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ORIGINAL RESEARCH

# Cardiovascular Multimorbidity in Older Adults in the United States by Race and Sex

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## ABSTRACT

**BACKGROUND** It is essential to understand the prevalence of cardiovascular multimorbidity and to recognize disparities by race and sex to promote health equity.

**OBJECTIVES** The objectives of the study are to investigate disparities in the development and progression of cardiovascular multimorbidity among older adults in the United States and estimate relative life expectancies among patients with cardiovascular multimorbidity.

**METHODS** This was a nationwide study of a 5% nationwide sample of fee-for-service Medicare beneficiaries aged 65 or older from 2010 to 2020. Multistate survival models were employed to estimate cardiovascular disease (CVD) progression and a microsimulation approach was used to derive life tables. Primary outcome was development and progression of cardiovascular multimorbidity.

**RESULTS** Of 2,189,633 beneficiaries, the median age was 69 (IQR: 66-78), median follow-up duration was 6 years (IQR: 3-9). Initially healthy males and females had similar risks for developing CVD (aHR: 1.00; 95% CI: 0.99-1.00), with males facing higher risks of progressing to multimorbidity (aHR: 1.29; 95% CI: 1.24-1.35). Males with CVD were more likely to advance to multimorbidity (aHR: 1.16; 95% CI: 1.15-1.17). Black beneficiaries showed greater risks of moving from a healthy state to CVD (aHR: 1.10; 95% CI: 1.09-1.11). Life table analysis showed that Black adults had lower chances of progressing to worse multimorbidity states or death from a healthy state. However, as their disease burden increased, they were more likely to die compared to White adults.

**CONCLUSIONS** These findings illuminate sex differences and racial disparities in cardiovascular multimorbidity progression, identifying a target for the promotion of health equity. (JACC Adv. 2025;4:102103) © 2025 The Authors. Published by Elsevier on behalf of the American College of Cardiology Foundation. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

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**ABBREVIATIONS AND ACRONYMS**

**aHR** = adjusted HR

**AF** = atrial fibrillation

**CMS** = Centers for Medicare and Medicaid services

**CVD** = cardiovascular disease

**HF** = heart failure

**MI** = myocardial infarction

**SPACE** = Stochastic Population Analysis for Complex Events

**TIA** = transient ischemic attack

Cardiovascular disease (CVD) is the leading cause of death in the United States, accounting for 1 in 3 deaths each year and estimated costs of 363.4 billion dollars.[1,2] Cardiovascular multimorbidity, characterized by the concurrent presence of 2 or more long-term cardiovascular conditions, may represent an important target for population health interventions.[3-6] The complexity introduced by multimorbidity compounds the clinical challenge of CVD, as patients with increased cardiovascular multimorbidity often have complicated medication regimens, may have markedly impaired the quality of life, suffer from multiple functional deficits, and require more complex management strategies than patients with only 1 cardiovascular condition.[7] Furthermore, cerebrovascular disease, ischemic heart disease, heart failure (HF), and atrial fibrillation (AF) are mechanistically interconnected, with each potentially increasing the risk for other cardiovascular pathologies.[6,8,9] Therefore, further data on how cardiovascular multimorbidity impacts patient care and health outcomes will inform decisions around patient care, resource allocation, and future areas of research.

There are well-documented disparities in cardiovascular outcomes and prevalence of chronic disease by race and sex.[9-11] Black individuals were more than twice as likely to die of CVD than Asian individuals between 1999 and 2017.[9,11] Older adults are at a particularly elevated risk of CVD, and many older adults have other chronic medical conditions, making management more complex. To generate the evidence necessary to promote health equity among older adults, this study aimed to illuminate these complexities by examining the development and progression of cardiovascular multimorbidity across different demographic groups.

## METHODS

**DATA SOURCE AND STUDY POPULATION.** Data were obtained from the Centers for Medicare and Medicaid services (CMS) under a data use agreement. CMS is an agency ran by the U.S. Federal Government which administers the Medicare and Medicaid health services programs. Data included inpatient, outpatient, and carrier claims for a 5% nationwide sample of fee-or-service Medicare beneficiaries from 2010-2020. A repeated cross-sectional cohort design was used, wherein for each year in the study period, beneficiaries were included in the cohort if they were 65 years of age as of January 1 of the study year and located in the United States. Information on patient demographics and Medicare enrollment were obtained from the annual Master Beneficiary Summary Files. Race and ethnicity were analyzed according to information provided in the Master Beneficiary Summary Files, which has categories that are constructed by CMS. Prior research has shown that non-Black minority groups such as Hispanic and Asian populations are underrepresented in Medicare populations and that Medicare classifications do not consistently reflect self-identified race or ethnicity for groups other than Black and White beneficiaries,[12] so 3 race/ethnicity categories were used for analysis: Black, White, and other race/ethnicity (which included Asian race, Hispanic ethnicity, North American Native, other race/ethnicity, and unknown race/ethnicity).

**STUDY OUTCOMES.** Study outcomes were the development and progression of severe cardiovascular multimorbidity, all-cause mortality, and life expectancies at any given health state and age. Cardiovascular multimorbidity of interest included 2 or more long-term cardiovascular conditions of AF, myocardial infarction (MI), HF, stroke or transient ischemic attack (TIA), or ischemic heart disease. These conditions were ascertained from claims data using valdated algorithms.[13-18] Development of multimorbidity was defined by beneficiaries initially with none or only 1 cardiovascular condition developing at least 2 cardiovascular conditions. Progression of multimorbidity was defined as beneficiaries developing an increased number of conditions (eg, a beneficiary with 3 cardiovascular conditions initially who went on to develop a fourth condition). All-cause mortality was defined as death from any cause as recorded in Medicare claims data. Life expectancies were estimated using the modeling approach described below.

