JACC: ADVANCES VOL. 4, NO. 12, 2025

STATE-OF-THE-ART REVIEW

Social Determinants of Cardiovascular Aging

Aaron L. Troy, MD, MPH,[a,b] Anjali Bhatla, MD MBA,[a] Scott A. Berkowitz, MD, MBA,[a] Roger S. Blumenthal, MD,[a,b] Thomas K.M. Cudjoe, MD, MPH, MA,[c] Parag Goyal, MD,[d] D. Elizabeth Le, MD,[e] Chiadi E. Ndumele, MD, PhD,[a,b] Rishi K. Wadhera, MD, MPP, MPhil,[f] Gary Gerstenblith, MD,[a,b] Abdulla A. Damluji, MD, PhD, MBA[a,g]

ABSTRACT

Social determinants of health are major drivers of adverse cardiovascular outcomes throughout the life course. As the population ages, understanding how social determinants influence vascular, myocardial, valvular, and electrophysiologic aging trajectories will be essential to improving cardiovascular outcomes. This review summarizes key frameworks for social determinants of health and cardiovascular aging, then examines social determinants' impacts on cardiovascular aging focusing on behavioral, biological, and health care-related mediators. Specifically, the review highlights race/ethnicity, gender, geographic context, and education as structural determinants with impact starting early in life; followed by food security, digital access, and financial security as intermediary determinants requiring targeted intervention in adulthood; then social connection, transportation access, and homebound status as intermediary determinants with outsized impact in elderhood. The review spotlights patient-, population-, and policy-level interventions for each determinant, as well as key considerations for improving atherosclerosis, heart failure, valvular, and atrial fibrillation outcomes, and priorities for study and intervention. (JACC Adv. 2025;4:102331) © 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/).

BACKGROUND

The burden of age-associated cardiovascular disease (CVD) is rising as the global population ages.[1,2] Morbidity and mortality from atherosclerosis, heart failure (HF), degenerative valve disease, and atrial fibrillation (AF) are unevenly distributed across the population, reflecting heterogeneous individual trajectories of cardiovascular aging.[3,4] Social determinants of health influence cardiovascular risk factors and outcomes throughout the life course and accelerate cardiovascular aging in socially vulnerable populations.[5,6] Improving cardiovascular outcomes will therefore require a nuanced understanding of how social determinants of health impact cardiovascular aging and how to deploy preventive medical and lifestyle interventions accordingly.

In this state-of-the-art review, we first summarize contemporary perspectives and frameworks for social determinants of health and cardiovascular aging. We then build on these frameworks summarizing evidence on key social determinants of

From the [a]Division of Cardiology, Johns Hopkins School of Medicine, Baltimore, Maryland, USA; [b]Ciccarone Center for the Prevention of Cardiovascular Disease, Johns Hopkins School of Medicine, Baltimore, Maryland, USA; [c]Division of Geriatric Medicine and Gerontology, Johns Hopkins School of Medicine, Baltimore, Maryland, USA; [d]Division of Cardiology, Weill Cornell School of Medicine, New York, New York, USA; [e]Division of Cardiology, Oregon Health and Science University, Portland, Oregon, USA; [f]Beth Israel Deaconess Medical Center, Harvard Medical School, Richard A. and Susan F. Smith Center for Outcomes Research in Cardiology, Boston, Massachusetts, USA; and the [g]Department of Cardiovascular Medicine, Cardiovascular Center on Aging, Cleveland Clinic Foundation, Cleveland, Ohio, USA.

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.

Manuscript received July 1, 2025; revised manuscript received September 30, 2025, accepted October 8, 2025.

ISSN 2772-963X https://doi.org/10.1016/j.jacadv.2025.102331

ABBREVIATIONS AND ACRONYMS

ASCVD = atherosclerotic cardiovascular disease

AF = atrial fibrillation

CVD = cardiovascular disease

EP = electrophysiologic

HF = heart failure

MRI = magnetic resonance imaging

SNAP = supplemental nutrition assistance program

VHD = valvular heart disease

WHO = World Health Organization

cardiovascular aging across the life course and corresponding evidence-based patient-, population-, and policy-level interventions. Finally, we share actionable insights on social determinants of cardiovascular aging in key age-associated cardiovascular conditions and consider future directions to promote healthy cardiovascular aging across the population.

CONCEPTUAL FRAMEWORKS FOR SOCIAL DETERMINANTS OF HEALTH

Effectively addressing the role of social determinants of health in cardiovascular aging requires a nuanced, contemporary understanding of social determinants writ-large and existing conceptual frameworks for investigation and intervention. Social determinants of health are the nonmedical factors that influence health outcomes. Specifically, the Centers for Disease Control defines social determinants of health as “the conditions in the environments where people are born, live, learn, work, play, worship, and age that affect a wide range of health, functioning, and quality-of-life outcomes and risks.”[7] Although the link between social context and health has been recognized for generations, the frameworks driving contemporary study and intervention crystalized in the late 1990s-2010s.

LIFE-COURSE APPROACH. First proposed in 1997 by Kuh and Ben-Shlomo,[8] the life-course approach has been the central to understanding chronic disease epidemiology and heterogeneity in population aging. This approach recognizes the importance of life stage and timing to understand the association between social exposures and health outcomes. Two theoretical perspectives underlie this framework: the developmental perspective that focuses on the outsized impact exposures can have during critical periods for normal development and the structural perspective that focuses on the accumulated biopsychosocial consequences of health-impacting exposures with repeated and differential exposure across life stages.

The life-course approach has been applied to social determinants of health, with key implications for study and intervention.[5] The cumulative and interactive nature of exposures over the life course necessitates study of multiple exposures and their interactions, as well as consideration of the life-stage timings of exposure and outcome: single-exposure studies with life stage-agnostic binary outcomes are insufficient to inform understanding and intervention. Improved understanding requires epidemiologic studies of the ways social determinants shift health trajectories in childhood, adulthood, and elderhood, as well as mechanistic studies of biological adaptations to social determinants and their manifestations in later life stages. Finally, and most importantly, life-course approaches must be integrated into interventions to optimally address social determinants of health, given the major differences in individual characteristics and community interactions by life-stage.

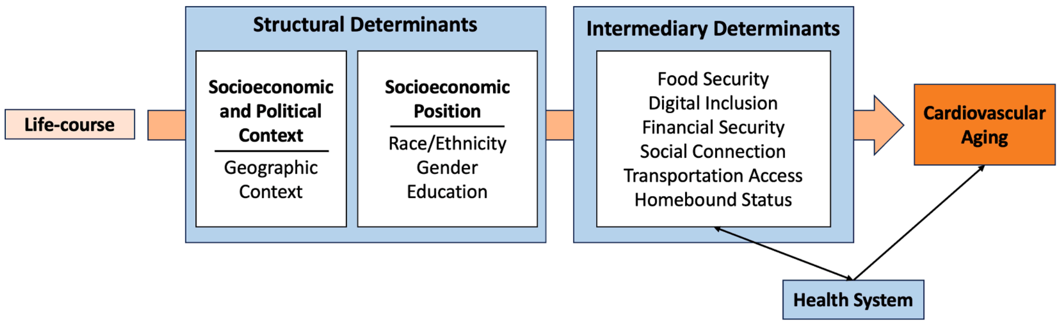
HIGHLIGHTS

- Addressing social determinants of cardiovascular aging is fundamental to improving cardiovascular outcomes in the aging global population.
- Structural determinants, particularly race/ethnicity, gender, geographic context, and education start impacting cardiovascular aging early and require multilevel interventions.
- Intermediary determinants, particularly food and financial security, transportation and digital access, social connection, and homebound status, affect cardiovascular aging in adulthood and elderhood and are modifiable with patient-, population-, and policy-level interventions.
- Further work should use life-course and implementation science approaches to develop tailored multimodal interventions for healthy cardiovascular aging.

WORLD HEALTH ORGANIZATION FRAMEWORK. The World Health Organization (WHO) Commission of Social Determinants of Health, led by Michael Marmot who popularized the term in his 1999 book *Social Determinants of Health*, combined the life-course approach with other key theories in the field into the pre-eminent contemporary framework.[9] Informed by social causation theory, the commission categorizes determinants as “structural” or “intermediary.”

“Structural determinants” include both the socioeconomic and political context that stratifies populations into socioeconomic positions and the positions themselves, including race/ethnicity, gender, education, occupation, and income (**Figure 1**).[9] This framing is informed by the work of Williams and Collins[10] who elucidated the structural

FIGURE 1 World Health Organization and Life-course Frameworks for Social Determinants of Cardiovascular Aging



The WHO frames structural determinants as shaping intermediary determinants that ultimately impact health and well-being, and the life-course approach emphasizes life stage and multiple interacting determinants in study and intervention. Key determinants highlighted in this review are shown here in context of the WHO[9] and life-course[5] frameworks. Adapted with permission from "A conceptual framework for action on the social determinants of health, 2010." WHO is not responsible for the content or accuracy of this adaptation.

mechanisms, for example, macroeconomic, social, and public policies, that stratify access to resources necessary to achieve health. For example, policies ranging from historical redlining to differential community investment have generated and perpetuated residential segregation that shapes housing, education, and employment opportunities that then influence socioeconomic status and health.[10,11] Structural determinants such as race/ethnicity are, accordingly, social constructs associated with differential health trajectories driven by racism and discrimination in the socioeconomic and political context.[11,12]

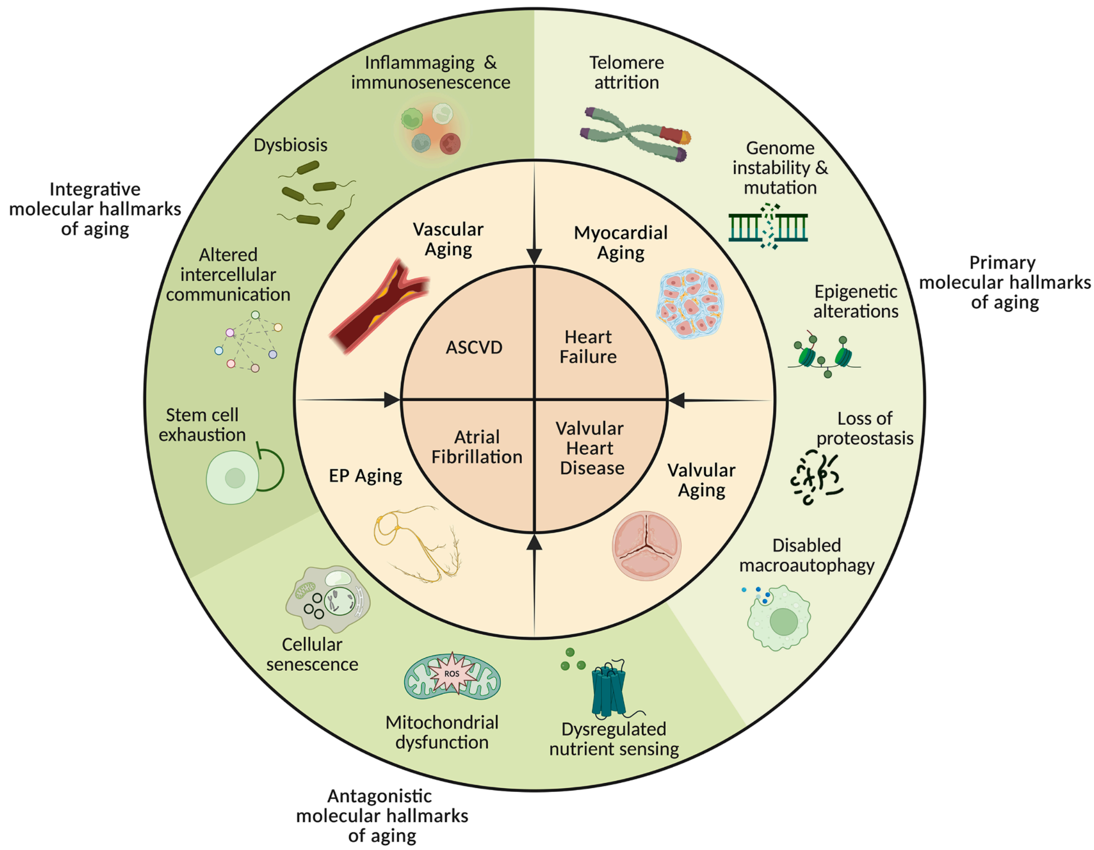
Socioeconomic positions then shape specific "intermediary determinants," namely material circumstances as well as behavioral, biological, and psychosocial factors that more proximally drive exposure and vulnerability to health-compromising conditions throughout life.[9] This framework calls attention to the need for interventions to tackle both structural and intermediary determinants on patient, population, and policy levels.

