REVIEW ARTICLE

Trends in cardiovascular disease mortality among US adults aged ≥65 with renal failure and hypertension, 1999-2020

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ABSTRACT

Background: Cardiovascular disease is a leading cause of death in older adults who have both renal failure and hypertensive disease. However, national trends describing mortality in this high-risk population remain unclear.

Hypothesis: We hypothesized that cardiovascular mortality in older adults with renal failure and hypertensive disease experienced significant changes from 1999 to 2020, with variations by sex, race, region, and urbanization status.

Methods: We used public-use mortality data from the Centers for Disease Control and Prevention for decedents ≥65 years with renal failure and hypertensive disease listed as contributing conditions and cardiovascular disease as the underlying cause of death. Annual percentage changes (APCs) in age-adjusted mortality rates were estimated using joinpoint regression. Statistical significance was set at $P < 0.05$.

Results: From 1999 to 2012, the overall mortality rate rose modestly (APC ~+2.1; $P = 0.12$), followed by a sharp decline from 2012 to 2015 (APC ~−47; $P < 0.01$). A subsequent increase from 2015 to 2020 (APC ~+13; $P = 0.09$) was not statistically significant. Analyses by sex showed similar patterns, with males and females both exhibiting substantial downturns between 2012 and 2015. Race and ethnicity subgroups likewise demonstrated steep drops (APC ~−43% to −53%) during 2012-2015, followed by partial rebounds. Regionally, the West had a small but significant rise from 1999 to 2012 (APC ~+3.6; $P = 0.01$) before a pronounced decline (APC ~−48; $P = 0.001$). Both metropolitan and non-metropolitan areas reflected the overall trend, with mild increases until 2012, then marked reductions, and modest upticks thereafter.

Conclusions: In older adults with renal failure and hypertensive disease, cardiovascular mortality underwent a modest increase through 2012, a dramatic dip from 2012 to 2015, and a partial rebound afterward. These patterns underscore the importance of ongoing surveillance and targeted prevention strategies to reduce cardiovascular burden in this susceptible population.

Keywords: Cardiovascular disease, mortality, renal failure, hypertension.

Introduction

Cardiovascular disease (CVD) remains the foremost health threat to older adults. In the U.S., heart disease is the leading cause of death among men, women, and most racial/ethnic groups, accounting for roughly 1 in 5 deaths annually [1]. Globally, CVs cause an estimated 17.9 million deaths each year [2]. The burden of CVD is particularly high in the elderly: age-adjusted heart disease death rates are far higher in persons ≥65 than in younger adults [3]. At the same time, chronic kidney disease (CKD) and hypertension (HTN) are widespread in older populations. National data indicate that 34%

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of adults aged ≥65 have CKD [4], and roughly three-quarters of adults 65-74 have hypertension. Importantly, hypertension is a leading cause of kidney damage [5], and CKD greatly amplifies cardiovascular risk. Patients with CKD have substantially higher rates of coronary artery disease, heart failure, arrhythmias, and sudden cardiac death than the general population [6,7]. Indeed, CKD is considered a risk factor for CVD, contributing to accelerated atherosclerosis and vascular calcification [6].

Despite these links, the joint impact of renal failure and hypertension on cardiovascular mortality in older adults has been under-studied. Most U.S. mortality reports focus on single underlying causes, but multiple comorbidities are common, especially in older decedents. We therefore examined "multiple cause" mortality data to identify decedents aged ≥65 who had both renal failure and hypertensive disease listed as contributing causes, with cardiovascular disease as the underlying cause of death. This unique cohort reflects individuals at very high cardiovascular risk.

To our knowledge, detailed long-term trends in CVD death rates for this group have not been reported. Using 22 years of CDC WONDER data (1999-2020), we characterized overall trends and differences by sex, race/ethnicity, U.S. Census region, and urbanization status. We hypothesized that mortality rates in this high-risk population might mirror broader CVD trends but could show distinct patterns due to improvements in hypertension and CKD management or changes in documentation practices. Understanding these trends can inform targeted prevention and health care planning for older Americans with cardiorenal risk factors.

