - 2012 (APC +3.92%) and decline, 2012 to 2020 (APC: 2.68%) with the highest mortality observed in males (56.6%), white individuals (76.7%), and metropolitan areas (81.50%). Trends showed an increase in AAMR in females (APC: +15.48 %) after 2012, black individuals with APC +22.10% after 2010 demonstrating disparities.
**Conclusions:** Mortality trends in HF have changed with rising disparities in gender and race, indicating need for cardiac interventions and improved health care access.

**Keywords:** CS, Heart failure, Age-adjusted mortality rate, Retrospective study, CDC MCD

## INTRODUCTION

Heart failure (HF) is a clinical syndrome characterised by symptoms and/or signs resulting from a structural or functional cardiac abnormality, supported by elevated natriuretic peptide levels or objective evidence of pulmonary or systemic congestion.[1] It is a significant public health concern, affecting millions worldwide. Globally, HF affects more than 64 million people.[2] According to the CDC, approximately 6.7 million U.S.

adults aged 20 and older have HF. The prevalence of HF increases with age, affecting about 1% of adults aged 18-44, 3.6% between 45-54, 9% aged 55-64, 14.3% aged 65-74 and 24.2% aged 75 and above. HF affects more than 10% of individuals over 70 years.[3]

CS is a life-threatening condition characterized by inadequate tissue perfusion due to the heart's inability to pump sufficient blood, leading to systemic hypoperfusion and potential multiorgan failure.[4] The relationship between HF and CS is significant, as HF-related CS (HF-CS) accounts for over 50% of all CS cases. This form of shock often arises from the progression of chronic HF or acute decompensated HF episodes. Notably, HF-CS patients often have a history of chronic HF may exhibit different responses to treatment modalities.[5,6]

HF and CS are interconnected conditions, with CS often arising as a severe complication of HF. The progression from HF to CS involves several key pathophysiological mechanisms such as beta-adrenergic desensitisation, neurohormonal activation, myocardial ischemia, mechanical complications like papillary muscle rupture.[7-10] A number of studies linking HF and CS have been done.[6,11] Analysing the relationship between HF and CS is crucial due to the high mortality of CS, its progression from HF, and the need for early risk stratification. Understanding their link helps in developing personalised treatment strategies, optimising mechanical circulatory support use, and reducing healthcare burdens. Additionally, research in this area can drive innovations in therapy and improve clinical outcomes.

### *Aim and objectives*

Aim and objectives were to evaluate mortality trends in HF, where CS is a contributing cause of death by using the CDC MCD by database. This study examines mortality trends from 1999-2020 and stratifies data by gender, race and geographic location to identify potential disparities in mortality pattern.

## METHODS

A retrospective original research study was conducted using the Centers for Disease Control and Prevention Wide-Ranging Online Dat for Epidemiologic Research (CDC WONDER) MCD database. This study used publicly available mortality data, which included deidentified death certificate information for all deaths recorded in the United States. The data extraction was performed on January 20, 2025 and the dataset consists of publicly available, de-identified information, so the study was classified as non-human participant research. Thus, exempt from institutional review board approval (IRB).

Mortality data was extracted for the years 1999-2020 from the CDC WONDER MCD databases. This study included individuals aged 25 years and above, as HF and CS-related mortality in younger populations is rare. In this study, the underlying cause of death as congestive HF (ICD-10, I50.0), left ventricular failure (i50.1) and HF, unspecified (ICD-10, I50.9) were selected and multiple cause of death as CS (ICD-10, R57.0) were selected to evaluate co-occurrence of these conditions. Demographic variables such as gender (male and female), race or ethnicity (American Indian or Alaska Native, Asian or Pacific Islander, Black or African American, White) were included to evaluate disparities in mortality rates or mortality outcomes. Metropolitan cities were categorized into large central metro, large fringe metro, medium metro and small metro, whereas non-metropolitan cities were categorized into micropolitan and non-core rural areas. These are included as geographic variables included from urbanization based on the 2013 classification. Additionally, the place of death was categorized into medical facility, home, hospice and nursing facility. Age-adjusted rates per 1,000,000 population were used to standardized the mortality rates, with adjustments based on the U. S. standard population from the year 2000 to permit accurate comparisons over time. To analyze the demographic and geographic variables, descriptive statistics were used including absolute numbers and percentages. Using the CDC WONDER MCD database, AAMR were calculated for each subgroup. To determine APCs in HF (ICD-10, I50.0) and CS (ICD-10, R57.0) related mortality and to evaluate temporal trends, JoinPoint Regression Analysis (JoinPoint software version 5.3.0.0, November 2024) was used. Over the 1999-2020 study period, trends were assessed to identify statistically significant changes in mortality patterns across different demographic and geographic groups. The analysis included stratification by gender and race, with trends for American Indian/ Alaska Native and Asian/Pacific Islander populations not displayed due to data suppression for less than 10 counts, limiting reliable trend analysis. To ensure accurate and reliable results, the findings were derived from a comprehensive analysis or mortality data, utilizing advanced statistical tools.