CARDIOVASCULAR AGING

Cardiovascular aging is the gradual process of molecular, cellular, and tissue-level change accrued to the cardiovascular system over the life course that increases the likelihood for, and adverse consequences of, CVD (**Figure 2**).[4] It is a multifaceted physiologic process that occurs at varying rates across individuals and populations. These heterogeneous trajectories are often modifiable; biopsychosocial stressors can accelerate cardiovascular aging, whereas preventive pharmacotherapies and lifestyle changes can slow its progression. In recent decades, Geroscience has broadened the recognized manifestations of cardiovascular aging, ranging from noninvasive imaging parameters to advanced cellular and molecular profiling (**Table 1**).[13] These aging processes predispose to age-related CVDs and decrease resilience to stressors once these diseases are present. To inform high-level appraisal of the social determinants of cardiovascular aging, we will highlight key manifestations and consequences of cardiovascular aging across myocardial, valvular, vascular, and electrophysiologic (EP) domains.

MOLECULAR HALLMARKS OF CARDIOVASCULAR AGING. Molecular hallmarks of cardiovascular aging can be categorized as "primary" processes of decline with age and stressors, "antagonistic" maladaptive responses to these changes, and "integrative" hallmarks that precipitate CVD.[14,15] The "primary" processes are telomere attrition; dysfunctional autophagy (decreased clearing of dysfunctional cytoplasmic components); loss of proteostasis (the balance between protein synthesis, folding, and degradation); genomic instability (mutation accumulation); and epigenetic modifications such as DNA methylation and histone modification[16] The "antagonistic" maladaptive responses are dysfunction of mitochondria, responsible for bioenergetics, and calcium homeostasis; neurohormonal dysregulation,

FIGURE 2 Framework for Cardiovascular Aging



The primary, antagonistic, and integrative molecular hallmarks of aging drive vascular, myocardial, valvular, and EP aging, which predispose to ASCVD, heart failure, degenerative valvular disease, and both atrial fibrillation and syncope respectively. Created in BioRender (BioRender.com/lnxeucd). ASCVD = atherosclerotic cardiovascular disease; EP = electrophysiologic.

including renin-angiotensin-aldosterone system and β-adrenergic pathways; and cellular senescence, meaning, cell cycle arrest driven by oxidative stress and other stressors. The key "integrative" hallmark is the dyadic interplay between inflammaging—chronic immune activation with age, and immunosenescence—immune dysfunction and suppression with age, that can be adaptive when balanced and maladaptive when imbalanced.[17] Stem cell exhaustion, dysbiosis, and altered intercellular communication are the final "integrative" molecular hallmarks that drive cardiovascular aging.[14,18]

VASCULAR AGING. These primary, antagonistic, and integrative processes drive the 2 primary hallmarks of vascular aging: arterial stiffening and endothelial cell dysfunction. An aging cardiovascular continuum has been described, by which repetitive expansion with each systole over the life course drives breakdown of elastic lamellae, increased collagen crosslinking, and thickening of the arterial media.[19] These changes increase vascular stiffness and pulse-wave velocity, with reflected pressure waves returning during late systole instead of diastole, with resultant increased afterload and pulse wave extension into the peripheral microvasculature. Endothelial cell dysfunction decreases the effectiveness of the endothelial barrier to the movement of lipids and monocytes across the barrier, increases the likelihood for platelets to adhere to the endothelium, and decreases vasodilator response to endothelial-dependent stressors. These increase the likelihood for the development, progression, and clinical manifestations of atherosclerosis.[20]

Physical exam changes associated with vascular stiffening include increased systolic pressure, pulse

TABLE 1 Cardiovascular Aging Physiology and Assessment

System	Cellular Processes	Tissue Processes	Noninvasive	Clinical
Vascular aging	Elastic lamellae breakdown Collagen crosslinking Arterial media thickening Endothelial dysfunction	Arterial stiffening Arteriosclerosis Atherosclerosis	↑ Systolic BP ↑ Pulse pressure ↑ ABI ↑ PWV Plaque geometry/inflammation Coronary calcification Carotid IMT Microvascular dysfunction	Hypertension CAD PAD Stroke Vascular dementia Sarcopenia
Myocardial aging	Myocyte attrition and senescence Myocyte hypertrophy Myocardial fibrosis	Ventricular stiffening Ventricular strain Atrial dilation	↑ LV mass ↓ LV volume ↓ GL strain ↑ Native T1 ↑ Extracellular volume ↑ E/A ratio ↑ E/e' ratio ↓ e' velocity ↑ LA volume	HFpEF HFrEF
Valvular aging	Valvular endothelial cell dysfunction Valvular interstitial cell fibroblastic and pro-calcific differentiation	Valvular thickening Valvular stiffening Valvular degeneration Valvular calcification	↑ Leaflet thickness ↑ Leaflet calcification ↑ Annular calcification ↓ Leaflet motion ↑ Pressure gradients ↑ Regurgitation	Aortic stenosis Aortic regurgitation Mitral regurgitation Mitral stenosis Tricuspid regurgitation
Electrophysiologic aging	Altered ion channel expression/function Conduction myocyte apoptosis Sinus node/conduction system fibrosis Decreased beta receptor sensitivity Decreased norepinephrine reuptake Decreased baroreceptor sensitivity Myocyte dysfunction and stretch	Sinus node dysfunction Chronotropic dysfunction Conduction delay Increased atrial ectopy	↓ Intrinsic HR ↓ Maximum HR AV block Bundle branch and fascicular blocks Orthostatic hypotension	Atrial fibrillation Atrial tachycardia Ventricular tachycardia Syncope Sick sinus syndrome Complete heart block

ABI = ankle-brachial index; AV = atrioventricular; BP = blood pressure; CAD = coronary artery disease; GL = global longitudinal; HFpEF = heart failure with preserved ejection fraction; HFrEF = heart failure with reduced ejection fraction; HR = heart rate; IMT = intima-media thickness, coronary artery disease, peripheral artery disease; LA = left atrium; LV = left ventricle; PAD = peripheral artery disease; PWV = pulse wave velocity.

pressure, and ankle-brachial index.[19] Noninvasive markers of vascular aging include structural changes such as coronary artery calcification on computed tomography, geometric changes including increases in aortic dimensions and carotid intima-media thickness, and functional changes such as increased pulse-wave velocity and decreased aortic distensibility.[4] Premature vascular aging contributes to hypertension and predisposes to atherosclerotic CVD (ASCVD), and microvascular dysfunction promotes vascular dementia and sarcopenia.[21]

MYOCARDIAL AGING. Dysfunctional autophagy and cellular senescence, combined with increased afterload from arterial stiffening, drive the primary processes of myocardial aging: myocyte attrition, cellular hypertrophy, and fibrosis. The aging myocardium is thereby comprised of a smaller number of hypertrophied, senescent cardiomyocytes that release paracrine signals to neighboring fibroblasts, immune cells, and endothelial cells, promoting fibrosis, inflammation, and cellular dysfunction.[22] These processes impair myocardial systolic coordination and diastolic relaxation, increasing left ventricular pressure and volume loads. The resultant constellation of atrial dilation, myocyte hypertrophy and fibrosis, and stimulation of stretch-activated ion channels facilitates arrhythmogenesis.[23]

Echocardiography and cardiac magnetic resonance imaging (MRI) allow advanced noninvasive assessment of changes associated with myocardial aging. On echocardiography, declining diastolic function, global longitudinal strain, and ventricular volumes, and increasing left atrial volume can reflect myocardial aging, as can increased myocardial native T1 and extracellular volume on MRI.[24-29] Clinically, ventricular myocardial aging can drive HF, whereas atrial myocardial aging predisposes to AF.[30]

VALVULAR AGING. Valvular endothelial and interstitial cells are also impacted by the molecular hallmarks of cardiovascular aging, mechanical stress imposed by myocardial aging, and increased pulse pressure associated with vascular aging.[31,32] Aging valvular endothelial cells exhibit decreased proliferation and self-repair as well as disrupted endothelial to interstitial cell communication, which drives proliferation of valvular interstitial cells, increased elastic and collagen fiber production, and differentiation to procalcific cells.[31-33] The resultant thickening, stiffening, degeneration, and calcification are readily detectable by echocardiography, computed tomography, and MRI, and underlie a broad spectrum of valve diseases, the most common being aortic stenosis, mitral regurgitation, and aortic regurgitation.[34]

ELECTROPHYSIOLOGIC AGING. The aforementioned primary, antagonistic, and integrative molecular processes affect the sinus node, conduction system, and autonomic nervous system and drive the EP consequences of aging.[35] With age and chronic hemodynamic stress, sinoatrial node and conduction system myocytes exhibit decreased expression and function of several ion channels, including voltage-gated calcium channels and channels responsible for funny current.[36] Simultaneously, these myocytes undergo age-related apoptosis, hypertrophy, and fibrotic extracellular matrix remodeling. These changes, as well as decreased density and function of beta-adrenergic receptors and decreased norepinephrine uptake, result in decreased resting and maximum heart rates, as well as atrioventricular and bundle branch blocks.[35-37] This multifactorial chronotropic incompetence, paired with decreased alpha adrenergic receptor and baroreceptor density and sensitivity, increases the risk of orthostatic hypotension and syncope.[38] Finally, these EP changes along with the previously described processes of myocardial aging such as fibrosis, apoptosis, oxidative damage, inflammation, and stretch predispose to atrial and ventricular arrhythmias.[35,39]

FRAILTY: INTEGRATED CARDIOVASCULAR AGING. Many of the molecular hallmarks of cardiovascular aging are shared with frailty, and vascular, myocardial, valvular, and EP aging all increases the risk of frailty.[30,39-42] Frailty is a manifestation of biological aging, predominantly assessed as a physical phenotype or deficit accumulation index.[43,44] Among the 60-plus validated tools to measure frailty, the Fried frailty phenotype is considered the reference standard, and the essential frailty toolset, FRAIL scale, and clinical frailty scale are streamlined tools validated in the cardiovascular patient population that can be efficiently employed in busy clinical settings, guiding tailored implementation of frailty-directed and cardiovascular interventions.[45]

INTEGRATED FRAMEWORK FOR SOCIAL DETERMINANTS OF CARDIOVASCULAR AGING. In this state-of-the-art-review, we advocate for adoption of the WHO framework with an emphasis on life-course perspectives to understand the social determinants of cardiovascular aging (Central Illustration). We will consider the impacts of multiple interacting determinants (Table 2), their behavioral-, biological-, and health care-related mechanisms of impact at critical periods across life stages, and highlight patient-, population-, and policy-level interventions to address their health effects (Table 3).