Methods

We retrospectively analysed national death certificate data from the Centers for Disease Control and Prevention (CDC) WONDER database (Multiple Cause of Death, 1999-2020) [8]. We selected all decedents aged ≥65 years for whom: [1] the underlying cause of death was any cardiovascular disease (ICD-10 codes I00–I99); and [2] chronic, acute, or unspecified renal failure (ICD-10 N17–N19) and hypertensive diseases (ICD-10 I10–I15) were listed as contributing (multiple) causes. Age-adjusted mortality rates (per 100,000 population) were calculated for each calendar year using direct standardization to the 2000 U.S. standard population [9]. In accordance with the TITAN Guidelines 2025 for transparent use of AI in scholarly communication, no AI tools were used in the research design, data collection, analysis, or interpretation; AI assistance was limited solely to language refinement during manuscript preparation[10]. Population denominators were based on bridged-race intercensal estimates provided by the CDC.

We stratified analyses by sex (female, male), race/ethnicity (Non-Hispanic White, Non-Hispanic Black, Non-Hispanic American Indian/Alaska Native [AI/AN], Non-Hispanic Asian/Pacific Islander [API], and Hispanic), U.S. Census region (Northeast, Midwest, South, West), and urbanization (metropolitan vs. non-metropolitan residence, per NCHS definitions) [11]. Trend analyses utilized the National Cancer Institute's Joinpoint Regression Program (version 4.9) to identify points where linear trends changed significantly [12]. We fitted log-linear regression models to the annual rates and computed annual percent changes (APCs) for each identified segment, with significance tested by permutation methods ($\alpha = 0.05$). Segments with fewer than four years were only fit if a joinpoint was detected by the program. Statistical analyses were conducted using SAS and the Joinpoint software. The study used publicly available, de-identified data and was exempt from institutional review.

Results

Age-adjusted CVD mortality rates among adults ≥65 with both CKD/renal failure and hypertensive disease exhibited three distinct phases (Figure 1). From 1999 to 2012, the rate increased modestly from about 30 per 100,000 to nearly 59 per 100,000 (APC ≈ +2.06%/year, $p = 0.12$). A dramatic decline followed from 2012 through 2015, when the rate plummeted from ~59 to ~10 per 100,000 (APC ≈ –47.2%/year, $p < 0.01$). After 2015, there was a modest rebound: by 2020, the rate had risen to ~13 per 100,000 (APC ≈ +13.1%/year, $p = 0.09$). Over the entire 1999-2020 period, the overall pattern was a slight net increase followed by a sharp dip and partial recovery (Figure 1, Supplementary Tables 1 and 2).

In sex-specific analyses (Figure 1), the trend phases were similar for females and males. Female mortality rose from ~20 per 100,000 in 1999 to ~52 per 100,000 by 2011-2012, then fell sharply to ~7.7 by 2014 (APC ~ +2.38% [1999-2012], $p = 0.11$; –49.7% [2012-2015], $p < 0.05$), before rising slightly to ~11.3 by 2020. Male rates were higher overall (reflecting higher CVD burden in men) and followed the same pattern: increasing from ~12.4 in 1999 to ~69.2 in 2012, declining to ~9.9 by 2014 (APC +2.61%, $p = 0.079$; –48.3%, $p = 0.0036$), then modestly rising to ~15.2 in 2020. By 2020, male rates remained higher than female rates (15.2 vs. 11.3 per 100k), but both sexes had experienced comparable proportional declines during 2012-2015 (Supplementary Tables 1–3).

Regional trends also showed the three-phase pattern for each Census region (Figure 2, Supplementary Tables 2 and 4). The West region had a significant upward trend before 2012 (APC ≈ +3.58%/yr, $p \approx 0.01$), while the Northeast, Midwest, and South had smaller, non-significant increases (APC +1.80% to +2.54%). However, all regions experienced steep declines in 2012-2015 (e.g., Northeast −51.3%, $p < 0.01$; Midwest −48.7%; South −48.7%; West −47.9%; all $p < 0.01$). From 2015 to 2020, rates trended upward in each region (APC +11.4% to +19.1%), though these rebounds did not reach statistical significance. By 2020, the age-adjusted rates ranged from ~8.7 per 100k in the Northeast to ~13-14 per 100k in the Midwest, South, and West.