The authors attest they are in compliance with human studies committees and animal welfare regulations of the authors' institutions and Food and Drug Administration guidelines, including patient consent where appropriate. For more information, visit the Author Center.

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**COHORT DESIGN.** Patients were included in the study after they had 1 year of fee-for-service enrollment (to allow for ascertainment of starting cardiovascular and noncardiovascular comorbidities). After this point, patients were followed until death or end of data availability (including enrollment in managed Medicare plans), and it was determined if these patients developed any new cardiovascular conditions throughout the follow-up period.

**NONCARDIOVASCULAR COMORBIDITY ASSESSMENT.** Comorbidities were assessed using a 1-year lookback period for each study year using the validated Charlson Comorbidity Index.

**STATISTICAL ANALYSIS.** First, multistate survival modeling was used, where the cumulative incidence of any CVD, cardiovascular multimorbidity (2 or more conditions), and death were modeled according to each patient's baseline health state. Unadjusted and adjusted HRs and their corresponding 95% CIs were estimated. Second, multistate life table models were used to estimate life expectancies at the ages of 65, 70, 75, 80, and 85. In brief, we employ multinomial logistic regression models to estimate transition probabilities from one state of health to another over the interval of 1 year as ORs, and then use these transition probabilities to model life expectancies at various states of health.[19,20] In this approach, 7 health states were examined: no CVD, 1, 2, 3, 4, and 5 severe cardiovascular conditions, and death. Cardiovascular conditions were unidirectional; since the conditions evaluated in our study have chronic, lifelong implications, models assumed that patients could not "recover" from a condition. To assess the Markov assumption under time homogeneity, we generated plots of fitted vs empirical survival probabilities. The Stochastic Population Analysis for Complex Events (SPACE) program, which is software designed in SAS (SAS Institute, Inc), was used to estimate multistate life tables.[21-23] The SPACE program estimates age-specific transition probabilities for all possible health state transitions. For both modeling approaches, adjustment variables included the Charlson Comorbidity Index, sex (for race/ethnicity models), race/ethnicity (for the sex model), and Medicaid dual eligibility. To derive life tables, which provide life expectancies from ages 65 to 85, a microsimulation approach was used, which simulates the life paths of the population based on the transition probabilities for all health states. Bootstrapping with 100 replicates was used to estimate variability (SEs and corresponding 95% CIs) of life expectancies.

**SENSITIVITY ANALYSES.** A sensitivity analysis was conducted by removing ischemic heart disease as a potential qualifying cardiovascular condition, given an expected overlap between chronic ischemic heart disease and MI. A further sensitivity analysis explored the differences in progression pathways for patients with 1 initial CVD (AF, stroke/TIA, HF, and MI, respectively), taking into account not only the number of cardiovascular conditions but also the specific cardiovascular conditions.

## RESULTS

Table 1 outlines the starting features of the population observed from 2011 to 2020, totaling 2,189,633 beneficiaries. The median follow-up duration was 5 years. On entrance into the cohort, the median age was 69.0 years. Female beneficiaries made up 55.9% (n = 1,223,306) of the study population. The cohort was predominantly White (84.4%, n = 1,848,410), with Black individuals representing 8.2% (n = 179,694) of the total, and individuals of other race/ethnicity representing 7.4% (n = 161,529). More than half the cohort entered in the first year of data availability (2011) and about 5% of new beneficiaries entered the cohort annually in the following years. Table 2 shows the prevalence of cardiovascular comorbidities at time of enrollment for beneficiaries in our sample.

**VARIATION IN SEVERE CARDIOVASCULAR DISEASE PROGRESSION AND MORTALITY BY SEX.** Figure 1 shows the results of unadjusted and adjusted survival models for male and female Medicare beneficiaries. In the adjusted model, males had a comparable risk to females of developing CVD from a healthy state (aHR: 1.00; 95% CI: 0.99-1.00), but had higher risks of progressing to multimorbidity (aHR: 1.29; 95% CI: 1.24-1.35) and to death (aHR: 1.41; 95% CI: 1.40-1.42). The adjusted HRs also show that males with CVD were more likely to progress to multimorbidity (aHR: 1.16; 95% CI: 1.15-1.17) and to death (aHR: 1.31; 95% CI: 1.30-1.33). In addition, males with multimorbidity were at an increased risk of death (aHR: 1.23; 95% CI: 1.22-1.25).