## RESULTS

From 1999 to 2020, the CDC MCD database recorded 14901 deaths in the United States among adults aged 25 years and older. Among these, deaths where HF (ICD-10: I50) was listed as the underlying cause of death and CS (ICD-10: R57) was recorded as MCD were included in the study (14901). The crude mortality rate for HF with CS as a contributing cause was 3.3 per 1,000,000 population. Deaths due to causes other than these criteria were excluded.

### *Demographic characteristics*

As per data analysis of total deaths (Figure 4), males were 8436(56.6%), while females were 6465 (43.4%). The mortality rate for HF with CS as a contributing cause was higher in males than females, indicating a potential demographic variation in Gender. As per racial

distribution, the highest proportion of deaths was noted among White individuals (n=11428, 76.7%), followed by Black or African American individuals (n=2978, 20%), Asian or Pacific Islander individuals (n=393, 2.6%), and American Indian or Alaska Native individuals (n=102, 0.7%). The mortality burden was highest among White individuals, featuring racial variation in mortality trends related to HF and CS.

### *Geographic characteristics*

Most deaths were noted in metropolitan areas (n=12152, 81.50%), while in non-metropolitan areas (n=2749, 18.50%) of deaths. As per place of death, (Figure 4) most deaths noted in medical facilities (n=13124, 88.1%), followed by nursing homes or long-term care facilities (n=896, 6.0%), decedent's homes (n=533, 3.6%), hospice facilities (n=209, 1.4%) and others (n=139, 0.9%).

### *Temporal trends*

Between 1999 and 2020, the AAMR for HF with CS as a contributing cause showed a significant declining trend from 1999 to 2009 with an APC of -4.84% ($p<0.05$). From 2009 to 2012, the AAMR began increasing with an APC of +3.92% ($p<0.05$). A Further significant decline of AAMR from 2012 to 2020 with an APC of -2.68% ($p<0.05$). A notable variation in mortality patterns over the past two decades, with a recent decline in AAMR, was identified as depicted in Figure 1.

Based on gender analysis data, males had a higher AAMR than females. However, both groups show a similar trend. In males from 1999 to 2007, there was a declining trend with APC of -1.45% ($p<0.05$), and from 2007 to 2012, and 2012 to 2020 there was a sharp increase in trend with APC of +10.67% ($p<0.05$) and +18.80%, respectively, indicating mortality risk in the past decade. For females from 1999 to 2008, there was a declining trend with an APC of -1.49%; from 2008 to 2012 and 2012 to 2020, there was an inclining trend with an APC of +6.44% and +15.48%, respectively (Figure 2).

Racial disparities were identified in HF with CS as a contributing cause. Black or African American individuals had the highest AAMR, significantly increasing from 2010 to 2020 (APC: +22.10%). White individuals also demonstrated an increase in AAMR, particularly from 2013 to 2020 (APC: +16.80%), while the earlier period (1999-2007) showed a decline (APC: -1.94%). Trends for American Indian/Alaska Native and Asian Pacific Islander populations were not displayed due to data suppression for counts <10, limiting reliable trend analysis as represented in Figure 3.