Trends by race/ethnicity (Figure 3, Supplementary Tables 2 and 5) were qualitatively similar across groups. All subgroups had mild upward trends through 2012, followed by dramatic declines. For example, Black decedents had a rise from ~27 per 100k in 1999 to ~118.5 in 2012, then fell to ~13.6 by 2014 (APC ~

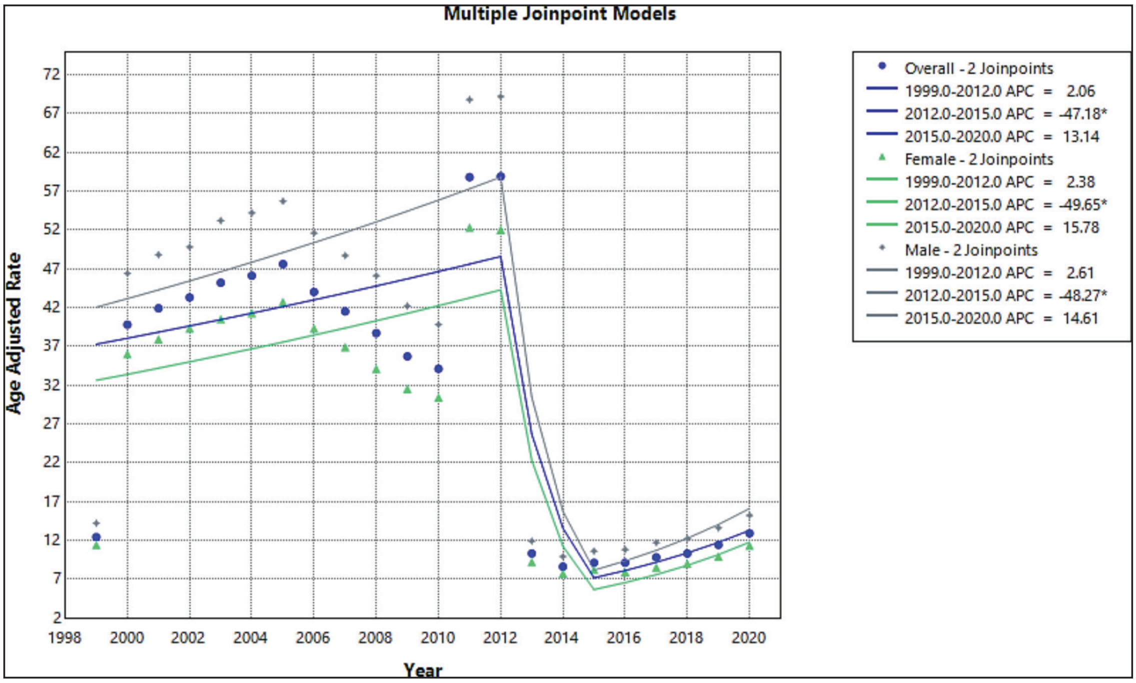


Figure 1. *Age-adjusted cardiovascular mortality rates (per 100,000 population) for US adults aged ≥65 with renal failure and hypertensive disease listed as contributing causes, 1999-2020, by sex.*