Table 3 demonstrates the results which were calculated with the SPACE program. For male adults initially without severe CVD, the annual odds (adjusted for age, race/ethnicity, Medicaid dual eligibility, and Charlson Comorbidity Index) of developing any number of cardiovascular conditions were increased compared with female adults, with ORs ranging from 1.20 (95% CI: 1.19-1.21) for the odds of developing 1 CVD to 1.97 (95% CI: 1.88-2.06) for the odds of developing 4 cardiovascular comorbidities. The corresponding OR for mortality was 1.50 (95% CI: 1.48-1.52). Male adults with 1 CVD present initially had ORs of 1.10 (95% CI: 1.09-1.11) for the

**TABLE 1 Starting Characteristics of Study Cohort From 2011-2020, at Time of Entry**

| Characteristic | Measure |
|---|---|
| N | 2,189,633 |
| Age, at first year of enrollment, in years | |
| Median [25th, 75th] | 69.0 (66.0, 77.0) |
| Mean (SD) | 72.3 (7.7) |
| Sex | |
| Male, n (%) | 966,327 (44.1) |
| Female, n (%) | 1,223,306 (55.9) |
| Race n (%) | |
| White | 1,848,410 (84.4) |
| Black | 179,694 (8.2) |
| Other/unknown | 161,529 (7.4) |
| CCI[a] | |
| Median (Q1, Q3) | 0 (0,1) |
| Categories of CCI scores, n (%) | |
| 0 | 1,395,241 (63.7) |
| 1-3 | 744,711 (34.0) |
| >3 | 49,681 (2.3) |
| US Census Region at first year of enrollment, n (%) | |
| South | 862,306 (39.4) |
| Midwest | 510,635 (23.3) |
| West | 415,642 (19.0) |
| Northeast | 401,050 (18.3) |
| Year of entry into study cohort, n (%) | |
| 2011 | 1,192,312 (54.5) |
| 2012 | 103,219 (4.7) |
| 2013 | 108,358 (4.9) |
| 2014 | 112,874 (5.2) |
| 2015 | 109,100 (5.0) |
| 2016 | 111,192 (5.1) |
| 2017 | 120,839 (5.5) |
| 2018 | 112,851 (5.2) |
| 2019 | 108,159 (4.9) |
| 2020 | 110,729 (5.1) |
| Number of years in study cohort | |
| Median [25th, 75th] | 5.0 (3.0, 9.0) |
| Mean (SD) | 5.6 (3.2) |

[a]Myocardial infarction, congestive heart failure, cerebrovascular disease, and peripheral vascular disease were outcomes of interest and were accordingly excluded from our calculation of the Charlson Comorbidity Index.

CCI = Charlson Comorbidity Index.

development of CVDs and 1.29 (95% CI: 1.24-1.34) for 4 CVDs with an OR for mortality of 1.19 (95% CI: 1.18-1.21). Male adults with 2 and 3 CVDs showed similar trends, but for those with 4 CVDs, the OR for developing 5 CVDs was not statistically significant at 1.00 (95% CI: 0.97-1.04). Nevertheless, across levels of initial cardiovascular multimorbidity, male adults compared to female adults had an elevated mortality risk. The difference in odds of mortality associated with male sex was greatest for patients with no initial CVD (OR: 1.50; 95% CI: 1.48-1.52) and decreased as levels of initial multimorbidity increased.

**SEVERE CARDIOVASCULAR DISEASE PROGRESSION AND MORTALITY ACROSS RACIAL AND ETHNIC GROUPS.** Figure 2 displays disparities in the transition through disease states among Medicare beneficiaries, with White beneficiaries as the reference group. Black beneficiaries demonstrate a risk of progressing from an initial healthy state to 1 CVD condition (aHR: 1.10; 95% CI: 1.09-1.11), from 1 CVD to multimorbidity (aHR: 1.02; 95% CI: 1.01-1.04), from 1 CVD to death (aHR: 1.03; 95% CI: 1.00-1.05), and from multimorbidity to death (aHR: 1.10; 95% CI: 1.07-1.12). Conversely, this group is not at a risk of progressing from being initially healthy to multimorbidity (aHR: 0.93; 95% CI: 0.86-1.00) or from being initially healthy to death (aHR: 0.94; 95% CI: 0.92-0.95).

Black beneficiaries without CVD initially showed almost identical odds of developing any number of CVD conditions compared to the White reference group (Table 3). Among individuals with 1 CVD initially, Black individuals had higher odds than White individuals of developing 2 to 5 CVDs (OR range: 1.02-1.09). Furthermore, Black adults with 2 to 4 CVDs generally had higher odds of transitioning to a greater burden of CVD multimorbidity compared to White adults (OR range: 1.00-1.25).

**MORTALITY AND LIFE EXPECTANCY.** In terms of mortality rates, distinct patterns were observed across racial groups for individuals with any starting level of CVD. Black adults had marginally lower ORs for mortality across all stages of CVD multimorbidity (OR range: 0.94-1.13).

Supplemental Table 1 details the life expectancy variations by sex and race and ethnicity among Medicare beneficiaries. Female beneficiaries have a longer life expectancy at all ages and levels of CVD multimorbidity; for instance, at age 65, females live on average 17.7 years, outpacing males who have a life expectancy of 15.4 years. This longevity gap is more pronounced among those with 5 severe CVD conditions, with females living nearly twice as long as males at the same age and disease burden.