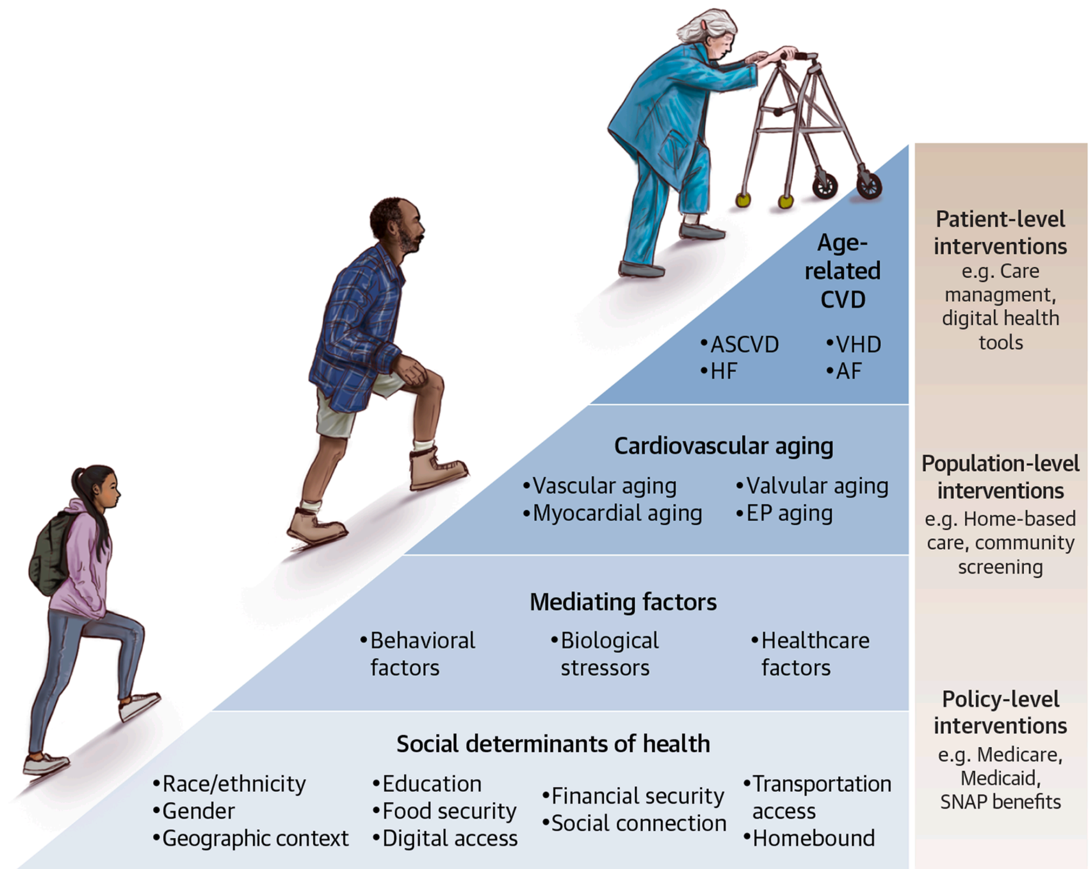
Specifically, we performed a scoping review of studies examining associations between key structural and intermediary social determinants of health and measures of cardiovascular aging, with priority given to molecular and imaging biomarkers followed by clinical manifestations of cardiovascular aging, and with particular emphasis on mechanisms and interventions. We will first discuss the key structural determinants, race/ethnicity, gender, geographic context, and education that start impacting social position and health trajectories in childhood. We will then address key intermediary determinants with impacts starting in early life and adulthood, namely food security, financial security, and digital access. Finally, we will explore key intermediary determinants with outsized impact during elderhood: social connection, transportation access, and homebound status.

STRUCTURAL DETERMINANTS: EARLY LIFE

Structural determinants, particularly race/ethnicity, gender, geographic context, and education have powerful effects on cardiovascular aging trajectories starting in early life and accumulating over the life course.

RACE/ETHNICITY. Cardiovascular aging trajectories begin to diverge by race and ethnicity in early development and childhood.[12,46] Race and ethnicity are social constructs reflecting socioeconomic positions driven by macroeconomic policies and social context that impact access to health-promoting resources.[10,11]

CENTRAL ILLUSTRATION Social Determinants of Cardiovascular Aging



Troy AL, et al. JACC Adv. 2025;4(12):102331.

Social determinants of health drive health drive cardiovascular aging throughout the life course. Through behavioral, biological, and healthcare-related mediators, these determinants drive vascular, myocardial, valvular, and electrophysiologic aging, predisposing to ASCVD, HF, VHD, and AF respectively. These determinants are targetable with evidence-based interventions at policy, population, and patient levels. ASCVD = atherosclerotic cardiovascular disease; AF = atrial fibrillation; CVD = cardiovascular disease; EP = electrophysiologic; HF = heart failure; SNAP = supplemental nutrition assistance program; VHD = valvular heart disease.

Multiple studies have demonstrated the association of race and ethnicity with divergent cardiovascular aging trajectories. Although social determinants differentially drive adverse outcomes across racial/ethnic groups, with recent evidence of accelerated myocardial aging across Asian, Hispanic, and Black American populations, cardiovascular aging trajectories remain underphenotyped in other minoritized populations relative to Black Americans.[12,47] Vascular stiffness develops earlier in Black children compared to White children, driving differences in hypertension and ankle branchial index in adulthood after adjusting for socioeconomic status.[46,48] This accelerated vascular aging drives myocardial aging, with higher rates of systolic and diastolic cardiac dysfunction seen in Black adults.[49] This also leads to divergence in integrated cardiovascular aging, including race-based differences in "weathering", or accelerated biologic aging, with Black individuals weathering 6 years faster than White individuals, and discrimination increasing the risk of frailty.[50,51]

TABLE 2 Social Determinants and Cardiovascular Aging

	Vascular	Myocardial	Valvular	EP	Frailty
Race/ethnicity	Kruger et al, 2021	Kishi et al, 2015	-	Rodriguez et al, 2015	Mandelblatt et al, 2023
Gender	Böhm et al, 2009	Gori et al, 2014	Myasoedova et al, 2020	Westerman and Wenger et al, 2019	Muka et al, 2016
Education	Liu et al 2023	Yan et al 2006	-	Lunde et al 2020	Graf et al 2024
Geographic context	Liu et al, 2025	Turecamo et al, 2023	Tan et al, 2024	Essien et al, 2022	Marinacci et al, 2025
Food security	Liu et al, 2021	Gondi et al, 2022	-	Markson et al, 2023	Wennberg et al, 2024
Digital access	Troy et al, 2023	-	-	-	-
Financial security	Hamad et al, 2020	Mathews and Brewer 2022	-	Misialek et al, 2014	Hanlon et al, 2024
Social connection	Liang et al, 2023	Cene CW et al, 2022	-	Qiao et al, 2025	Davies et al, 2021
Transportation access	Remillard et al, 2022	Acquah et al, 2022	-	-	Fukuei et al, 2024
Homebound status	Qiu et al, 2010	Ornstein et al, 2015	-	-	Leff et al, 2024

These accumulated changes decrease cardiovascular longevity, with 7.9 million excess years of potential life lost between 2020 and 2022 in Black Americans relative to White Americans due to ischemic heart disease.[52,53] Racism directly and indirectly impacts cardiovascular aging through toxic stress, which increases inflammatory markers and impacts DNA methylation in Black individuals, accelerating atherosclerosis and neurocognitive decline.[54-56] Limited resources for preventive health behaviors in Black communities has driven low Life's Simple 7 scores in Black adults across the United States, with unequal access to cardiologists further impeding healthy cardiovascular aging.[57,58]

A multipronged approach is needed to improve cardiovascular aging across racial/ethnic groups.[59] Evidence-based patient-level interventions include culturally sensitive lifestyle change programs like Black Impact, that improves Life's Simple 7 scores in Black men.[58,60] On a population level, a blood pressure screening and pharmacist intervention in Black barbershops improves blood pressure compared with usual care.[57] Moreover, improving clinical trial enrollment of understudied racial and ethnic groups and increasing physician and researcher representation from these communities are vital to improve uptake of preventive pharmacotherapies in diverse populations.[61,62] Ultimately, policy-level support of state- and federally-funded health centers and other resources in under-resourced communities, and continued Medicaid support are necessary for healthy cardiovascular aging across race and ethnicity.[59]

GENDER. There are substantial gender-based differences in cardiovascular aging that start early in life.[63] Gender is a social construct with health impacts related to socioeconomic and political context separate from biological differences in sex.[63] Recognizing that historic underinvestigation of women's cardiovascular health has contributed to gender-based outcome differences, we will first describe sex-based cardiovascular aging trajectories and then address gender-related mechanisms and opportunities.[64]

Sex-based differences in vascular aging, specifically intima-media thickness, are seen starting in early childhood.[65] The vasculature of females also exhibits greater mineralocorticoid receptor expression, which has been associated with endothelial and microvascular dysfunction.[66] Heterogeneity in vascular aging drives disparate myocardial aging, with females more likely to have interstitial myocardial fibrosis, concentric remodeling, and HF with preserved ejection fraction.[67] In addition, valvular aging differs by sex, with females more likely to have mitral valve disease due to connective tissue disorders and men more likely to have aortic valve disease.[4] These differences in cardiac remodeling and valvular disease also manifest in disparate EP aging, with men more likely to have AF and women having higher rates of stroke due to arrhythmia.[68] Estrogen has a protective effect before menopause, and premature cardiovascular aging is more common in males due to shorter telomeres and higher rates of CVD earlier in life.[69] Later, postmenopause, decreased estrogen increases oxidative stress and, thereby, risk of frailty in women.[70]

Gender itself also impacts cardiovascular aging. Women are less likely to receive intensive risk factor modification and treatment when presenting with CVD.[71] For example, women have been labeled to have "atypical" chest pain leading to underdiagnosis, undertreatment, and adverse outcomes because the clinical presentation of CVD has historically been defined through an androcentric lens.[72] The current paradigm has broadened to emphasize myocardial infarction with nonobstructive coronary arteries, spontaneous coronary artery dissection, and

TABLE 3 Social Determinant-Directed Interventions to Improve Cardiovascular Aging

	Patient	Population Health	Policy
Race/ethnicity	Community-based lifestyle change program Joseph et al, 2022	Hypertension screening and management in Black barber shops Victor et al, 2018	Support government-funded health centers in under-resourced communities Albert et al, 2024
Gender	Gender-specific cardiovascular risk factor questionnaires Nguyen et al, 2024	Increasing representation of women cardiologists Fatunde et al, 2025	Support inclusive and targeted clinical trials across sex Sullivan et al, 2021
Education	Polyipll use to improve adherence Muñoz D et al, 2019	Community-based risk-factor management classes, workshops Hassen et al, 2022	Vocational training to improve employment, access Flores 2022
Geographic context	Telehealth expansion Butzner and Cuffee 2021	Community gardens Litt et al, 2023	Regional planning and transfer networks Greenwood-Ericksen et al, 2020
Food security	Food prescriptions Hager et al, 2023	Meals on Wheels Mozaffarian et al, 2024	SNAP benefit expansions Troy et al, 2024
Digital access	Community partnerships for mobile health tools Johnson et al, 2023	Flexible cardiac rehabilitation models Mathews and Brewer 2021	Universal broadband and telehealth access Troy et al, 2023
Financial security	Multidimensional poverty index for risk assessment Butt et al, 2024	Capping out of pocket drug costs Narasimmaraj et al, 2023	Medicaid expansion Wadhera et al, 2018
Social connection	Digital or in-person CBT Berkman et al, 2003	Caregiver support programs Rippon et al, 2024	Accessible, age-friendly community infrastructure Welch et al, 2024
Transportation access	Combined care coordination and transportation services Onyekere et al, 2016	Public transport vouchers, rural nonemergency medical transportation Lin and Cui, 2021	Integration of stakeholder input into transportation and infrastructure policy Summers et al, 2020
Homebound status	Home-based telemedicine Lindenfeld et al, 2023	Home-based primary care Zimbroff et al, 2021	Improved Medicare coverage for long-term services and supports DeCherrie et al, 2021

CBT = cognitive behavioral therapy.