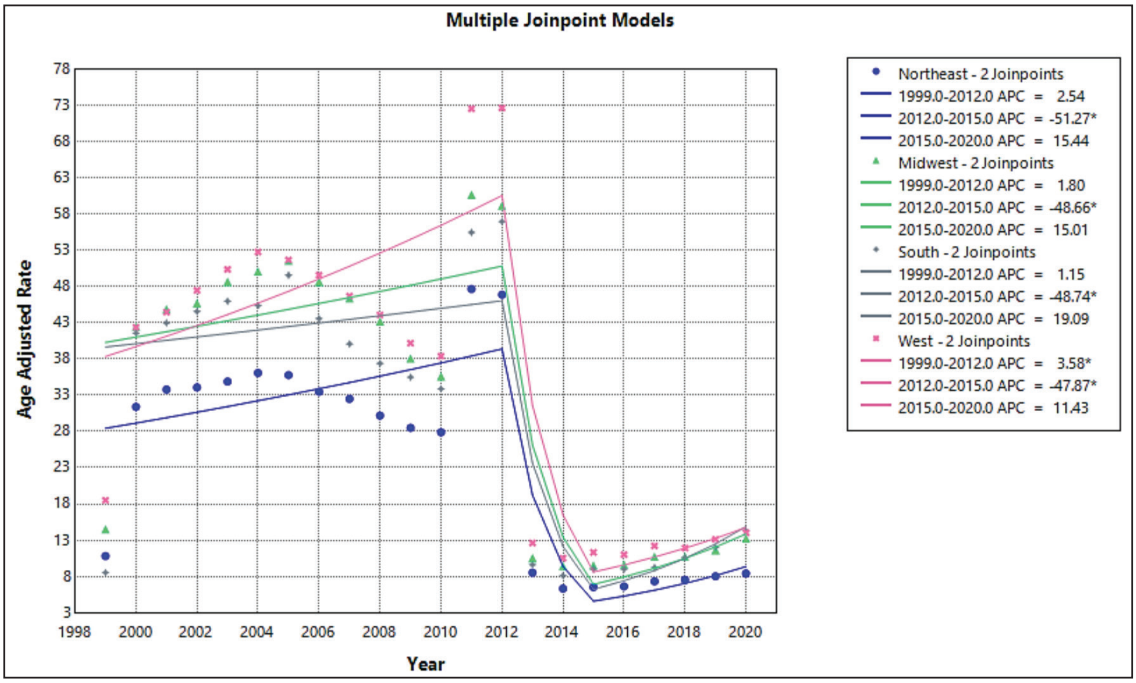


Figure 2. *Age-adjusted cardiovascular mortality rates (per 100,000) by U.S. Census region, 1999-2020.*

+0.88% [1999-2012], $p = 0.46$; –53.8% [2012-2015], $p = 0.005$). By contrast, Asians/Pacific Islanders rose from ~25 to ~61 per 100k (APC +1.54%, $p = 0.20$) then fell to ~11.9 (APC –50.2%, $p < 0.001$). American Indian/Alaska Native rates increased from ~39 to ~54 (APC +1.19%, $p = 0.28$), then dropped to ~9.6 (APC –43.4%, $p = 0.01$). Hispanic and White decedents showed similar peaks [~64 and ~53 per 100k in 2012] and ~49%-51% declines in 2012-2015 (all $p < 0.01$). After 2015, all groups had modest increases in age-adjusted rates (APC +8%-21%, none significant). Throughout the study, Black older adults had the highest CVD mortality rates and Asian/Pacific Islanders the lowest, but the sharp downturn from 2012 to 2015 occurred in every race/ethnic group.

Mortality by place of residence (Figure 4, Supplementary Tables 2 and 6) similarly exhibited the three-phase trend. Both metropolitan and non-metropolitan decedents had increases from 1999 to 2012 (APC ≈ +2.5%/yr, $p \approx 0.07$ for each, not significant) and pronounced declines in 2012-2015. The 2012-2015 APC was –52.8% in metropolitan