In racial and ethnic comparisons, patients from other race and ethnicity groups consistently exhibit the highest life expectancy, with individuals at age 65 expected to live 20.4 years, compared to 16.6 for Black and 16.3 for White beneficiaries. Black beneficiaries display marginally higher life expectancies than White beneficiaries without severe CVD, yet this trend reverses with the onset of CVD, where increased multimorbidity is associated with increased disparities in

**TABLE 2** Events, Time in Cardiovascular Disease State, and Cardiovascular Comorbid Conditions for Study Cohort

| | Metrics Over the Follow-Up Duration | | | Metrics at Time of Study Entry | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| State | N | Number of Events | Restricted Mean Time in State in Years | Atrial Fibrillation | Myocardial Infarction | Coronary Heart Disease | Stroke/TIA | Heart Failure | Peripheral Vascular Disease | Multimorbidity |
| Sex | | | | | | | | | | |
| All states | | | | | | | | | | |
| Male | 966,215 | | | 108,900 (11.3%) | 55,441 (5.7%) | 273,031 (28.3%) | 122,508 (12.7%) | 107,209 (11.1%) | 121,528 (12.58%) | 184,320 (19.1%) |
| Female | 1,223,167 | | | 105,295 (8.6%) | 39,056 (3.2%) | 220,478 (18.0%) | 153,002 (12.5%) | 121,067 (9.9%) | 156,400 (12.79%) | 167,750 (13.7%) |
| Healthy | | | | | | | | | | |
| Male | | | 5.78 | | | | | | | |
| Female | | | 5.86 | | | | | | | |
| 1 CVD | | | | | | | | | | |
| Male | | 245,297 (24.62%) | 0.88 | | | | | | | |
| Female | | 329,337 (26.92%) | 0.94 | | | | | | | |
| Multimorbidity | | | | | | | | | | |
| Male | | 117,466 (11.79%) | 0.53 | | | | | | | |
| Female | | 152,710 (12.48%) | 0.54 | | | | | | | |
| Death | | | | | | | | | | |
| Male | | 286,018 (28.71%) | 1.82 | | | | | | | |
| Female | | 344,677 (28.18%) | 1.68 | | | | | | | |
| Race | | | | | | | | | | |
| Baseline (all states) | | | | | | | | | | |
| Black | 179,665 | | | 11,448 (6.4%) | 8,012 (4.5%) | 38,186 (21.3%) | 26,165 (14.6%) | 25,633 (14.3%) | 22,786 (12.68%) | 29,816 (16.6%) |
| White | 1,848,206 | | | 193,116 (10.4%) | 81,235 (4.4%) | 424,965 (23.0%) | 232,066 (12.6%) | 189,001 (10.2%) | 235,713 (12.75%) | 189,001 (10.2%) |
| Healthy | | | | | | | | | | |
| Black | | | 5.56 | | | | | | | |
| White | | | 6.21 | | | | | | | |
| 1 CVD | | | | | | | | | | |
| Black | | 45,491 (25.32%) | 0.91 | | | | | | | |
| White | | 494,645 (26.76%) | 0.91 | | | | | | | |
| Multimorbidity | | | | | | | | | | |
| Black | | 21,667 (12.06%) | 0.55 | | | | | | | |
| White | | 234,400 (12.68%) | 0.52 | | | | | | | |
| Death | | | | | | | | | | |
| Black | | 51,058 (28.67%) | 1.97 | | | | | | | |
| White | | 549,483 (29.73%) | 1.38 | | | | | | | |

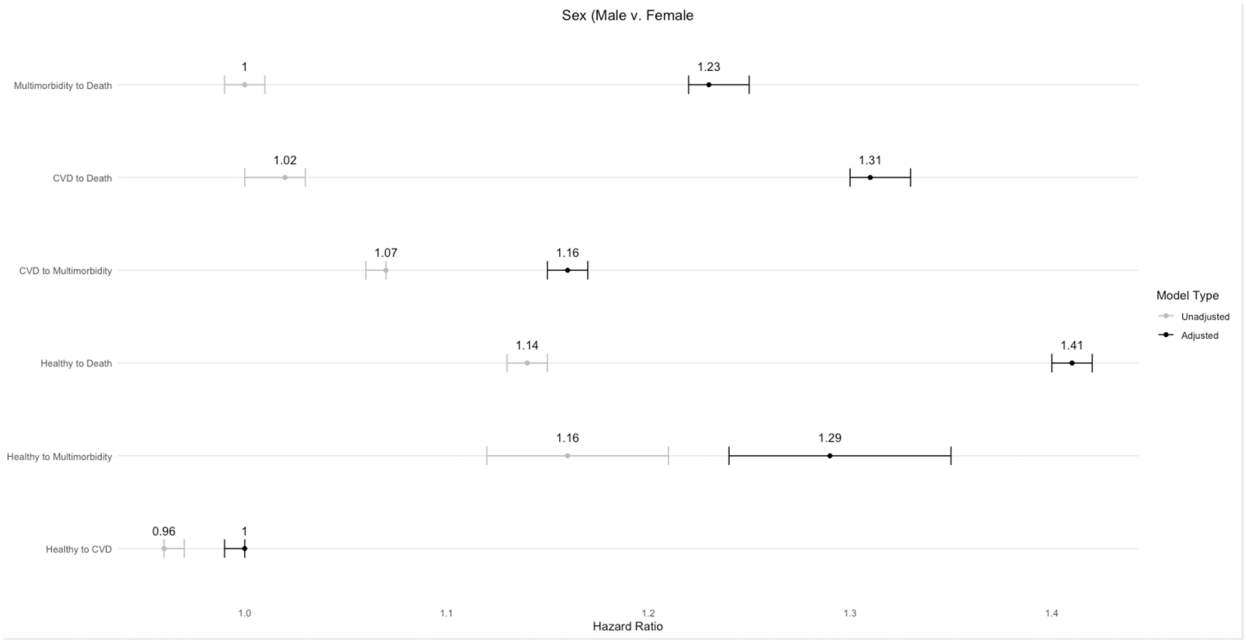
CVD = cardiovascular disease.

life expectancy. The broad message of this analysis is presented in the **Central Illustration**.