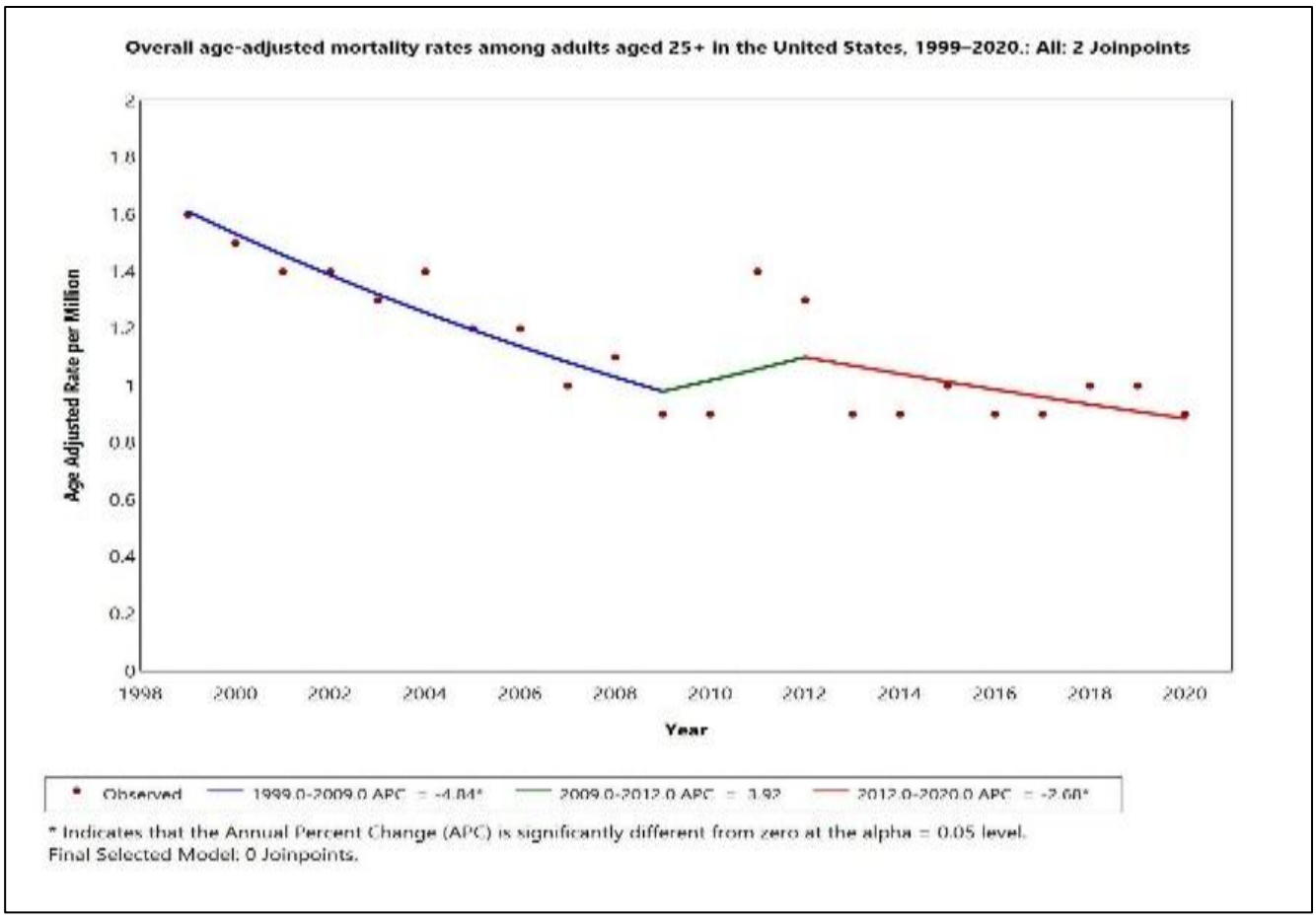


**Figure 1: Overall AAMR among adults aged 25+ in the United States, 1999-2020.**

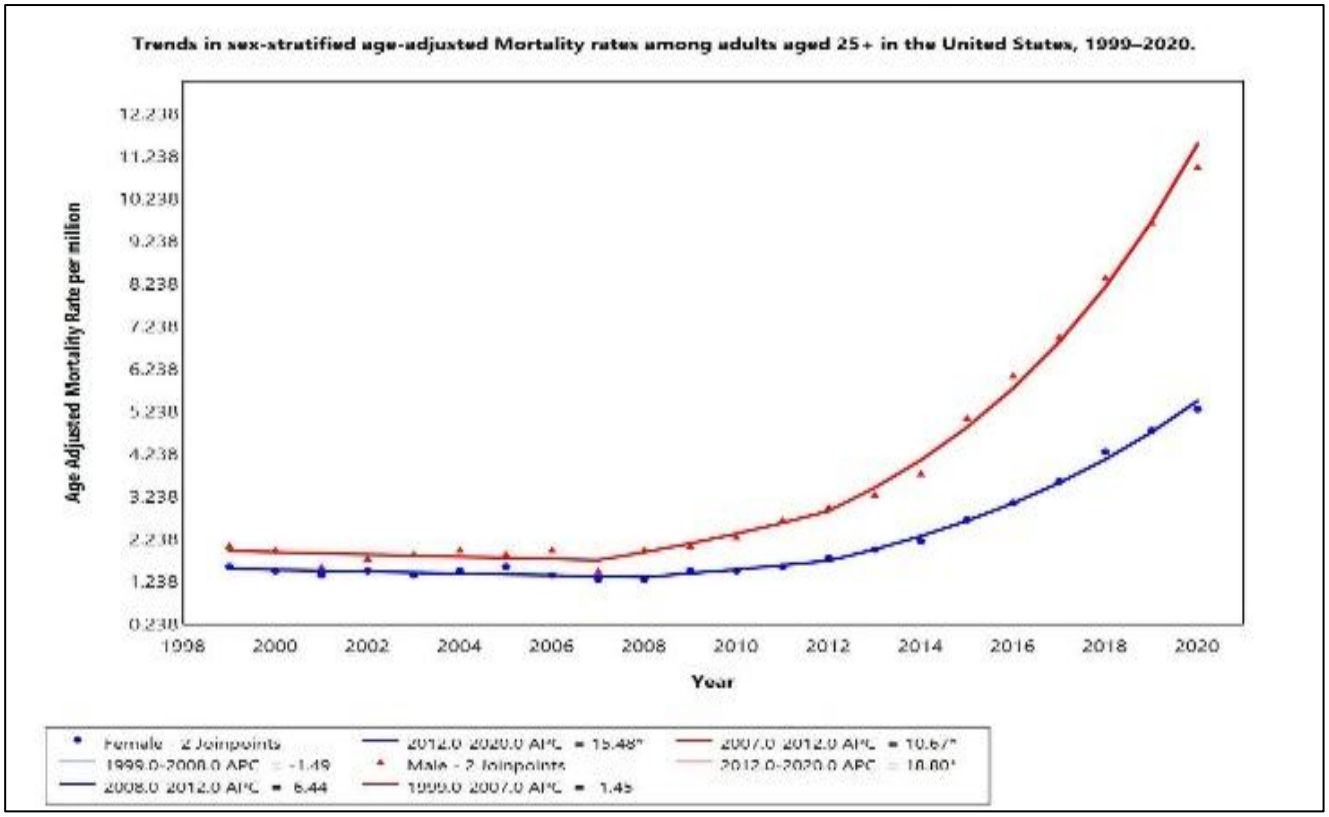


**Figure 2: Trends in sex-stratified AAMR among adults aged 25+ in the United States, 1999-2020.**

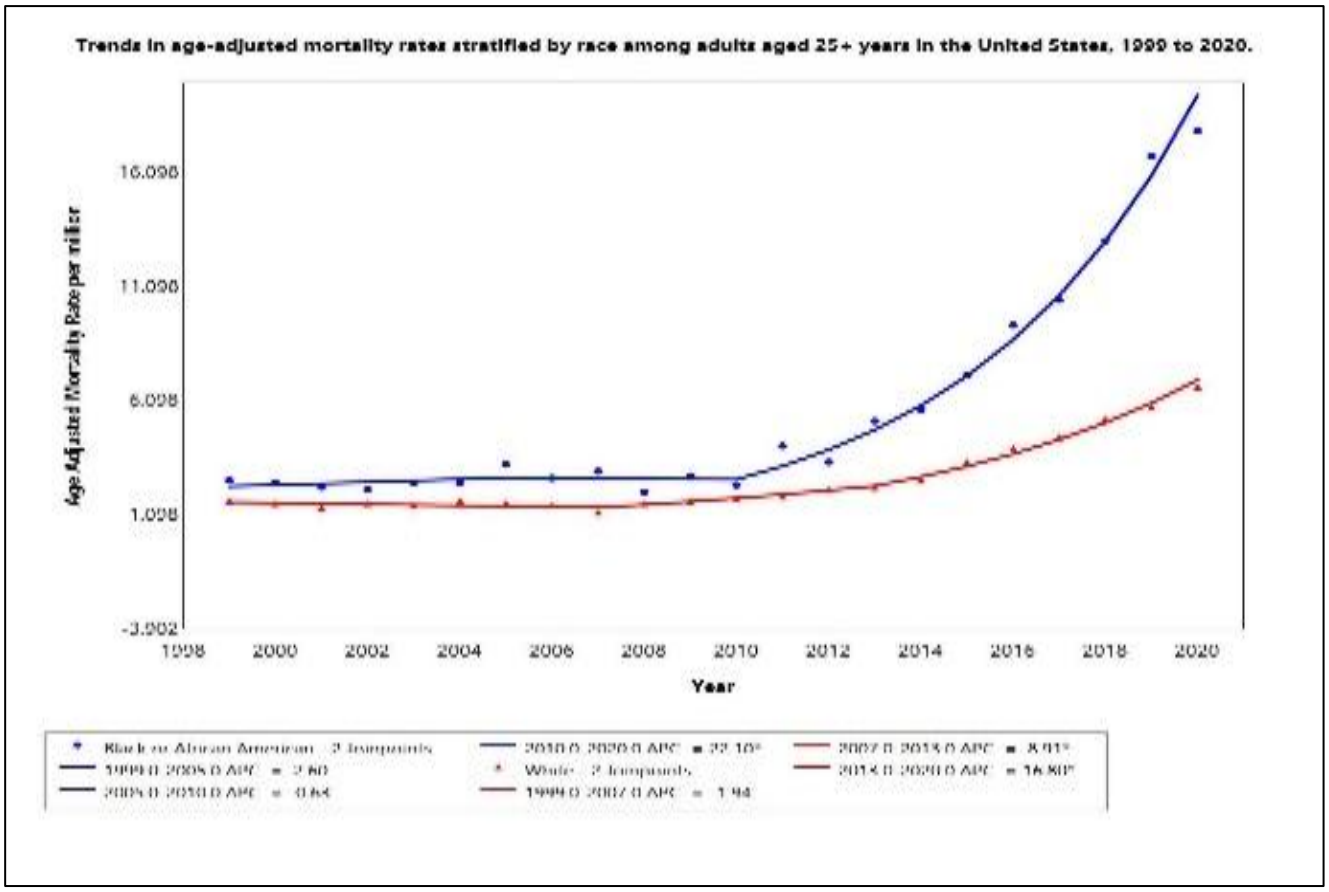


**Figure 3: Trends in AAMR stratified by race among adults aged 25+ years in the United States, 1999 to 2020.**

## DISCUSSION

This retrospective study analyzed mortality trends from 1999 to 2020 in U.S. adults (≥25 years) diagnosed with HF (ICD I50.0) and CS (ICD R57.0) using data from the CDC MCD database. A total of 14,901 deaths were recorded, with a crude mortality rate of 3.3 per million. Mortality rates varied across demographic and geographic groups. The highest mortality rates were observed in males (56.6%) and White individuals (76.7%), followed by Black/African Americans (20%). Metropolitan areas accounted for 81.5% of deaths, with large central metros contributing the highest share (28.4%).

The majority of deaths occurred in medical facilities (88.1%). These findings indicate significant demographic and regional disparities in HF and CS mortality trends.