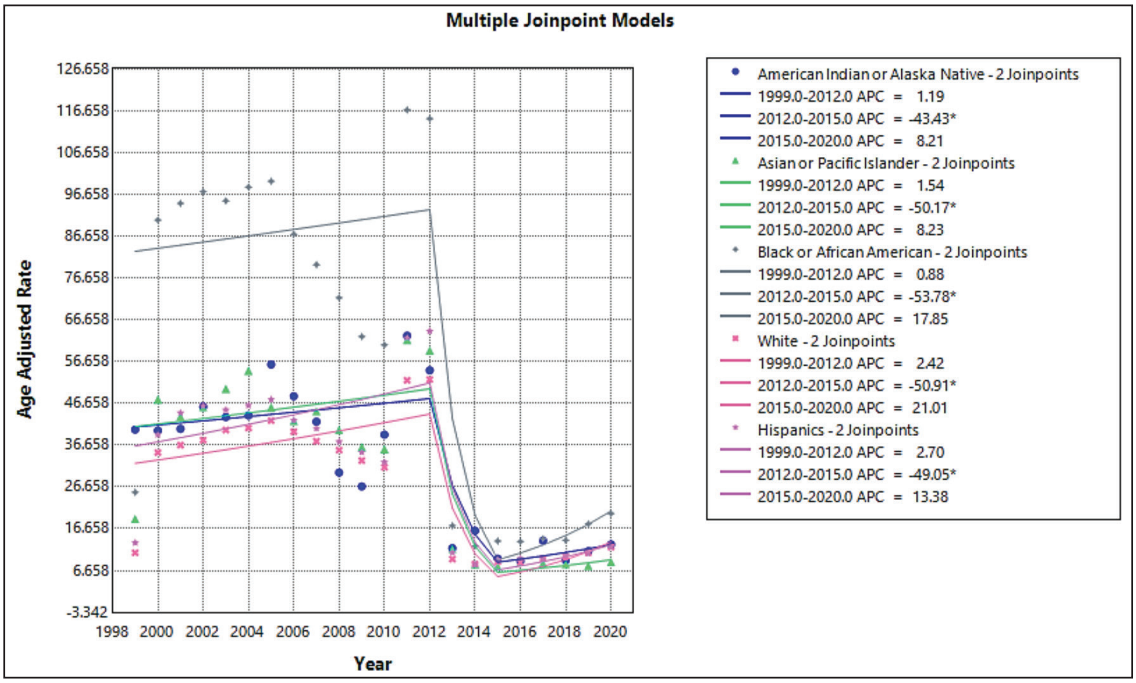


Figure 3. *Age-adjusted cardiovascular mortality rates (per 100,000) by race/ethnicity, 1999-2020.*

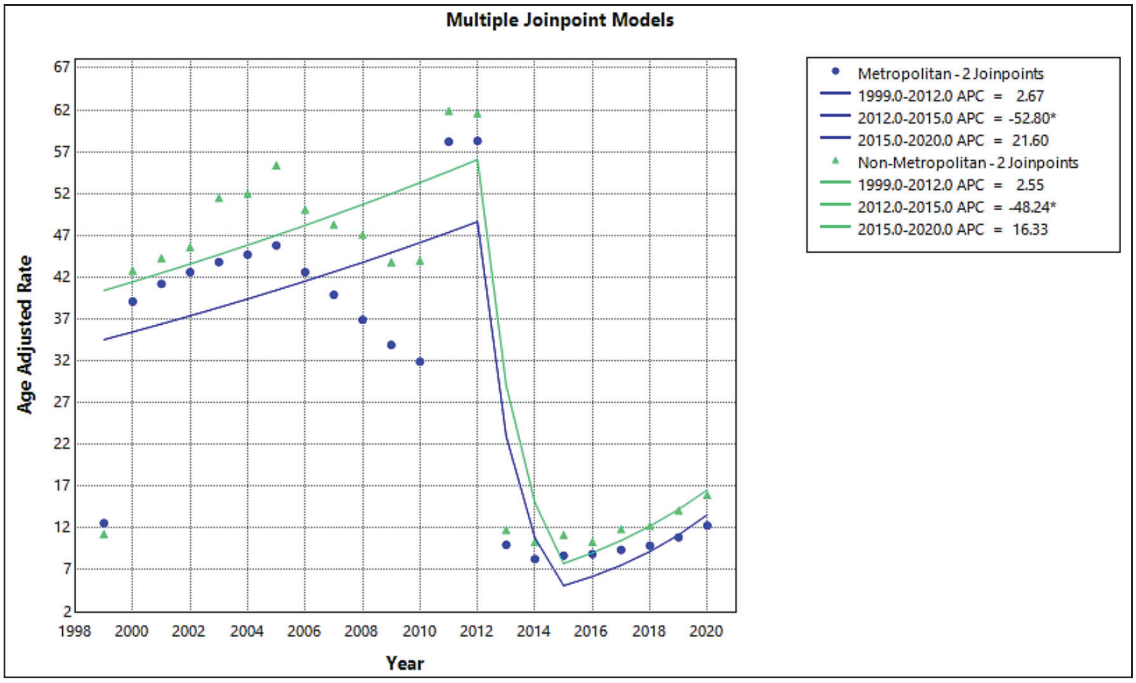
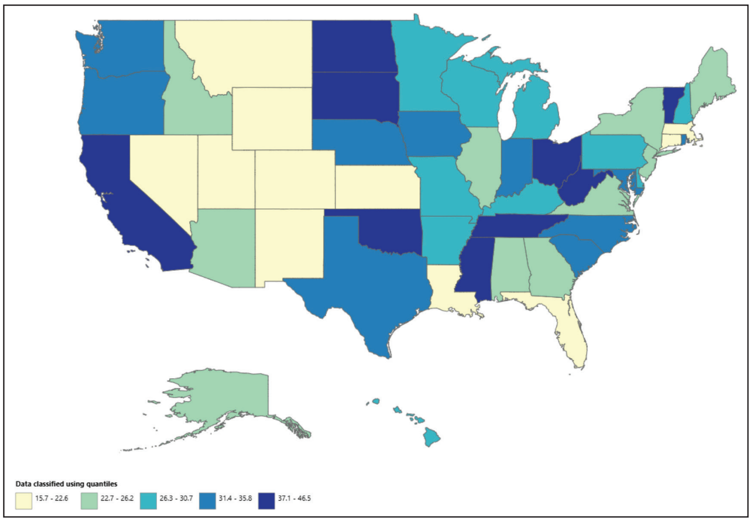