Because of the broad range of racial and ethnic categories present in the "other race/ethnicity group", our analysis for this group is presented in the Supplemental Appendix. Supplemental Table 2 presents the number of events and mean time in state. Supplemental Table 3 displays the life table estimates.

**SENSITIVITY ANALYSES.** A sensitivity analysis excluding ischemic heart disease as a potential

**FIGURE 1** **Sex Differences for Multistate Survival Models of Cardiovascular Disease Progression and Mortality**




Female sex was the reference group. HRs provided present results for males. CVD = cardiovascular disease.

qualifying cardiovascular condition (due to expected overlap with MI) was performed; fully adjusted results are shown in Supplemental Figures 1 and 2; overall, results were similar to the main analysis. An additional sensitivity analysis explored whether progression pathways differed by the starting cardiovascular condition, which are shown in Supplemental Figures 3 to 6.

Male patients with an initial diagnosis of AF had higher risks of developing MI or HF after AF and were generally more likely to progress directly to having 3 or 4 cardiovascular conditions, although female patients had a higher risk of stroke/TIA after AF and had generally higher mortality. Male patients with an initial diagnosis of MI were more likely to be diagnosed with AF or HF and less likely to be diagnosed with stroke/TIA and were more likely to develop 3 CVDs after having either MI and stroke/TIA or MI and HF. Male patients with initial diagnosis of MI also had higher rates of mortality without developing intervening multimorbidity. Male patients with initial diagnosis of HF were more likely to develop most forms of multimorbidity and generally had higher mortality. Finally, male patients with initial diagnosis of stroke/TIA were more likely to develop almost all forms of multimorbidity and had higher mortality rates.

Black patients with initial diagnosis of AF were more likely to develop nearly all cardiovascular conditions, were more likely to develop 3 or 4 cardiovascular conditions, and had generally higher mortality rates. Black patients with an initial diagnosis of MI were less likely to be diagnosed with AF but were more likely to be diagnosed with stroke/TIA, were generally more likely to develop further multimorbidity, and had generally higher mortality. Black patients with an initial diagnosis of HF were less likely to be diagnosed with MI but more likely to develop 3 or 4 CVDs after already developing multimorbidity with HF and MI or HF and AF; Black patients with initial diagnosis of HF also had high mortality rates. Finally, Black patients with initial diagnosis of stroke/TIA were more likely to be subsequently diagnosed with MI or HF and less likely to be diagnosed with AF, were more likely to develop more advanced multimorbidity after diagnosis of stroke/TIA and MI or stroke/TIA and AF, respectively, and had generally higher mortality rates.

The conceptual model for the study is shown in Supplemental Figure 7; plots of empirical vs predicted survival probabilities are shown in Supplemental Figure 8 and showed close alignment between predicted and empirical survival probabilities. Estimates of the variability for restricted mean time in state,

**TABLE 3** Odds Ratio of Health Expectancies by Sex and Racial Group

| Starting State | Ending State | Male vs Female | Black Race vs White Race |
|---|---|---|---|
| Healthy | Healthy | Reference | Reference |
| | 1 CVD | 1.20 (1.19-1.21) | 0.99 (0.98-1.01) |
| | 2 CVD | 1.49 (1.47-1.51) | 0.98 (0.96-1.01) |
| | 3 CVD | 1.75 (1.71-1.80) | 0.96 (0.92-1.00) |
| | 4 CVD | 1.97 (1.88-2.06) | 0.86 (0.78-0.94) |
| | 5 CVD | 1.76 (1.54-2.01) | 1.02 (0.80-1.29) |
| | Died | 1.50 (1.48-1.52) | 0.95 (0.94-0.98) |
| 1 CVD | 1 CVD | Reference | Reference |
| | 2 CVD | 1.10 (1.09-1.11) | 1.02 (1.01-1.04) |
| | 3 CVD | 1.24 (1.22-1.27) | 1.07 (1.04-1.11) |
| | 4 CVD | 1.29 (1.24-1.34) | 1.08 (1.01-1.16) |
| | 5 CVD | 1.22 (1.10-1.36) | 1.09 (0.89-1.33) |
| | Died | 1.19 (1.18-1.21) | 0.94 (0.92-0.96) |
| 2 CVD | 2 CVD | Reference | Reference |
| | 3 CVD | 1.10 (1.09-1.11) | 1.00 (0.98-1.02) |
| | 4 CVD | 1.16 (1.23-1.19) | 1.09 (1.03-1.14) |
| | 5 CVD | 1.09 (1.00-1.18) | 1.07 (0.92-1.24) |
| | Died | 1.16 (1.14-1.18) | 0.95 (0.92-0.97) |
| 3 CVD | 3 CVD | Reference | Reference |
| | 4 CVD | 1.03 (1.01-1.04) | 1.09 (1.06-1.13) |
| | 5 CVD | 0.99 (0.93-1.05) | 1.25 (1.13-1.38) |
| | Died | 1.17 (1.16-1.19) | 0.97 (0.94-0.998) |
| 4 CVD | 4 CVD | Reference | Reference |
| | 5 CVD | 1.00 (0.97-1.04) | 1.22 (1.15-1.31) |
| | Died | 1.17 (1.15-1.19) | 1.04 (0.999-1.08) |
| 5 CVD | 5 CVD | Reference | Reference |
| | Died | 1.16 (1.11-1.21) | 1.13 (1.04-1.22) |

Values are OR (95% CI).
CVD = cardiovascular disease.

using a 20% subsample due to computing requirements, are shown in Supplemental Table 4 and Supplemental Table 5 and show that estimated CIs for restricted mean time in state are narrow enough that variability within the 95% CI is not clinically meaningful even with a subsample, which would overestimate the true variability in the full population.