microvascular disease as major drivers of ischemic heart disease in women.[73] In men, on the other hand, higher male gender expressivity in adolescence is associated with increased hypertension and diabetes in adulthood.[74] There is also emerging evidence of unhealthy cardiovascular aging in sexual and gender minority populations, with mechanisms including impaired access to preventive care, minority stress, and hormonal therapies, although further investigation is needed.[75]

There are numerous targets for intervention to reduce gender-based differences in cardiovascular aging trajectories across the life course.[76] On the patient level, increased education about CVD in women, development of gender-aware risk scores that include gynecologic, obstetric, and hormonal treatment histories, as well as cardiologists that focus specifically on women's health can help optimize management of individual patient risk factors.[77] On a population level, efforts to optimize cardiovascular prevention in women should include increasing representation of women in cardiology, who currently comprise only 15% of the workforce, including systemic solutions such as mentorship programs, parental leave, and pumping breaks.[78] Innovative clinical research is needed, such as the sensitivity analysis of the PARAGON-HF (Prospective Comparison of Angiotensin Receptor-Neprilysin Inhibitor with Angiotensin-Receptor Blockers Global Outcomes in HF with Preserved Ejection Fraction) trial demonstrating improved sacubitril-valsartan-driven outcomes in women compared with men, as are guidelines that incorporate this evidence.[79,80] This will require optimal gender representation in clinical trials across life stages, as delineated in the 2024 Food and Drug Administration draft guidance about diversity action plans for clinical trials that is at risk of incomplete implementation.[81] On a policy level, future cardiac care models should include reducing gender-based outcome gaps as a metric for physicians and health systems to spur care delivery innovations that address unique needs of cardiovascular patients across gender.[82]

GEOGRAPHIC CONTEXT. Geographic context, including neighborhood characteristics and rural vs urban status, interacts directly with many other determinants including race/ethnicity, gender, education, and food security, contributing to variations in cardiovascular aging trajectories through behavioral, biological, and health care-related mechanisms. Rurality and county-level differences in cardiovascular aging are largely driven by differences in access to care as well as income, education, food availability, and housing stability that impact successful navigation of developmental milestones.[83,84] Vascular aging has been accelerating in rural areas, manifesting in increased hypertension prevalence.[85] Geography also interacts with race and income to drive premature myocardial aging, with Black men in rural areas having compounded increased risk of developing HF.[86] Valvular and EP aging are also accelerated in rural residents due to cardiovascular risk factor exposure across the life course.[87,88] These clinical risk factors drive premature cardiovascular mortality in rural areas.[89,90] Lower access to primary and specialty cardiovascular care impacts preventive care and medical risk factor management needed for healthy cardiovascular aging.[91-93]

Neighborhood-level factors are also associated with accelerated cardiovascular aging and weathering. In early life, neighborhood factors such as excessive noise, residing in a food desert, limited greenspace access, and low neighborhood walkability mediate premature vascular aging.[94] Environmental pollution is also associated with endothelial dysfunction, oxidative stress, and cell signaling dysfunction that can accelerate atherogenesis resulting in a higher burden of CVD.[95,96] Racial residential segregation also promotes differences in cardiovascular aging between Black vs White residents.[97] Neighborhood violence and perceptions of violence increase psychological distress, predict development of metabolic syndrome, and increase inflammaging, with a particularly pronounced effect on women.[98] In elderhood, neighborhood socioeconomic disadvantage and individuals' senses of security and neighborhood belonging are associated with frailty as well as accelerated vascular and myocardial aging.[99-101]

Achieving equity in cardiovascular aging by geographic context requires diverse interventions. On a patient level, increasing access to care for rural populations via telehealth has improved outcomes and the use of appropriate therapies, although such strategies risk widening the digital divide without concurrent broadband expansion.[102,103] On a population level, infrastructure programs such as community gardens improve nutrition, access to food, and social cohesion.[104] Policy interventions such as securing the financial future of critical access hospitals, incentivizing physicians work in rural areas, and creating regional planning networks to link community facilities with tertiary care are needed to improve cardiovascular aging equity across geographic contexts.[91,105,106]

EDUCATION. Educational attainment impacts cardiovascular aging trajectories through health care access, health literacy, and health behaviors throughout the life course. Individuals with lower educational attainment have increased risk of coronary artery disease, stroke, HF, and AF.[107-109] These differences start early, with 1 study showing that lower educational attainment accelerates atherosclerosis progression in youth and, by adulthood, drives disparate rates of CVD.[110] Among patients with acute myocardial infarction (MI), education is an independent risk factor for worse short- and long-term outcomes and lower medication adherence.[111] In adulthood and elderhood, differences in vascular risk factors by education can drive vascular dementia, with up to 44% increased dementia risk in those with lower educational attainment in a dose-response pattern.[112] Ultimately, lower educational attainment is associated with accelerated biologic aging, conferring decreased lifespan and healthspan.[113]

Divergent cardiovascular aging trajectories by educational attainment are driven by behavioral and health care-related differences connected to education itself and its socioeconomic consequences. Behaviorally, higher levels of education are associated with lower smoking rates, improved cholesterol management, and higher rates of physical activity.[114] In addition, lower educational attainment is associated with lower medication adherence in older patients with polypharmacy and multimorbidity.[115] Educational attainment is also associated with employment, health literacy, and health care access for patients with CVD.[116]

Educational interventions are needed throughout the life course to improve cardiovascular outcomes. On a patient level, assessing educational attainment and personalizing resources and decision aids accordingly during shared decision-making and counseling may improve preventive behaviors and care plan adherence. Single-pill combination use also improves medication adherence, a key mediator of divergent cardiovascular aging trajectories by education.[117] Community-based interventions proven to improve CVD knowledge such as participatory workshops and group meetings, diabetes self-management classes, and mobile messaging interventions are needed to improve health behaviors and adherence.[118] On a policy level, improving educational equity will require multiple approaches, from metrics that encourage interventions for populations with lower educational attainment, aligning school schedules with working days, incorporating vocational training in high school to improve graduation rates, and improving teacher retainment given teachers' outsized early impact on health literacy.[119]

INTERMEDIARY DETERMINANTS: ADULTHOOD

In adulthood, the impacts of intermediary determinants like food security, digital access, and financial security increase along with autonomy in managing cardiovascular risk factors, necessitating targeted health-related social needs interventions to promote healthy cardiovascular aging.

FOOD SECURITY. Access to healthy food is one of the most important means of promoting healthy cardiovascular aging. Food insecurity, defined as having limited or uncertain access to adequate nutritious food needed for an active and healthy life, accelerates aging via multiple biologic pathways including allostatic load: wear and tear associated with repeated stress response activation.[120] Food insecurity increases risk of obesity, hypertension, and high predicted 10-year ASCVD risk, reflecting accelerated vascular aging.[121,122] Food insecurity is associated both with increased mortality for patients with HF and with frailty in Medicare beneficiaries, reflecting myocardial and integrated cardiovascular aging, respectively.[123,124] Malnutrition has also been associated with EP aging and cardiac cachexia decreases salutatory cytokine secretion, predisposing to AF.[125] Living in a food desert, an exposure at the intersection of food insecurity and geographic context, is associated with accelerated vascular aging: increased arterial stiffness, oxidative stress, inflammation, and 10-year ASCVD risk.[126]

Food insecurity promotes consumption of foods that are less nutrient-dense, higher in fat and sodium, and more processed.[127] In addition, families may have to choose food over medicine due to financial scarcity, driving decreased medication adherence among the food insecure. Food insecurity is also associated with depression and stress, activating the sympathetic nervous symptom, impacting glucose and lipid levels, and accelerating vascular and EP aging, which may partially explain two-fold higher rates of food insecurity in patients with vs without CVD.[128] Ultraprocessed foods in particular decrease longevity, partially via inflammatory pathway modulation.[129]

Targeted approaches are required to address food insecurity. Patient-level interventions, such as produce prescriptions and paired food insecurity screening and resource referrals can improve food security and cardiometabolic health.[130] On population and policy levels, programs across the life course such as Supplemental Nutrition Assistance Program (SNAP), WIC, and Meals on Wheels can be helpful. For example, SNAP benefit expansions during the COVID-19 pandemic improved food insecurity, particularly among individuals with hypertension, hyperlipidemia, and diabetes, with 1 model projecting that subsidizing fruit and vegetables by 30% for SNAP participants could prevent >35,000 CVD deaths annually.[131-133] Numerous additional policies have been proposed to promote healthy cardiovascular aging, including improving nutrition standards for school meals, refining food labels, and strengthening regulatory standards around food content.[134]

DIGITAL ACCESS. Bridging the digital divide is vital to improving access to cardiovascular care and equity in cardiovascular aging. Digital access has health implications across the life course and is especially helpful in maintaining social connectedness, access to resources, and societal engagement for older adults, all of which are associated with healthy cardiovascular aging. Broadband access in particular has been studied as a social determinant of health and is associated with cardioprotective resources such as employment and education.[135] On the county-level, low broadband access is associated with accelerated vascular aging, specifically premature coronary artery disease, stroke, and cardiovascular mortality, driven by higher age-adjusted prevalence of hypertension, hyperlipidemia, diabetes, smoking, and obesity, as well as fewer cardiologists and primary care physicians per capita.[102] In addition, there has been increased focus on apps and other mobile technologies that help optimize cardiovascular health, but without expanded digital access, these resources remain underutilized by target populations.[136]

Multiple strategies have been explored leveraging digital access to promote healthy cardiovascular aging. On a patient level, remote patient monitoring interventions have gained traction, with novel approaches for optimal efficacy and inclusion currently under investigation.[137,138] On a population level, flexible cardiac rehabilitation models, including virtual, home-based, and community-based programs, can improve access and facilitate equitable adherence to guideline-directed therapies.[139,140] Delivering targeted digital tools via community-based programs can help improve efficacy and uptake of these programs.[141] On a policy level, universal access to both broadband and internet-capable devices is required for the aforementioned interventions to narrow rather than widen the digital divide. However, despite recent federal funding to improve broadband access via the broadband equity, access, and deployment program, many patients remain with unmet digital needs, and this program's impact remains to be seen.[142]

FINANCIAL SECURITY. Low income and low financial security are associated with cardiovascular risk factor development and premature cardiovascular aging. Although studies have shown that childhood low financial security leads to increased cardiovascular events in adulthood, the impact of financial security continues to accumulate throughout the life course, accelerating vascular, myocardial, and EP aging as well as frailty.[143-147] Financial status impacts not only access to cardiovascular clinicians but also quality and quantity of care due to the high costs of cardiovascular services. Household family income has a dose-response relationship with cardiovascular aging and longevity, with a $10,000 positive change in neighborhood median income increasing longevity by 10%.[148,149] Financial toxicity associated with CVD management and medications is high.[150] In addition, financial status may impact care provided, with 1 study showing residents in a low-income area being less likely to receive coronary angiography after a ST-segment elevation myocardial infarction due to perceptions of medication adherence.[151] Intergenerational impact of financial security has been observed, with low income in adulthood perpetuating cardiovascular risk across generations.[152] Financial savings throughout adulthood also have important implications in elderhood, with evidence that economic benefits derived from the social security program improve health outcomes in older adults.[153]

Low financial security may impact cardiovascular aging through multiple mechanisms. Biologically, it is associated with increased stress and sympathetic nervous system activation, which accelerates molecular hallmarks of cardiovascular aging.[154] Financial security also serves as an intermediary determinant driven by upstream structural determinants such as race/ethnicity, geography, education, and employment, and its impacts on cardiovascular aging are partially mediated downstream by food security, digital access, and social connection.