Figure 4. *Age-adjusted cardiovascular mortality rates (per 100,000) by urbanization (metropolitan vs. non-metropolitan) for US adults ≥65 with CKD and hypertension, 1999-2020.*

areas (p = 0.0028) and –48.2% in non-metro areas (p = 0.0116). In 2015-2020, both lines show rising rates (APC +21.6% metro, +16.3% non-metro; $p > 0.05$). At all times, metro and non-metro rates were very close, with metro areas slightly lower than non-metro before 2012 and marginally higher afterward. Overall, rural residence bore no substantially different pattern from urban in this cohort.

State-level analysis revealed notable geographic variations in cardiovascular mortality among older adults with renal failure and hypertension. States in the South, such as Alabama (age-adjusted rate 25.8 per 100,000), Arkansas (28.1 per 100,000), and Mississippi, exhibited higher mortality rates compared to states in other regions, like Alaska (22.7 per 100,000) and Arizona (23.3 per 100,000). California had one of the highest mortality rates overall (39.8 per 100,000). Despite these disparities, all states experienced significant declines during the critical period from 2012 to 2015, aligning with the national trend. Post-2015, a moderate rebound in mortality rates occurred



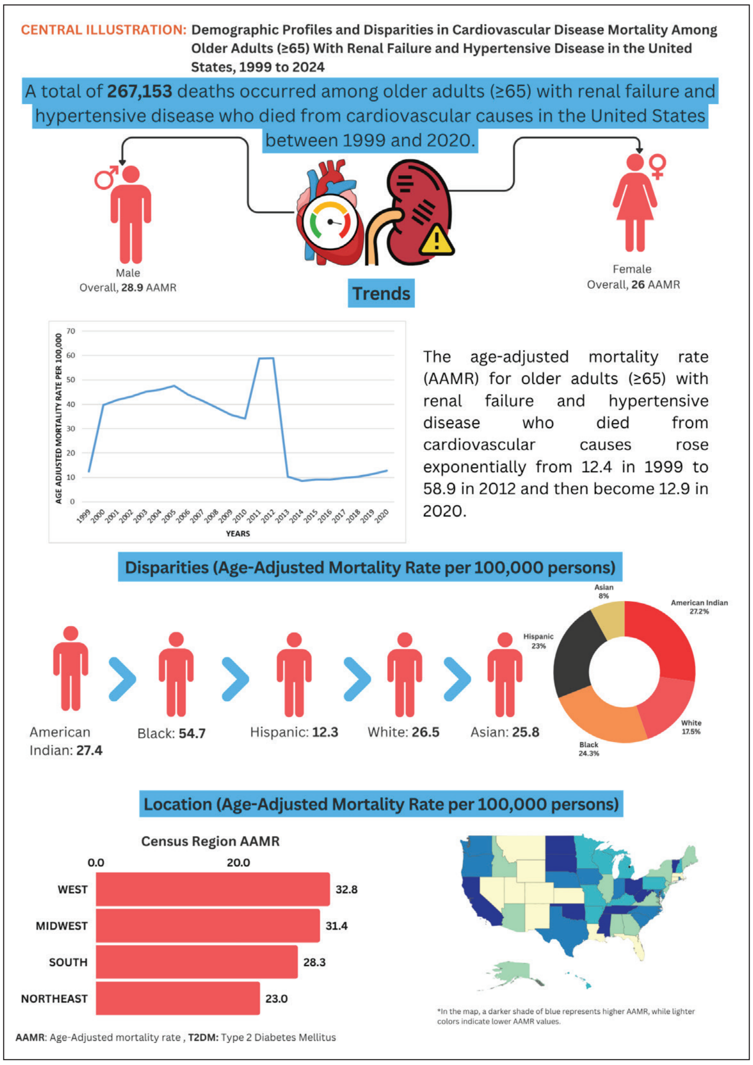


Figure 5. *Age-adjusted cardiovascular mortality rates (per 100,000) by States for US adults ≥65 with CKD and hypertension, 1999-2020.*

across most states, but rates generally did not return to pre-2012 peaks (Figure 5 and Supplementary Table 7).