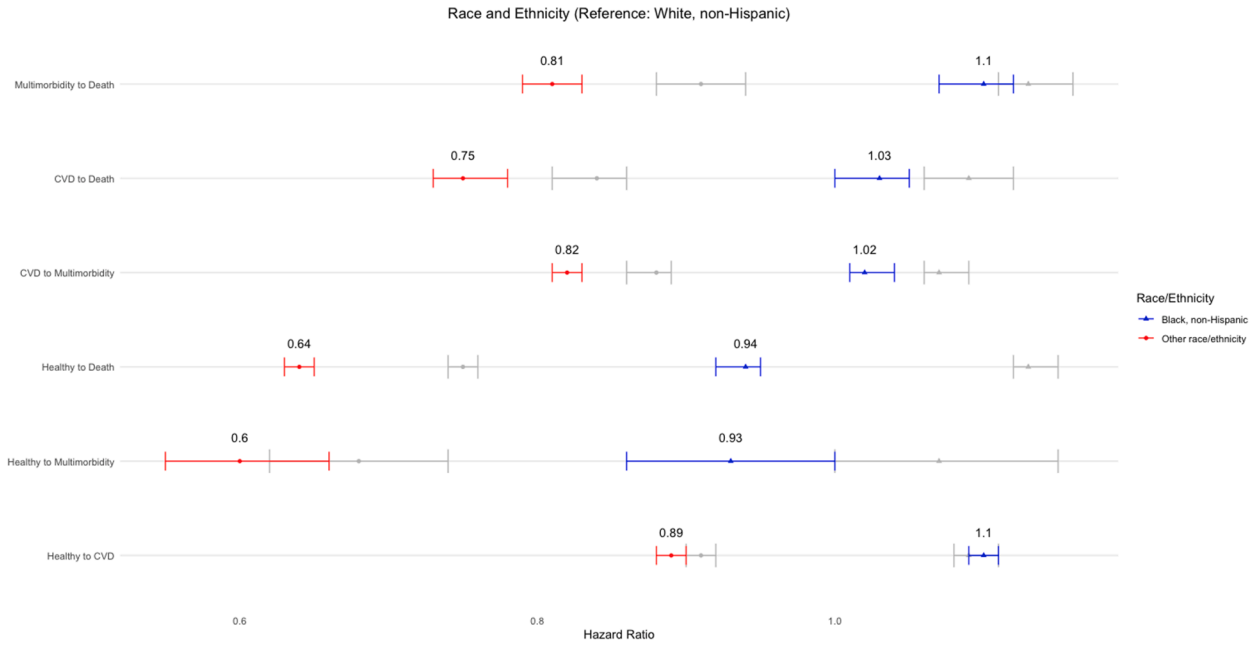
## DISCUSSION

This study assessed the development and progression of cardiovascular multimorbidity among Medicare beneficiaries from 2010-2020 and modeled associated mortality and life expectancy. The findings reveal pronounced sex differences and racial disparities. Specifically, males were markedly more likely to develop severe CVD morbidity and mortality, with odds ranging from 20% greater to nearly double than that of female older adults. Black beneficiaries also had slightly higher odds of progression to severe cardiovascular multimorbidity compared to White beneficiaries, whereas individuals of other race/ethnicity generally exhibited lower likelihoods of such progression compared to White beneficiaries.

This study, involving a substantial national sample of older adults in the United States, provides a detailed analysis of the progression of CVD multimorbidity, a topic that, to our knowledge, has not been explored in such depth previously. The evidence presented adds to the body of literature that underscores the complex nature of multimorbidity and its relationships with CVDs in diverse populations globally, including those studied in Singapore.[24] Cardiovascular conditions consistently emerge as prevalent comorbidities, and our findings align with previous work identifying distinct multimorbidity patterns, particularly where male patients faced higher odds of advancing disease severity.[8] Our investigation deepens the evidence base concerning multimorbidity in older adults, which previously considered combinations of cardiovascular risk factors like hypertension-hyperlipidemia rather than severe, end-organ diseases such as stroke or MI, which are associated with greater decrements in quality of life and very high associated health care expenditures.[25] Recent studies have explored associations between cardiometabolic multimorbidity and increased mortality risks in different populations,[26] underlining the global clinical relevance of CVD. Comparisons across large datasets like UK Biobank and Secure Anonymised Information Linkage databank have shown the necessity for careful consideration of underlying demographics and potential selection bias, which our study accomplishes through its use of nationally representative Medicare data[27,28] Using a more broad clinical definition, cardiometabolic multimorbidity, a study analyzing Jackson Heart Study data demonstrated increased risk among Black adults with a higher disease burden, for both all-cause mortality and congenital heart disease-related mortality.[29] Our findings contribute to the growing body of research assessing severe outcomes such as stroke, using approaches that associate increased risks with the presence of certain CVD clusters.[30]

In our study, the observed differences in CVD progression between male and female older adults are particularly notable. Males have significantly higher odds of dying from any number of CVD conditions, and mostly higher odds of progressing to worse CVD conditions. Despite findings from previous research that suggest potential biases in the treatment of female patients for specific acute conditions such as MI, which could contribute to

**FIGURE 2 Racial and Ethnic Disparities for Multistate Survival Models of Cardiovascular Disease Progression and Mortality**




All models with color are fully adjusted, gray models are unadjusted. Abbreviation as in Figure 1.