Multilevel policy approaches have been considered to ameliorate the impact of low financial security on cardiovascular outcomes. On a patient level, financial security screening during visits can support adherence by enabling cost-conscious prescribing and insurance navigation, with prior work demonstrating utility of a multidimensional poverty index in cardiovascular risk assessment.[155-157] Notably, cash transfers to low-income adults have been shown to improve stress and food security, but there is limited evidence that they improve physical health.[158] On population and policy levels, ensuring continued access to social programs with proven cardiovascular benefit such as Medicare, Medicaid, and Social Security is important to prevent exacerbation of income-based differences in cardiovascular aging trajectories.[159-161] In addition, legislation to reduce prescription drug spending, including capping out-of-pocket drug costs, has been projected to yield significant patient savings, with further work needed to differentiate the impact of prescription caps by household income.[162,163]

INTERMEDIARY DETERMINANTS: ELDERHOOD

Although much of the cardiovascular aging trajectory has been set by the time adults reach elderhood, intermediary determinants, particularly social connection, transportation access, and homebound status, can make the difference between accelerated cardiovascular aging and curtailed longevity vs healthy aging in place.

SOCIAL CONNECTION. One in four Americans over age 65 experience social isolation.[164] There is abundant evidence that social isolation negatively impacts vascular aging and mortality in older adults.[165] Among 19,360 diabetic individuals in the U.K. Biobank, the most socially isolated had almost 2-fold increased risk of fatal MI or stroke, 36% higher risk of cardiovascular mortality, and 33% higher risk of all-cause mortality over 13 years median follow-up.[166] Also in the United Kingdom, social isolation is associated with higher incidence and worse prognosis of AF and increased risk of frailty, reflecting EP and integrated cardiovascular aging.[167,168] Among 9,573 older adults in Copenhagen, participants with ≥3 intimate contacts with family, colleagues, or friends had a 17% lower risk of mortality and 18% lower risk of ischemic heart disease after adjustment for age, gender, and atherosclerotic risk factors.[169] And, in an Australian cohort of 19,114 healthy older adults, social isolation and low social support were associated with 66% increased incidence of CVD and 2-fold increased risk of mortality.[170]

Moreover, social connection and gender interact, with social isolation particularly accelerating cardiovascular aging in women. In the Women's Initiative Extension Study II, older postmenopausal women with social isolation had 5% increased risk of incident CVD, with the most socially isolated having

13% to 27% higher risk of CVD than the least isolated.[171] More specifically, social isolation has been associated with a 23% higher risk of HF hospitalization and 12% increased risk of coronary heart disease in women.[172,173]

Social connection's impact on cardiovascular aging is mediated by behavioral factors such as physical activity and nutrition, psychological stressors, and adherence to medical recommendations.[174,175] These mediators drive hyperactivation of the hypothalamic-pituitary-adrenocortical axis and sympathetic nervous system as well as glycemic dysregulation that accelerate molecular hallmarks of cardiovascular aging including inflammaging, oxidative stress, epigenetic modification, and neurohormonal dysregulation.[175-178] Social isolation is associated with increased systolic and diastolic blood pressures, and loneliness with decreased heart rate variability, markers of vascular and EP aging, respectively.[177,179,180]

Multifaceted interventions are required to target social isolation and its acceleration of cardiovascular aging. As part of its "Decade of Healthy Aging" initiative, the WHO supported development of evidence and gap maps for interventions to reduce social isolation.[181,182] Although high-quality evidence is limited, commonly studied patient-level interventions include cognitive behavioral therapy, social skills trainings, group activities, and digital interventions to support interactions with family and friends. In the post-MI population, the ENRICHD (Enhancing Recovery in Coronary Heart Disease Patients) randomized trial found that cognitive behavioral therapy reduced depression and social isolation scores at 6 months without a significant difference in death or recurrent MI at a mean of 29 months.[183] Nonrandomized studies supporting holistic approaches ranging from community-engaged music and arts to yoga and tai chi, from social networking sites and video games to exercise and pet therapy are promising, with several now undergoing randomized controlled trials.[181,182,184,185] One example: pet therapy reduces blood pressure in nursing home residents, and pet ownership is associated with increased survival in patients with CVD, possibly assuaging cardiovascular impacts of social isolation via downregulation of sympathetic and upregulation of parasympathetic pathways, as well as oxytocin, dopamine, and endorphin release.[186,187] On population and policy levels, increased state and federal support of caregiver support programs, area agencies on aging, and age-friendly infrastructure will be essential in coming decades.[182,186-189]

TRANSPORTATION ACCESS. Over 5 million Americans delay medical care annually due to a lack of available transportation.[190] Among U.S. adults with ASCVD, approximately 5% delay care due to transportation barriers annually, with a higher risk in the low-income and Medicaid-insured populations. Transportation access has been associated with accelerated aging among Medicare beneficiaries with CVD, with those reporting a lack of transportation being 3 times as likely to have disability.[191] Conversely, among individuals unable to engage with activities due to transportation disadvantage, hypertension and diabetes are highly prevalent: 77% and 39%, respectively.[192] Specifically, the TRACE-CORE (Transitions, Risks, and Actions in Coronary Events Center for Outcomes Research and Education) study of acute coronary syndrome survivors assessed transportation barriers, financial barriers, and lack of a usual source of care, and found patients with at least 2 of those barriers had decreased health-related quality of life.[193] Transportation status, specifically nondriving status and public transportation nonuse, is also associated with premature frailty.[194]

Transportation disadvantage is a powerful intermediary determinant of cardiovascular aging, as it can directly delay or defer indicated cardiovascular tests and treatments, allowing vascular and other aging processes to progress unchecked.[195] It is also a key mediator for structural determinants, given demonstrated differences in transportation access by race/ethnicity, gender, and rurality.[196,197] Its impact is also mediated by other intermediary determinants, as transportation disadvantage limits food security and social connection and promotes homebound status.[192] In elderhood, mobility and sensory impairment, financial limitations of fixed incomes, challenges with public transportation access, and insufficiently accessible infrastructure (eg, undermaintained sidewalks, ramps, and accessible bus stops) also drive transportation disadvantage, accelerating biological and cardiovascular aging.[198-200]

Transportation access represents a vital frontier for intervention given its direct effect on cardiovascular care and clinical connection, with solutions needed to target transportation accessibility, affordability, availability, and safety for the aging population.[201] At the policy level, investment in age-friendly infrastructure, public transportation, and rural nonemergency medical transportation could support healthy cardiovascular aging, as could public transport vouchers for transportation disadvantaged individuals at elevated cardiovascular risk.[201] Population-level interventions including community-based shuttle services, adjustments in public transportation routes, and health care-transit partnerships are most likely to succeed in partnership with local community organizations and stakeholders.[202] Finally, age-friendly patient-level resources have been deployed, including Cars2Care from the American College of Cardiology, as have combined care-coordination and transportation services using medical student volunteers.[203,204]

HOMEBOUND STATUS. Homebound status, defined as never or rarely leaving home, and semi-homebound status, leaving home only with assistance or difficulty, are prevalent in the older population and accelerate cardiovascular aging.[205] Between 2011 and 2019, approximately 5% of U.S. adults over age 70 were homebound, larger than the nursing home population, and more than twice that number were semi-homebound.[205,206] During the COVID pandemic, however, prevalence of homebound status more than doubled to 13% of U.S. adults age 70 and above.[206]

The relationship between CVD and homebound status is understudied and likely bidirectional. Chronic diseases commonly contribute to homebound status, and CVD is the most common category of disorders among homebound older adults, with estimated prevalence between 20% to 44%, with homebound older adults having more advanced vascular, myocardial, and EP aging than the non-homebound, evidenced by higher prevalence of hypertension, stroke, MI, HF, and arrhythmia.[205,207-209] Simultaneously, homebound status is associated with an increased risk of mortality both before and after adjusting for comorbidities and sociodemographic factors, an association compounded by coexisting social isolation.[210,211]

Many social and geriatric determinants with strong cardiovascular impacts associate with homebound status. In a large national Medicare advantage care plan, frailty and dementia were independently associated with being homebound.[207] Leading risk factors for homebound status include frailty, sarcopenia, reduced physical activity, limited access to health care, and coexiting medical conditions.[21,205] Homebound individuals have a difficult time adhering to medical appointments, resulting in fragmented care and inappropriate medication prescribing: both polypharmacy and underprescription.[212,213] Low financial security also interacts with homebound status, accelerating cardiovascular aging by generating barriers to health care access and affordable and efficient transportation.[214]

Given the high risk and expense of hospital-based care in homebound older adults, there is a strong imperative to develop and deploy digital and home-based solutions to improve cardiovascular aging in this population. Synchronous telemedicine has demonstrated promise; however, success has been partly dependent on caregiver assistance.[215,216] Although outcomes have varied between programs, home-based care initiatives have been associated with decreased emergency department visits, hospital admissions, and health care costs, as well as increased primary and outpatient care utilization.[217] Finally, a study of 974 Medicare beneficiaries suggests that home-based long-term services and supports are underutilized, underscoring the need for improved coverage of home-based care by Medicare and other payers.[218,219]

SOCIAL DETERMINANTS IN AGE-RELATED CARDIOVASCULAR CONDITIONS

Not only do social determinants of cardiovascular aging predispose to ASCVD, HF, valvular heart disease (VHD), and AF, they decrease resilience to stressors and represent targets to support healthy aging in place for patients with these conditions.

ATHEROSCLEROTIC CARDIOVASCULAR DISEASE. Social determinants of cardiovascular aging have powerful impacts on ASCVD incidence and outcomes in adulthood and elderhood. It is the best studied of age-associated cardiovascular conditions, with documented associations with all structural and intermediary determinants discussed previously (Table 2). Some highlights: lower income, unemployment, and lower educational attainment increase the risk of ASCVD, particularly among Black Americans.[220,221] In the National Health and Nutrition Examination Survey population, adults with income below $25,000 a year and those with less than high school education have the highest risk of developing ASCVD.[221] Lower educational attainment in early life is associated with lower health literacy, fewer employment opportunities, and reduced lifetime earnings.[220] Such disadvantages drive biologic stress and inflammaging, impact dietary behaviors, and decrease access to preventive health care, all predisposing to phenotypic coronary or polyvascular disease.[220]

Significant racial and ethnic differences persist in utilization of primary preventive medications and adherence to the national secondary prevention guidelines. Black and Hispanic Americans are less likely to receive guideline-directed antihypertensive medications or statins.[222,223] These differences are multifactorial, with drivers including system-level underappreciation of cardiovascular risk factor burden of among Black and Hispanic Americans and under-representation of these groups in landmark clinical trials. Furthermore, residents of rural areas face several challenges including limited access to health care services and lower-quality care compared to large urban centers.[83,84,105] Thus, improving affordability of care for low-income communities, implementing preventive strategies for populations with lower health literacy such as single-pill combinations and community-based groups, and optimizing regional planning and transfer networks to ensure timely access to quality medical and procedural care are critical priorities to improve healthy vascular aging and ASCVD outcomes.

HEART FAILURE. Social determinants of cardiovascular aging are highly relevant to the development and management of HF, with mechanisms of impact including biological, behavioral, and health care-related factors. Data on the biology of adversity and myocardial aging are growing.[6,224] Social determinants promote activation of the sympathoadrenomedullary and hypothalamic-pituitary-adrenal axes, conversion from classical to noncanonical β2-adrenergic receptor signaling pathways, release of inflammatory cytokines, and multiple molecular hallmarks of cardiovascular aging, all associated with incident HF.[6,225] Social determinants also impact lifestyle greatly, driving maladaptive health behaviors such as suboptimal diet and limited physical activity, well-known risk factors for incident HF, as well as increased HF decompensation, impaired quality of life, and worse prognosis among people with HF.[99,101,226]

Social determinants can also impact physician behavior and thereby HF management. For example, recent data indicate that patients with HF who have low income are less likely to receive inpatient cardiology consultation during HF hospitalization.[227] Explicit and implicit bias are important factors that can impact decision-making in both HF prevention and treatment. This may be particularly relevant when considering patient candidacy for advanced HF therapies like a left ventricular assist device or heart transplantation, where having social support and stable income are often important factors for patients to thrive with either advanced therapy. On the other hand, excluding patients negatively impacted by social determinants from these life-saving therapies can exacerbate well-described gaps in HF outcomes.