Examining trends by place of death revealed substantial shifts from inpatient hospital settings toward non-hospital environments over the study period. From 1999 to around 2012, inpatient medical facilities dominated as the primary place of death, peaking notably with around 6,915 deaths recorded in 2003. However, after the pivotal decline in cardiovascular mortality during 2012-2015, deaths in hospitals markedly decreased, accompanied by increases in deaths at home or in hospice care. This trend indicates a significant evolution in end-of-life care practices, emphasizing comfort-oriented approaches and home-based management for elderly patients with complex cardiovascular and renal conditions (Supplementary Table 8).

Discussion

In this first long-term analysis of CVD mortality among older Americans with both CKD and hypertension, we observed a striking three-phase pattern: a modest rise through 2012, a dramatic 2012-2015 decline, and a partial rebound thereafter. These trends were remarkably consistent across demographic subgroups. While minor sex and regional variations existed in baseline rates, the downturn in 2012-2015 occurred universally. We know such a precipitous mid-period decline has not been reported in other cohorts (Central Illustration).

Our findings must be placed in the context of broader trends. Nationally, age-adjusted CVD death rates have generally declined over recent decades, due to better risk factor control and treatment [1,6]. For example, CDC data indicate that in 2022, there were ~703,000 heart disease deaths in the US (age-adjusted rate ~210.9 per 100,000) [1], and large surveys report increasing prevalence of risk factors: nearly 47% of US adults have hypertension and over 70% have overweight/obesity [13]. In the Medicare population aged ≥65, approximately three-quarters have hypertension [3], and CKD is diagnosed in about one-third [4]. These high-risk factors compound, as roughly 20% of adults with hypertension and 33% of those with diabetes have CKD [5]. Thus, the cohort we studied represents a convergence of major CVD risk drivers in the very elderly.

Notably, CKD itself is known to increase cardiovascular mortality risk. CKD patients often die of CVD before reaching end-stage renal disease [6]. A recent study of mortality certificates found that among persons with CKD, 31.2% of deaths were cardiovascular in etiology [6]. That study also reported that CKD-related age-adjusted mortality from all causes rose by 50.2% between 1999 and 2020, driven almost entirely by non-CVD causes, while CKD-related CVD mortality declined by 7.1%. These results are broadly consistent with our findings of a long-term decrease in CVD deaths among people with CKD, although the magnitude and timing differ. Notably, Kobo et al. found that Black patients with CKD experienced a 38.6% reduction in CV mortality (1999-2020) versus a 2.7% increase among Whites [6]. In contrast, we observed dramatic declines across all racial groups in 2012-2015 (APCs ~ –43% to –54%), with similar patterns in Black, White, Hispanic, API, and AI/AN decedents. Baseline rates were highest for Black older adults (consistently above the others), aligning with known racial disparities in CVD and kidney disease, but the timing of decline did not differ by race.

What explains the abrupt decline in 2012-2015? This period is notable: it predates widespread clinical use of recent cardioprotective drugs (SGLT2 inhibitors appeared ~2013-2014) and does not coincide with any known changes in death certificate coding [14]. One possibility is that shifts in clinical practice or diagnostic criteria led to fewer deaths being attributed to CVD in this subgroup[14]. However, we restricted to cases where CVD was coded as the underlying cause, so such misclassification seems unlikely to account for a 50% rate drop [15]. Another conjecture could involve improvements in managing hypertension and CKD in older adults around that time (e.g., more aggressive blood pressure targets advocated by the 2014 JNC-8 panel) [16]. Still, those incremental changes would not typically produce such a steep inflection.

It is also noteworthy that similar patterns have been reported in related datasets. For example, Faheem et al. found that deaths attributed to hypertensive kidney disease in adults showed a surge through 2010-2012 and then fell dramatically by 2015 [age-adjusted rates dropping from ~257/million in 2012,to 46.8/million in 2015] [17].