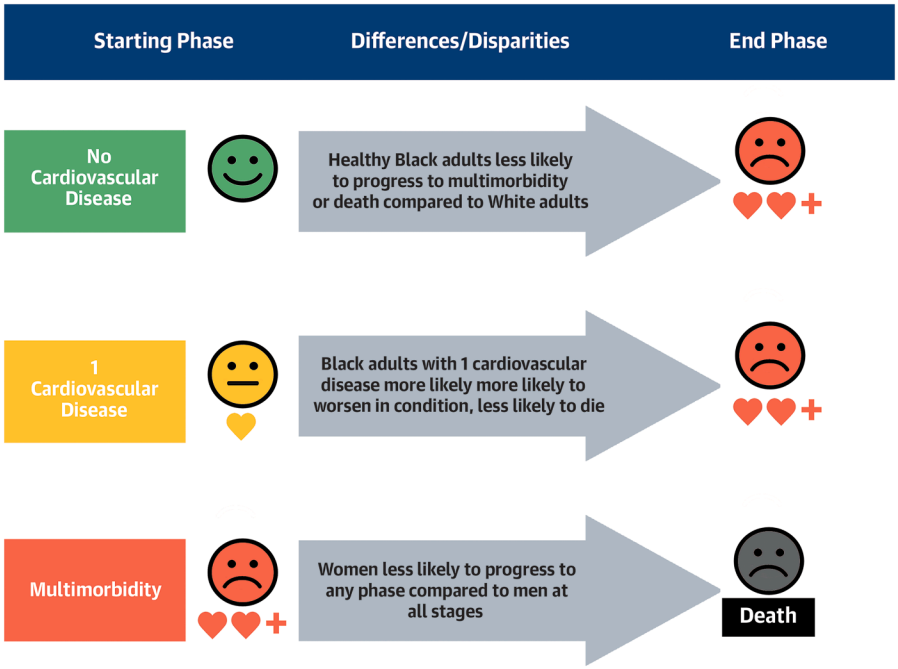
worsened outcomes,[31-33] our data indicate that female beneficiaries have a longer life expectancy across various ages and starting CVD states. This presents a more nuanced view that, although treatment biases for acute events may persist, the broader impact on life expectancy and progression of cardiovascular multimorbidity in women could be influenced by a range of factors, including but not limited to comorbidities, disease progression, and response to treatment. Given that our study relies on Medicare data and therefore only includes patients who have survived to the age of Medicare eligibility, survivorship bias among female beneficiaries with CVD in mid-life could also play a role. These findings indicate a complex relationship between sex, cardiovascular multimorbidity, and mortality risk, necessitating further investigation into treatment biases, social determinants of health, and other underlying factors.

Moreover, the shift in life expectancy patterns between Black and White patients as cardiovascular multimorbidity becomes more severe could indicate the presence of underlying health care disparities. Such disparities might be associated with variations in access to care, treatment quality, and health system focus on secondary prevention, which all merit further investigation. Notably, as our study relies on routinely collected data, patients who have a disease but have not been formally diagnosed, for example, due to lack of access to health care resources, would not be identified, which could bias our results and minimize the apparent size of disparities observed. Although our study does not establish direct causal associations, the observed associations highlight the critical need for research into the systemic challenges that may disproportionately affect Black individuals.

In our observation of the differences in life expectancy between male and female older adults, it is imperative to consider the broader context of quality of life, particularly when dealing with severe CVD multimorbidity. Although female patients exhibited a longer life expectancy, even in the face of severe CVD conditions, this does not necessarily translate into better overall well-being or quality of life. Living with multiple severe cardiovascular comorbidities can bring significant challenges and complexities in daily living, health care management, and emotional well-being. It is important to acknowledge that these differences in life expectancy between patients of different sex do not imply an inherent advantage or disadvantage but rather highlight an area for further exploration and intervention.

Our supplementary analyses, which evaluated multimorbidity progression pathways for patients

**CENTRAL ILLUSTRATION** **Main Findings from "Cardiovascular Multimorbidity in Older Adults in the United States by Race and Sex"**




**Green MD, et al. JACC Adv. 2025;4(11):102103.**

The Central Illustration overviews the results from our study of inpatient, outpatient, and carrier claims for a 5% nationwide sample of fee-for-service Medicare beneficiaries aged 65 or older from 2010 to 2020. Multistate survival models were employed to estimate cardiovascular disease (CVD) progression (adjusted for age, medical comorbidities, and Medicaid dual eligibility). The primary outcome was development and progression of cardiovascular multimorbidity, defined by the number of major cardiovascular conditions (atrial fibrillation, acute myocardial infarction, heart failure, stroke, and coronary heart disease). Comorbidities were assessed using validated algorithms based on diagnostic codes billed over a 1-year lookback period, and beneficiaries were followed forward from their first visit.