Social determinants directly impact all domains of access to HF care.[228] For example: advanced HF specialists may not be physically available to people in particular regions (accessibility) and residential settings (accommodation and availability), some people have underinsurance or financial insecurity limiting affordability of newer HF guideline-directed medical therapies (affordability), and people with lower educational attainment or health literacy may have challenges adhering to anticipatory guidance around weight checks, sodium intake, and diuretic adjustments (acceptability).

Promising strategies, including self-management programs, patient-caregiver dyadic interventions, and transitional care interventions have been tested to address HF across social determinant exposures.[229-231] The SMAC-HF (Self-Management and Care of Heart Failure) trial found that a multidisciplinary group clinic visit intervention for HF, a promising strategy to address HF in the setting of social isolation and low health literacy, improved medication adherence and increased hospitalization-free survival time.[232] The ENSPIRE (Education and Supportive Partners Improving Self-Care) study found that a patient-family partnership intervention designed to reduce dietary sodium and improve medication adherence compared with patient-family education and usual care in a majority Black population, and found both partnership and educational interventions improved dietary sodium intake and HF knowledge but not medication adherence.[233] A randomized controlled trial of a primary care-based HF self-management program for patients of all educational and literacy levels reduced rates of hospitalization and mortality.[234] Finally, a randomized controlled trial of a 3-month advance practice nurse-led transitional care intervention that included a home follow-up protocol for older adults hospitalized with HF increased the length of time to readmission or death, reduced readmissions, and decreased health care costs, representing a promising intervention to support healthy aging in homebound patients with HF.[235] Harnessing implementation science and other rigorous and holistic approaches to the study of patient-, population-, and policy-level interventions to address social determinants will be necessary to improve cardiovascular aging in HF in coming decades.[230,236]

VALVULAR HEART DISEASE. VHD is common in older adults and is independently associated with limiting symptoms and mortality.[237] Although social determinants of cardiovascular aging have been less extensively studied in VHD compared with other age-associated CVD, race/ethnicity, gender, and geographic context are associated with VHD diagnosis and access to procedural interventions.[238-240] Black patients are diagnosed at younger ages and have more comorbidities such as hypertension, diabetes, and chronic kidney disease. Older Black patients are less likely to be referred to cardiology and receive diagnostic imaging, and more likely to decline intervention and be lost to follow-up than non-Black patients.[241] Older patients living in rural Florida counties faced significantly longer travel distance and times to transcatheter aortic valve replacement (TAVR), lower TAVR utilization rates, and higher adjusted TAVR mortality.[240] County-level social vulnerability has also been associated with increased 5-year mortality in a national sample of older patients who underwent transcatheter or surgical mitral valve interventions with an adjusted HR of 1.1 (95% CI: 1.07-1.14).[242] Social determinants can interact when present together, with impacts on financial security that result in decreased odds of receiving transcatheter VHD therapies, similar to other expensive life-saving interventions.[241] Taken together, factors like race and ethnicity, geographic location, and socioeconomic status influence the age of onset of disease, comorbidity burden and complexity at presentation, and likelihood of receiving guideline-directed device and drug therapies, meriting further study as well as patient-, population-, and policy-level interventions.

ATRIAL FIBRILLATION. AF is a common consequence of myocardial and EP aging, and its prevalence, management, and associated outcomes are impacted by social determinants of health.[243,244] Black race, lower income, neighborhood-level disadvantage, and social isolation are associated with earlier mortality among patients with AF.[168,243] These and other social determinants accelerate cardiovascular aging, frailty, and dementia among the over 60 million older adults with AF globally, necessitating targeted screening, anticoagulation, and rhythm control strategies.[39,245,246]

Although lower financial security is associated with increased incidence of AF, data regarding race/ethnicity, gender, and geographic context are mixed.[247-250] These disparate results may be partially driven by differences in screening, as the STROKESTOP (Systematic ECG Screening for Atrial Fibrillation Among 75 Year Old Subjects in the Region of Stockholm and Halland, Sweden) study reported decreased screening participation in individuals with lower income, lower educational attainment, and immigrant status.[251] In response, the STROKESTOP II investigators decentralized screening with 2 sites close to lower-income neighborhoods, which increased participation across sociodemographic groups.[252] This result highlights the importance of social determinant-sensitive screening strategies. For example, mobile health approaches may work for many, but for homebound and digitally isolated older adults, home-based screening paired with other public health interventions such as vaccination or physical therapy could be a more optimal strategy.[253,254]

Black race, lower income, and neighborhood-level disadvantage are associated with an increased risks of stroke and bleeding in the AF population.[255,256] These complications increase frailty risk and are largely mediated by differences in anticoagulation. Minoritized race, lower educational attainment, neighborhood disadvantage, rurality, and lower socioeconomic status are associated with decreased likelihood of anticoagulation.[256,257] Many of these determinants are also associated with prescription of warfarin as opposed to direct oral anticoagulant, lower anticoagulant adherence, higher likelihood of supratherapeutic warfarin dosing, and lower rates of left atrial appendage occlusion, explaining the higher rates of both stroke and bleeding.[258-261] Improving pharmacoequity for patients with AF will require improved patient education, clinician training, and decision aids for diverse populations, population health interventions such as automated electronic health record algorithms and mobile health interventions, as well as federal policies to improve direct oral anticoagulant affordability.[162,262-265]

Finally, given the potential for rhythm control to slow AF-driven acceleration in cardiovascular aging, reducing well-established gaps and delays in guideline-based catheter ablation across race, gender, education, income, and geographic context is imperative.[39,266-270] Progress will hinge on improving access to electrophysiologists through telemedicine and referral networks, increasing diversity in both clinical trials and the EP workforce, and ensuring comprehensive Medicare and Medicaid coverage for AF ablation.[271,272]

CONCLUSIONS

Structural and intermediary social determinants of health drive vascular, myocardial, valvular, and EP aging throughout the life course. Some determinants and aging processes are more thoroughly studied than others (**Table 2**), with underexplored areas including digital access, transportation access, and homebound status, as well as determinants' impact on valvular and EP aging. Although patient-, population-, and policy-level interventions have been proposed and studied across determinants (**Table 3**), the impacts of these interventions on cardiovascular aging and outcomes remain understudied across the risk and severity spectra for ASCVD, HF, VHD, and AF.

As the global population ages, improving cardiovascular outcomes will require focused study of, and interventions for, social determinants that incorporate the life-course approach, accounting for life stage and multiple intersecting determinants. Structural determinants will require policies reducing race- and gender-based discrimination, improving health literacy, and increasing access to preventive care in rural areas starting early in life. Intermediary determinants will require multilevel and multi-life stage interventions to improve food and financial security, digital and transportation access, as well as social connection and home support. Centering patients' holistic needs in research, interventions, advocacy, and medical care is paramount to advancing healthy cardiovascular aging for all.

FUNDING SUPPORT AND AUTHOR DISCLOSURES

Dr Troy was supported by the National Heart, Lung, and Blood Institute Ruth L. Kirschstein Institutional National Research Service Award T32-HL007227. Dr Damluji receives research funding from the Pepper Scholars Program of the Johns Hopkins University Claude D. Pepper Older Americans Independence Center (OAIC) funded by the National Institute on Aging P30-AG021334 and he receives mentored patient-oriented research career development award from the National Heart, Lung, and Blood Institute K23-HL153771-01. Dr Cudjoe was supported by the National Institute on Aging (grant K23-AG075191) and the Johns Hopkins University Center for Innovative Medicine Human Aging Project as a Caryl & George Bernstein Scholar and he reported receiving personal fees from Edenbridge Healthcare and Papa, Inc, outside the submitted work. All other authors have reported that they have no relationships relevant to the contents of this paper to disclose. The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health.

ADDRESS FOR CORRESPONDENCE: Dr Aaron Troy, Division of Cardiology, Department of Medicine, Johns Hopkins University School of Medicine, 600 North Wolfe Street, Halsted 500, Baltimore, Maryland 21287, USA. E-mail: atroy2@jh.edu. X handle: @AaronTroyMD.

REFERENCES

1. United Nations Department of Economic and Social Affairs. *Population Division. World Population Ageing 2023: Challenges and Opportunities of Population Ageing in the Least Developed Countries. UN DESA/POP/2023/TR/NO.5*. New York, NY: United Nations; 2023.

2. Joynt Maddox KE, Elkind MSV, Aparicio HJ, et al. Forecasting the burden of cardiovascular disease and stroke in the United States through 2050—prevalence of risk factors and disease: a presidential advisory from the American Heart Association. *Circulation*. 2024;150(4):e65–e88. https://doi.org/10.1161/CIR.0000000000001256

3. Ministrini S, Wenzl FA, Lüscher TF, Camici GG. Trajectories of cardiovascular ageing—from molecular mechanisms to clinical implementation. *Cardiovasc Res*. 2024;23:cvae178. https://doi.org/10.1093/cvr/cvae178

4. Raisi-Estabragh Z, Szabo L, Schuermans A, et al. Noninvasive techniques for tracking biological aging of the cardiovascular system. *JACC Cardiovasc Imaging*. 2024;17(5):533–551. https://doi.org/10.1016/j.jcmg.2024.03.001

5. Jones NL, Gilman SE, Cheng TL, Drury SS, Hill CV, Geronimus AT. Life course approaches to the causes of health disparities. *Am J Public Health*. 2019;109(Suppl 1):S48–S55. https://doi.org/10.2105/AJPH.2018.304738

6. Powell-Wiley TM, Baumer Y, Baah FO, et al. Social determinants of cardiovascular disease. *Circ Res*. 2022;130(5):782–799. https://doi.org/10.1161/CIRCRESAHA.121.319811

7. U.S. Department of Health and Human Services, Office of Disease Prevention and Health Promotion. Healthy People 2030. Accessed April 18, 2025. https://odphp.health.gov/healthypeople/priority-areas/social-determinants-health

8. Kuh D, Ben-Shlomo Y. *A Life Course Approach to Chronic Disease Epidemiology*. Oxford, UK: Oxford University Press; 1997.