### *Association between HF and CS*

HF and CS share a complex pathophysiological relationship. CS is a severe complication of HF, characterized by inadequate cardiac output leading to organ hypoperfusion and high mortality. Studies indicate that worsening HF can precipitate CS through left ventricular failure, systemic inflammation, and progressive ischemia.[12] The interplay of metabolic stressors, neurohormonal activation, and hemodynamic instability contributes to mortality in the HF-CS patients.[13]

### *Comparison of overall mortality findings with literature*

This study found an AAMR of 3.3 per million for HF-CS. Previous research has reported similar trends. A study analysing CS mortality from 1997-2012 in France found a declining mortality trend due to improvements in early interventions.[14] Another study using U.S. data from 2005-2014 noted an increasing incidence of CS in HF patients but a decline in in-hospital mortality due to better management strategies.[13] Findings of our study align with these reports, suggesting that while incidence has increased, mortality has stabilized or declined due to improved interventions.

### *Demographic disparities in mortality*

This study found that White individuals accounted for the highest mortality share (76.7%), followed by Black/African Americans (20%). Similar racial disparities have been reported in prior research. A study found that Black HF patients had higher hospitalization rates and poorer outcomes due to disparities in healthcare access and treatment adherence.[15] Gender disparities were also noted, with males showing higher mortality (56.6%), consistent with previous studies indicating that male HF-CS patients have worse outcomes due to delayed healthcare-seeking behaviour and higher prevalence of comorbidities.[16]

### *Geographic disparities in mortality*

Metropolitan areas accounted for 81.5% of deaths, with large central metros (28.4%) showing the highest mortality. This aligns with studies that suggest urban areas have higher HF-CS mortality rates due to population density, environmental stressors, and limited access to specialized cardiac care.[17] However, non-metropolitan areas (18.5%) also showed considerable mortality, likely due to limited healthcare infrastructure and delayed treatment access. These findings suggest the need for improved HF-CS management in both urban and rural settings.