initially diagnosed with a single cardiovascular condition (AF, HF, stroke/TIA, or MI) revealed additional nuance beyond our primary analysis. Athough these analyses found similar trends with regard to mortality and overall multimorbidity as the primary analysis, these additional analyses suggest that there are unique factors for specific diseases, such as lower rates of AF diagnosis among Black patients initially with other CVD conditions despite rates of multimorbidity and mortality after AF diagnosis among Black patients, which could suggest underdiagnosis or delayed diagnosis of AF among Black patients. Similarly, although male patients generally had a higher risk of multimorbidity and mortality, female patients had higher rates of stroke/TIA after AF and higher general mortality after AF. Taken together, these results motivate future research evaluating CVD progression over the life course, which could be a promising strategy to develop precise interventions to improve health equity with secondary prevention.

The study's findings have several clinical applications. They underscore the necessity of tailoring cardiovascular screening and prevention strategies to account for sex and racial disparities, particularly to address the higher risks of CVD progression in certain groups. Personalization of treatment plans is imperative, especially for female patients who may live longer but with complex health needs due to multimorbidity. The disparities highlighted point toward the need for health care systems to formulate health equity strategies, especially to improve care for Black older adults. Clinicians should strive for a balance between longevity and quality of life in managing severe CVD multimorbidity.

**STUDY LIMITATIONS.** This study's conclusions are drawn within the context of several limitations. The racial and ethnic categories used were broad and may not capture the granular differences in health outcomes, calling for more detailed classifications in future work. Reliance on claims data for comorbidity

and severity assessment raises concerns about potential misclassification and this study design cannot be used to make conclusions about causality. In addition, the generalizability of results is limited to a Medicare population and may not reflect the experiences of younger individuals or those without Medicare. Although our study is focused on older adults above the age of 65 according to current American Geriatrics Society guidance, there is a growing recognition that people over the age of 75 may have distinct clinical needs, which our study does not explore in detail.[34,35] The impact of socioeconomic and other social determinants on health outcomes was also not fully addressed, which is a significant gap given their known influence on health disparities. The intersecting influences of age, gender, race, ethnicity, and socioeconomic factors is particularly important, and Medicare claims data contain only minimal information about social and environmental exposures, so future work should carefully decompose this work in other data sources with more detailed information on the life course and characteristics of individual patients. Future studies could use medical records as a data source for possibly more granular racial and ethnic categories alongside more accurate clinical diagnoses.

Our study is additionally limited by the fact that the diseases studied are not strictly discrete entities but arise from shared underlying risk factors and pathophysiology: for example, a patient with HF from ischemic cardiomyopathy due to a MI who has chronic angina truly has 1 underlying disease (coronary artery disease) which has given rise to the other disorders. Similarly, stroke and TIA were grouped as one condition in our study, despite being clinically distinct entities. Our results are therefore susceptible to alternative classifications of CVD, and future work should explore alternative systems to classify specific major cardiovascular disorders, specifically the inclusion of peripheral arterial disease, which our study excluded due to difficulty with reliable ascertainment in our data source. The temporality of the progression of specific cardiovascular conditions is another intriguing avenue for research that we did not elucidate. For example, if an individual's first diagnosed condition was congenital heart disease, are there implications on the progression of multimorbidity compared to if their first condition was a different CVD. Our study has limitations in the modeling methods employed. Although the SPACE program uses a multinomial regression approach to model transition probabilities across CVD states and death, future work could explore alternative modeling frameworks that could potentially improve performance. Similarly, our multistate survival methods do not account for interval censoring, because our data rely on administrative claims data and we are principally focused on the timing of recorded diagnoses, which are known exactly; however, underlying disease processes may be observed only within specific intervals, so future studies concerned with those underlying disease processes could consider using methods that account for interval censoring. In addition, our multistate modeling approach was extremely computationally intensive, preventing us from using a higher number of bootstrap replicates (eg, 1,000), meaning that our estimates of variability for life and health expectancies should be interpreted cautiously.

## CONCLUSIONS

This repeated cross-sectional cohort analysis of Medicare beneficiaries highlights the distinct vulnerabilities of older male adults and the higher progression risk of severe cardiovascular multimorbidity among Black older adults. These findings underscore the importance of tailored interventions to mitigate multimorbidity and advance cardiovascular health equity. Health care strategies must be adapted to meet the unique needs of these populations, ensuring that prevention, screening, and treatment are equitable and effective.

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## PERSPECTIVES

**COMPETENCY IN MEDICAL KNOWLEDGE:** Cardiovascular disease does not progress uniformly across populations. Sex and race are factors with differing multimorbidity trajectories and long-term outcomes.

**TRANSLATIONAL OUTLOOK 1:** Knowledge of these differential patterns could inform clinical training so that early signs of disease progression can be interpreted in context and not treated as uniform across patient populations. Future research could focus on integrating multimorbidity progression modeling into clinical risk prediction tools to guide early intervention, particularly in racially diverse and aging populations. Such models could inform screening schedules and care planning based on disease pathways.

**TRANSLATIONAL OUTLOOK 2:** Health systems can invest in improving the detection, monitoring, and secondary prevention of CVD among women and Black older adults.

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**KEY WORDS** **cardiovascular multimorbidity, Medicare, racial disparities, sex differences**

**APPENDIX** **For supplemental tables and figures, please see the online version of this paper.**