9. Solar O, Irwin A. A conceptual framework for action on the social determinants of health. Social determinants of health discussion paper 2 (policy and practice). Accessed April 16, 2025. https://www.who.int/publications/i/item/9789241500852

10. Williams DR, Collins C. Racial residential segregation: a fundamental cause of racial disparities in health. *Public Health Rep*. 2001;116(5):404–416. https://doi.org/10.1093/phr/116.5.404

11. Clouston SAP, Link BG. A retrospective on fundamental cause theory: state of the literature, and goals for the future. *Annu Rev Sociol*. 2021;47(1):131–156. https://doi.org/10.1146/annurev-soc-090320-094912

12. Javed Z, Haisum Maqsood M, Yahya T, et al. Race, racism, and cardiovascular health: applying a social determinants of health framework to racial/ethnic disparities in cardiovascular disease. *Circ Cardiovasc Qual Outcomes*. 2022;15(1):e007917. https://doi.org/10.1161/CIRCOUTCOMES.121.007917

13. Forman DE, Kuchel GA, Newman JC, et al. Impact of geroscience on therapeutic strategies for older adults with cardiovascular disease. *J Am Coll Cardiol*. 2023;82(7):631–647. https://doi.org/10.1016/j.jacc.2023.05.038

14. López-Otín C, Blasco MA, Partridge L, Serrano M, Kroemer G. Hallmarks of aging: an expanding universe. *Cell*. 2023;186(2):243–278. https://doi.org/10.1016/j.cell.2022.11.001

15. Abdellatif M, Rainer PP, Sedej S, Kroemer G. Hallmarks of cardiovascular ageing. *Nat Rev Cardiol*. 2023;20(11):754–777. https://doi.org/10.1038/s41569-023-00881-3

16. Paneni F, Diaz CC, Libby P, Lüscher TF, Camici GG. The aging cardiovascular system. *J Am Coll Cardiol*. 2017;69(15):1952–1967. https://doi.org/10.1016/j.jacc.2017.01.064

17. Fulop T, Larbi A, Dupuis G, et al. Immunosenescence and inflamm-aging as two sides of the same coin: friends or foes? *Front Immunol*. 2018;8:1960. https://doi.org/10.3389/fimmu.2017.01960

18. Tang WHW, Bäckhed F, Landmesser U, Hazen SL. Intestinal microbiota in cardiovascular health and disease: JACC state-of-the-art review. *J Am Coll Cardiol*. 2019;73(16):2089–2105. https://doi.org/10.1016/j.jacc.2019.03.024

19. O'Rourke MF, Safar ME, Dzau V. The cardiovascular continuum extended: aging effects on the aorta and microvasculature. *Vasc Med*. 2010;15(6):461–468. https://doi.org/10.1177/1358863X10382946

20. Donato AJ, Machin DR, Lesniewski LA. Mechanisms of dysfunction in the aging vasculature and role in age-related disease. *Circ Res*. 2018;123(7):825–848. https://doi.org/10.1161/CIRCRESAHA.118.312563

21. Damluji AA, Alfaraidhy M, AlHajri N, et al. Sarcopenia and cardiovascular diseases. *Circulation*. 2023;147(20):1534–1553. https://doi.org/10.1161/CIRCULATIONAHA.123.064071

22. Tang X, Li PH, Chen HZ. Cardiomyocyte senescence and cellular communications within myocardial microenvironments. *Front Endocrinol (Lausanne)*. 2020;11:280. https://doi.org/10.3389/fendo.2020.00280

23. Medvedev RY, Afolabi SO, Turner DGP, Glukhov AV. Mechanisms of stretch-induced electro-anatomical remodeling and atrial arrhythmogenesis. *J Mol Cell Cardiol*. 2024;193:11–24. https://doi.org/10.1016/j.yjmcc.2024.05.011

24. Piechnik SK, Ferreira VM, Lewandowski AJ, et al. Normal variation of magnetic resonance T1 relaxation times in the human population at 1.5 T using ShMOLLI. *J Cardiovasc Magn Reson*. 2013;15(1):13. https://doi.org/10.1186/1532-429X-15-13

25. Obokata M, Reddy YNV, Borlaug BA. Diastolic dysfunction and heart failure with preserved ejection fraction: understanding mechanisms by using noninvasive methods. *JACC Cardiovasc Imaging*. 2020;13(1 Pt 2):245–257. https://doi.org/10.1016/j.jcmg.2018.12.034

26. Kleijn SA, Pandian NG, Thomas JD, et al. Normal reference values of left ventricular strain using three-dimensional speckle tracking echocardiography: results from a multicentre study. *Eur Heart J Cardiovasc Imaging*. 2015;16(4):410–416. https://doi.org/10.1093/ehjci/jeu213

27. Zheng C, Rao P, Troy A, Mukherjee M, Strom JB, et al. Mismatch between echocardiography-predicted cardiac age and chronologic age: insights from the multi-ethnic study of atherosclerosis. *J Gerontol A Biol Sci Med Sci*. 2025;80(12). https://doi.org/10.1093/gerona/glaf223

28. Raisi-Estabragh Z, Kenawy AAM, Aung N, et al. Variation in left ventricular cardiac magnetic resonance normal reference ranges: systematic review and meta-analysis. *Eur Heart J Cardiovasc Imaging*. 2021;22(5):494–504. https://doi.org/10.1093/ehjci/jeaa089

29. Singh A, Carvalho SC, Miyoshi T, et al. Normal values of left atrial size and function and the impact of age: results of the world alliance societies of echocardiography study. *J Am Soc Echocardiogr*. 2022;35(2):154–164.e3. https://doi.org/10.1016/j.echo.2021.08.008

30. James K, Jamil Y, Kumar M, et al. Frailty and cardiovascular health. *J Am Heart Assoc*. 2024;13(15):e031736. https://doi.org/10.1161/JAHA.123.031736

31. Hsu CPD, Tchir A, Mirza A, et al. Valve endothelial cell exposure to high levels of flow oscillations exacerbates valve interstitial cell calcification. *Bioengineering (Basel)*. 2022;9(8):393. https://doi.org/10.3390/bioengineering9080393

32. Gumpangseth T, Lekawanvijit S, Mahakkanukrauh P. Histological assessment of the human heart valves and its relationship with age. *Anat Cell Biol*. 2020;53(3):261–271. https://doi.org/10.5115/acb.20.093

33. Troy AL, Narula N, Massera D, et al. Histopathology of the mitral valve residual leaflet in obstructive hypertrophic cardiomyopathy. *JACC Adv*. 2023;2(3):100308. https://doi.org/10.1016/j.jacadv.2023.100308

34. Andell P, Li X, Martinsson A, et al. Epidemiology of valvular heart disease in a Swedish nationwide hospital-based register study. *Heart*. 2017;103(21):1696–1703. https://doi.org/10.1136/heartjnl-2016-310894

35. Curtis AB, Karki R, Hattoum A, Sharma UC. Arrhythmias in patients ≥80 years of age. *J Am Coll Cardiol*. 2018;71(18):2041–2057. https://doi.org/10.1016/j.jacc.2018.03.019

36. Peters CH, Sharpe EJ, Proenza C. Cardiac pacemaker activity and aging. *Annu Rev Physiol*. 2020;82:21–43. https://doi.org/10.1146/annurev-physiol-021119-034453

37. Kaye DM, Esler MD. Autonomic control of the aging heart. *Neuromol Med*. 2008;10(3):179–186. https://doi.org/10.1007/s12017-008-8034-1

38. Dani M, Taraborrelli P, Panagopoulos D, et al. New horizons in the ageing autonomic nervous system: orthostatic hypotension and supine hypertension. *Age Ageing*. 2022;51(8):afac150. https://doi.org/10.1093/ageing/afac150

39. Rosas Diaz AN, Troy AL, Kaplinskiy V, et al. Assessment and management of atrial fibrillation in older adults with frailty. *Geriatrics (Basel)*. 2024;9(2):50. https://doi.org/10.3390/geriatrics9020050

40. Kundi H, Wadhera RK, Strom JB, et al. Association of frailty with 30-day outcomes for acute myocardial infarction, heart failure, and pneumonia among elderly adults. *JAMA Cardiol*. 2019;4(11):1084–1091. https://doi.org/10.1001/jamacardio.2019.3511

41. Denfeld QE, Jha SR, Fung E, et al. Assessing and managing frailty in advanced heart failure: an international society for heart and lung transplantation consensus statement. *J Heart Lung Transplant*. 2024;43(1):1–27. https://doi.org/10.1016/j.healun.2023.09.013

42. Li F, Li D, Yu J, et al. Silent myocardial infarction and long-term risk of frailty: the atherosclerosis risk in communities study. *Clin Interv Aging*. 2021;16:1139–1149. https://doi.org/10.2147/CIA.S315837

43. Mitnitski AB, Graham JE, Mogilner AJ, Rockwood K. Frailty, fitness and late-life mortality in relation to chronological and biological age. *BMC Geriatr*. 2002;2:1. https://doi.org/10.1186/1471-2318-2-1

44. Fried LP, Tangen CM, Walston J, et al. Frailty in older adults: evidence for a phenotype. *J Gerontol A Biol Sci Med Sci*. 2001;56(3):M146–M156. https://doi.org/10.1093/gerona/56.3.m146

45. Ijaz N, Buta B, Xue QL, et al. Interventions for frailty among older adults with cardiovascular disease: JACC state-of-the-art review. *J Am Coll Cardiol*. 2022;79(5):482–503. https://doi.org/10.1016/j.jacc.2021.11.029

46. Kruger R, Gafane-Matemane LF, Kagura J. Racial differences of early vascular aging in children and adolescents. *Pediatr Nephrol*. 2021;36(5):1087–1108. https://doi.org/10.1007/s00467-020-04593-5

47. Huang X, Hughes Z, Fonarow GC, et al. Racial and ethnic differences in patient age at first hospitalization for heart failure. *J Am Coll Cardiol*. 2025;86(10):711–720. https://doi.org/10.1016/j.jacc.2025.06.046

48. Rooks RN, Simonsick EM, Miles T, et al. The association of race and socioeconomic status with cardiovascular disease indicators among older adults in the health, aging, and body composition study. *J Gerontol B Psychol Sci Soc Sci*. 2002;57(4):S247–S256. https://doi.org/10.1093/geronb/57.4.s247

49. Kishi S, Teixido-Tura G, Ning H, et al. Cumulative blood pressure in early adulthood and cardiac dysfunction in middle age: the CARDIA study. *J Am Coll Cardiol*. 2015;65(25):2679–2687. https://doi.org/10.1016/j.jacc.2015.04.042

50. Mandelblatt JS, Ruterbusch JJ, Thompson HS, et al. Association between major discrimination and deficit accumulation in African American cancer survivors: the detroit research on cancer survivors study. *Cancer*. 2023;129(10):1557–1568. https://doi.org/10.1002/cncr.34673

51. Forrester S, Jacobs D, Zmora R, Schreiner P, Roger V, Kiefe CI. Racial differences in weathering and its associations with psychosocial stress: the CARDIA study. *SSM Popul Health*. 2019;7:003. https://doi.org/10.1016/j.ssmph.2018.11.003

52. Kyalwazi AN, Loccoh EC, Brewer LC, et al. Disparities in cardiovascular mortality between Black and White adults in the United States, 1999 to 2019. *Circulation*. 2022;146(3):211–228. https://doi.org/10.1161/CIRCULATIONAHA.122.060199

53. Arun AS, Sawano M, Lu Y, et al. Excess cardiovascular mortality among Black Americans 2000-2022. *J Am Coll Cardiol*. 2024;84(6):581–588. https://doi.org/10.1016/j.jacc.2024.06.004

54. Elbasheir A, Katrinli S, Kearney BE, et al. Racial discrimination, neural connectivity, and epigenetic aging among Black women. *JAMA Netw Open*. 2024;7(6):e2416588. https://doi.org/10.1001/jamanetworkopen.2024.16588

55. Bale BF, Doneen AL, Leimgruber PP, Vigerust DJ. The critical issue linking lipids and inflammation: clinical utility of stopping oxidative stress. *Front Cardiovasc Med*. 2022;9:1042729. https://doi.org/10.3389/fcvm.2022.1042729

56. Ranjit N, Diez-Roux AV, Shea S, Cushman M, Ni H, Seeman T. Socioeconomic position, race/ethnicity, and inflammation in the multi-ethnic study of atherosclerosis. *Circulation*. 2007;116(21):2383–2390. https://doi.org/10.1161/CIRCULATIONAHA.107.706226

57. Breathett K, Liu WG, Allen LA, et al. African-Americans are less likely to receive care by a cardiologist during an intensive care unit admission for heart failure. *JACC Heart Fail*. 2018;6(5):413–420. https://doi.org/10.1016/j.jchf.2018.02.015

58. Joseph JJ, Nolan TS, Williams A, et al. Improving cardiovascular health in black men through a 24-week community-based team lifestyle change intervention: the black impact pilot study. *Am J Prev Cardiol*. 2022;9:100315. https://doi.org/10.1016/j.ajpc.2022.100315

59. Albert MA, Churchwell K, Desai N, et al. Addressing structural racism through public policy advocacy: a policy statement from the American Heart Association. *Circulation*. 2024;149(6):e312–e329. https://doi.org/10.1161/CIR.0000000000001203

60. Victor RG, Lynch K, Li N, et al. A cluster-randomized trial of blood-pressure reduction in Black barbershops. *N Engl J Med*. 2018;378(14):1291–1301. https://doi.org/10.1056/NEJMoa1717250