Recent studies provide further insights into the geographic and temporal disparities in HF and CS mortality. A nationwide study found that HF-related cardiovascular mortality showed significant geographic variations, with the highest mortality rates in the South and Midwest of the U.S. This trend was attributed to regional differences in cardiovascular health, socioeconomic factors, and healthcare access. Another study assessing state-level disparities found that rural areas had a greater burden of HF-related deaths due to limited availability of specialized cardiac care and delayed medical interventions.[18]

### *Temporal trends*

From 1999 to 2020, mortality trends for HF-CS showed a general decline, consistent with findings from prior studies. Research on U. S. trends from 2001-2011 reported a reduction in HF-CS mortality due to improved use of mechanical circulatory support and percutaneous interventions.[19] Another study from 2005-2015 indicated that while HF-CS hospitalizations remained stable, 1-year mortality decreased, reflecting advancements in acute cardiac care.[20] These findings highlight the impact of evolving medical practices in reducing HF-CS mortality.

Temporal trends indicate improvements in HF-CS outcomes due to advancements in treatment. A study analyzing data from 2005 to 2017 found that while overall CS incidence increased, in-hospital mortality rates declined, likely due to increased use of mechanical circulatory support devices such as extracorporeal membrane oxygenation (ECMO) and intra-aortic balloon pumps.[21] Similarly, a study focusing on ischemic CS patients observed a significant reduction in mortality over a decade, attributed to increased utilization of micro-axial pumps and inotropic drug therapies.[22] These findings emphasize the role of evolving medical interventions in improving survival rates for HF-CS patients.

### *Public health implications*

The observed disparities in HF-CS mortality underscore the need for targeted public health interventions to reduce these gaps. Addressing regional and demographic differences requires a multifaceted approach, including

improved healthcare access, early screening, and enhanced patient education. Studies indicate that rural and underserved areas experience higher mortality due to delayed interventions and limited access to specialized cardiac care.[20] Expanding telemedicine and mobile health clinics could bridge this gap, ensuring timely interventions for high-risk populations. Additionally, racial and gender disparities in HF-CS outcomes highlight the need for culturally competent care and equitable healthcare policies. Research has shown that Black patients have worse HF outcomes due to socioeconomic factors, healthcare access barriers, and differences in treatment adherence.[23] Public health efforts should focus on increasing awareness, promoting heart health initiatives, and implementing community-based programs to enhance early detection and treatment adherence.

Moreover, advancements in treatment, such as increased use of mechanical circulatory support, have significantly improved survival rates.[21] Future research should explore cost-effective strategies to expand access to these life-saving technologies. Strengthening healthcare policies to subsidize advanced cardiac treatments and improve emergency response systems can further reduce mortality rates in HF-CS patients.

In conclusion, targeted interventions, healthcare equity, and policy reforms are essential to mitigating disparities in HF-CS outcomes. Future research should focus on treatment disparities, risk factor modifications, and healthcare accessibility. Policies promoting early intervention strategies, patient education, and improved rural healthcare infrastructure may help mitigate disparities and improve survival outcomes.

### *Limitations*

This study is subject to several limitations, coding inaccuracies in death certificates may have led to misclassification biases. Lack of data on comorbidities and treatment history limits insight into patient risk profiles. Changes in diagnostic and reporting practices over time may have influenced observed trends. Retrospective observational design prevents establishing causality. Socioeconomic factors, healthcare access, and lifestyle influences were not accounted for, potentially affecting mortality disparities.

## CONCLUSION

This study highlights rising mortality trends in the HF patients with CS, with the highest burden in males, white individuals and metropolitan areas. AAMR significantly declined initially, then increased after 2009 and significant decline was seen after 2012 as well, however there was marked mortality in males and females during the initial period and after 2012. These findings emphasize the need for best cardiac interventions and improved health care access to address gender and geographic disparities. Further research should focus on early risk assessment and prevention strategies to reduce mortality.

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