Their joinpoint analysis showed an APC of –46.9% during 2010-2015, akin to our –47% in 2012-2015. While their study focused on kidney disease as the underlying cause (with hypertension as a cause), the parallel suggests a broader phenomenon in hypertension-related mortality reporting. Both analyses indicate an unusual mid-decade decline in vascular-renal deaths, meriting further investigation.

After 2015, rates rose again by 2020 in our cohort, though not significantly. This rebound may partly reflect regression to the pre-2012 trend, or alternatively, the waning of any short-term factor that caused the 2012-2015 dip. The overall 1999-2020 net result is a flattening of mortality in this group: rates in 2020 (~13 per 100k) were only slightly above those in 1999 (~12 per 100k), despite intervening volatility. This modest long-term change contrasts with the substantial declines in general population CVD mortality over a similar period [18], suggesting that the subgroup of older adults with both CKD and hypertension may have experienced a different trajectory.

Our findings have implications for public health and clinical care. The consistent pattern across sex, race, and geography indicates that whatever factors drove the trend affected the entire population of older Americans with CKD/HTN. Preventive efforts should therefore remain broad-based, targeting control of blood pressure, diabetes, and other risk factors in all high-risk groups [19]. The marked decline in 2012-2015 is encouraging in that some positive change may have occurred, but the reasons are unclear. If real, it might reflect temporary improvements in acute care or reductions in precipitating events (e.g., fewer hospitalizations for uncontrolled HTN). Conversely, it raises the question of whether older adults with CKD were being underdiagnosed or recorded in other ways during those years. In any case, the steep rebound post-2015 suggests that gains were not sustained [20].

Notably, we observed no evidence that rural Americans fared worse in this specific context: metropolitan and non-metropolitan groups showed similar trends. This finding aligns with NCHS reports that heart disease death rates are higher overall in rural areas [21], but in our CKD/HTN cohort, the urban–rural difference was minimal. Similarly, regional differences before 2012 (with the

West showing slightly steeper increases) were minor; by 2015, all regions converged on low mortality rates.

In summary, CVD mortality among seniors with renal failure and hypertension has undergone significant shifts. The precipitous mid-decade decline and rebound in mortality have not been previously highlighted and suggest changes in either disease dynamics or death certification. These observations underscore the importance of ongoing surveillance of mortality trends in high-risk populations, and raise hypotheses for future research. Clinicians and public health officials should be aware of the substantial CVD burden in elderly patients with CKD and ensure that evidence-based risk reduction continues.

Limitations

This analysis has several limitations. First, it relies on death certificate data, which depends on accurate reporting of diagnoses. Misclassification or under-reporting of CKD or hypertension on certificates could bias our cohort selection. Second, the ICD-10 codes for "renal failure" (N17–N19) include both acute and chronic conditions, and we could not distinguish chronic kidney disease from acute kidney injury. Third, we required both CKD and hypertension to be listed, which selects a highly specific subgroup but excludes many individuals with only one of these conditions. Fourth, we analyzed only aggregate rates; we lack individual-level data on comorbidities, treatments, or socioeconomic status that could explain subgroup differences. Fifth, joinpoint regression can identify inflection points but does not test causal reasons; data irregularities could also influence the timing of the breakpoints. Lastly, we focused on older adults (≥65), so our findings do not apply to younger populations. Despite these caveats, the large national database and extended period lend robustness to the observed temporal patterns.

Conclusion

In a national cohort of U.S. adults aged ≥65 with both CKD (renal failure) and hypertension, cardiovascular mortality trends from 1999-2020 were characterized by an initial rise, a dramatic decline during 2012-2015, and a subsequent partial rebound. This pronounced dip was seen in all demographic subgroups. The causes of this unusual mortality pattern are uncertain, warranting further study. Meanwhile, our findings reinforce that older patients with kidney disease and hypertension remain at very high risk for cardiovascular death. Continued emphasis on blood pressure control, CKD management, and other preventive measures is essential to sustain and enhance the long-term gains against CVD in these vulnerable populations.

Ethics approval

As this study was based solely on publicly accessible, de-identified data from the CDC WONDER database, it did not involve human subjects directly and thus did not require institutional review board approval or informed consent.

Consent for publications

No individual-level or personally identifiable information is included, rendering publication consent irrelevant.

Conflict of Interest

The authors declare the absence of any financial, personal, or academic conflicts that might have influenced the conduct or outcomes of this study.

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Supplementary content (If any) is available online.

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