61. Snyder JE, Upton RD, Hassett TC, Lee H, Nouri Z, Dill M. Black representation in the primary care physician workforce and its association with population life expectancy and mortality rates in the US. *JAMA Netw Open*. 2023;6(4):e236687. https://doi.org/10.1001/jamanetworkopen.2023.6687

62. Prasanna A, Miller HN, Wu Y, et al. Recruitment of black adults into cardiovascular disease trials. *J Am Heart Assoc*. 2021;10(17):e021108. https://doi.org/10.1161/JAHA.121.021108

63. Regitz-Zagrosek V, Gebhard C. Gender medicine: effects of sex and gender on cardiovascular disease manifestation and outcomes. *Nat Rev Cardiol*. 2023;20(4):236–247. https://doi.org/10.1038/s41569-022-00797-4

64. Bello NA, Cheng S. Where do we go from here: reflections on a century in women's cardiovascular health research, 1924–2024. *Circ Res*. 2024;134(3):247–251. https://doi.org/10.1161/CIRCRESAHA.123.323182

65. Böhm B, Hartmann K, Buck M, Oberhoffer R. Sex differences of carotid intima-media thickness in healthy children and adolescents. *Atherosclerosis*. 2009;206(2):458–463. https://doi.org/10.1016/j.atherosclerosis.2009.03.016

66. DuPont JJ, Kim SK, Kenney RM, Jaffe IZ. Sex differences in the time course and mechanisms of vascular and cardiac aging in mice: role of the smooth muscle cell mineralocorticoid receptor. *Am J Physiol Heart Circ Physiol*. 2021;320(1):H169–H180. https://doi.org/10.1152/ajpheart.00262.2020

67. Gori M, Lam CSP, Gupta DK, et al. Sex-specific cardiovascular structure and function in heart failure with preserved ejection fraction. *Eur J Heart Fail*. 2014;16(5):535–542. https://doi.org/10.1002/ejhf.67

68. Westerman S, Wenger N. Gender differences in atrial fibrillation: a review of epidemiology, management, and outcomes. *Curr Cardiol Rev*. 2019;15(2):136–144. https://doi.org/10.2174/1573403X15666181205110624

69. Barrett ELB, Richardson DS. Sex differences in telomeres and lifespan. *Aging Cell*. 2011;10(6):913–921. https://doi.org/10.1111/j.1474-9726.2011.00741.x

70. Muka T, Oliver-Williams C, Kunutsor S, et al. Association of age at onset of menopause and time since onset of menopause with cardiovascular outcomes, intermediate vascular traits, and all-cause mortality: a systematic review and meta-analysis. *JAMA Cardiol*. 2016;1(7):767–776. https://doi.org/10.1001/jamacardio.2016.2415

71. Hemal K, Pagidipati NJ, Coles A, et al. Sex differences in demographics, risk factors, presentation, and noninvasive testing in stable outpatients with suspected coronary artery disease: insights from the PROMISE trial. *JACC Cardiovasc Imaging*. 2016;9(4):337–346. https://doi.org/10.1016/j.jcmg.2016.02.001

72. van Oosterhout REM, de Boer AR, Maas AHEM, Rutten FH, Bots ML, Peters SAE. Sex differences in symptom presentation in acute coronary syndromes: a systematic review and meta-analysis. *J Am Heart Assoc*. 2020;9(9):e014733. https://doi.org/10.1161/JAHA.119.014733

73. Reynolds HR, Bairey Merz CN, Berry C, et al. Coronary arterial function and disease in women with no obstructive coronary arteries. *Circ Res*. 2022;130(4):529–551. https://doi.org/10.1161/CIRCRESAHA.121.319892

74. Glasser NJ, Jameson JC, Huang ES, et al. Male gender expressivity and diagnosis and treatment of cardiovascular disease risks in men. *JAMA Netw Open*. 2024;7(10):e2441281. https://doi.org/10.1001/jamanetworkopen.2024.41281

75. Satti DI, Chan JSK, Mszar R, et al. Social determinants of health, cardiovascular health, and mortality in sexual minority individuals in the United States. *J Am Coll Cardiol*. 2025;85(5):515–525. https://doi.org/10.1016/j.jacc.2024.11.026

76. Lindley KJ, Aggarwal NR, Briller JE, et al. Socioeconomic determinants of health and cardiovascular outcomes in women: JACC review topic of the week. *J Am Coll Cardiol*. 2021;78(19):1919–1929. https://doi.org/10.1016/j.jacc.2021.09.011

77. Nguyen AH, Hurwitz M, Sullivan SA, Saad A, Kennedy JLW, Sharma G. Update on sex specific risk factors in cardiovascular disease. *Front Cardiovasc Med*. 2024;11:1352675. https://doi.org/10.3389/fcvm.2024.1352675

78. Fatunde OA, Grant JK, Lara-Breitinger K, et al. Gender disparities in cardiology: learning from history to envision the future. *JACC: Adv*. 2025;4(4):101642. https://doi.org/10.1016/j.jacadv.2025.101642

79. Sullivan K, Doumouras BS, Santema BT, et al. Sex-specific differences in heart failure: pathophysiology, risk factors, management, and outcomes. *Can J Cardiol*. 2021;37(4):560–571. https://doi.org/10.1016/j.cjca.2020.12.025

80. DeFilippis EM, Van Spall HGC. Is it time for sex-specific guidelines for cardiovascular disease? *J Am Coll Cardiol*. 2021;78(2):189–192. https://doi.org/10.1016/j.jacc.2021.05.012

81. Biga C. Comment from American college of cardiology. Regulations.gov. Accessed May 30, 2025. https://www.regulations.gov/comment/FDA-2021-D-0789-0183

82. Ellingrud K, Pérez L, Petersen A, Sartori V. Closing the women's health gap. McKinsey. Accessed May 30, 2025. https://www.mckinsey.com/mhi/our-insights/closing-the-womens-health-gap-a-1-trillion-dollar-opportunity-to-improve-lives-and-economies

83. Loccoh E, Joynt Maddox KE, Xu J, et al. Rural-urban disparities in all-cause mortality among low-income medicare beneficiaries, 2004–17. *Health Aff (Millwood)*. 2021;40(2):289–296. https://doi.org/10.1377/hlthaff.2020.00420

84. Liu M, Marinacci LX, Joynt Maddox KE, Wadhera RK. Cardiovascular health among rural and urban US adults-healthcare, lifestyle, and social factors. *JAMA Cardiol*. 2025;10(6):585–594. https://doi.org/10.1001/jamacardio.2025.0538

85. Kuehn BM. Hypertension rates in rural areas outpace those in urban locales. *JAMA*. 2020;323(24):2454. https://doi.org/10.1001/jama.2020.9382

86. Turecamo SE, Xu M, Dixon D, et al. Association of rurality with risk of heart failure. *JAMA Cardiol*. 2023;8(3):231–239. https://doi.org/10.1001/jamacardio.2022.5211

87. Lin AL, Allen K, Gutierrez JA, Piccini JP, Loring Z. Care for atrial fibrillation and outcomes in rural versus urban communities in the United States: a systematic and narrative review. *J Am Heart Assoc*. 2025;14(5):e036899. https://doi.org/10.1161/JAHA.124.036899

88. Tan MC, Yeo YH, San BJ, et al. Trends and disparities in valvular heart disease mortality in the United States from 1999 to 2020. *J Am Heart Assoc*. 2024;13(8):e030895. https://doi.org/10.1161/JAHA.123.030895

89. Aggarwal R, Chiu N, Loccoh EC, Kazi DS, Yeh RW, Wadhera RK. Rural-urban disparities: diabetes, hypertension, heart disease, and stroke mortality among black and white adults, 1999-2018. *J Am Coll Cardiol*. 2021;77(11):1480–1481. https://doi.org/10.1016/j.jacc.2021.01.032

90. Marinacci LX, Zheng Z, Mein S, Wadhera RK. Rural-urban differences in cardiovascular mortality in the United States, 2010-2022. *J Am Coll Cardiol*. 2025;85(1):93–97. https://doi.org/10.1016/j.jacc.2024.09.1215

91. Liu M, Wadhera RK. Primary care physician supply by county-level characteristics, 2010-2019. *JAMA*. 2022;328(19):1974–1977. https://doi.org/10.1001/jama.2022.15106

92. Zhang D, Son H, Shen Y, et al. Assessment of changes in rural and urban primary care workforce in the United States from 2009 to 2017. *JAMA Netw Open*. 2020;3(10):e2022914. https://doi.org/10.1001/jamanetworkopen.2020.22914

93. Kim JH, Cisneros T, Nguyen A, van Meijgaard J, Warraich HJ. Geographic disparities in access to cardiologists in the United States. *J Am Coll Cardiol*. 2024;84(3):315–316. https://doi.org/10.1016/j.jacc.2024.04.054

94. Blaustein JR, Quisel MJ, Hamburg NM, Wittkopp S. Environmental impacts on cardiovascular health and biology: an overview. *Circ Res*. 2024;134(9):1048–1060. https://doi.org/10.1161/CIRCRESAHA.123.323613

95. Liu M, Patel VR, Salas RN, et al. Neighborhood environmental burden and cardiovascular health in the US. *JAMA Cardiol*. 2024;9(2):153–163. https://doi.org/10.1001/jamacardio.2023.4680

96. Sagheer U, Al-Kindi S, Abohashem S, et al. Environmental pollution and cardiovascular disease: part 1 of 2: air pollution. *JACC: Adv*. 2024;3(2):100805. https://doi.org/10.1016/j.jacadv.2023.100805

97. Reddy KP, Eberly LA, Julien HM, et al. Association between racial residential segregation and black-white disparities in cardiovascular disease mortality. *Am Heart J*. 2023;264:143–152. https://doi.org/10.1016/j.ahj.2023.06.010

98. Moniruzzaman M, Reid LA, Jones KK, et al. Multilevel mediators on the associations of neighborhood social environmental factors and severity of metabolic syndrome: the Jackson heart study. *J Am Heart Assoc*. 2025;14(1):e035216. https://doi.org/10.1161/JAHA.124.035216

99. Wadhera RK, Secemsky EA, Xu J, Yeh RW, Song Y, Goldhaber SZ. Community socioeconomic status, acute cardiovascular hospitalizations, and mortality in medicare, 2003 to 2019. *Circ: Cardiovasc Qual Outcomes*. 2024;17(4):e010090. https://doi.org/10.1161/CIRCOUTCOMES.123.010090

100. Cramm JM, Nieboer AP. Relationships between frailty, neighborhood security, social cohesion and sense of belonging among community-dwelling older people. *Geriatr Gerontol Int*. 2013;13(3):759–763. https://doi.org/10.1111/j.1447-0594.2012.00967.x

101. Hermes Z, Joynt Maddox KE, Yeh RW, Zhao Y, Shen C, Wadhera RK. Neighborhood socioeconomic disadvantage and mortality among medicare beneficiaries hospitalized for acute myocardial infarction, heart failure, and pneumonia. *J Gen Intern Med*. 2022;37(8):1894–1901. https://doi.org/10.1007/s11606-021-07090-z

102. Troy AL, Xu J, Wadhera RK. Access to care and cardiovascular health in US counties with low versus higher broadband internet availability. *Am J Cardiol*. 2023;209:190–192. https://doi.org/10.1016/j.amjcard.2023.09.111

103. Butzner M, Cuffee Y. Telehealth interventions and outcomes across rural communities in the United States: narrative review. *J Med Internet Res*. 2021;23(8):e29575. https://doi.org/10.2196/29575

104. Litt JS, Alaimo K, Harrall KK, et al. Effects of a community gardening intervention on diet, physical activity, and anthropometry outcomes in the USA (CAPS): an observer-blind, randomised controlled trial. *Lancet Planet Health*. 2023;7(1):e23–e32. https://doi.org/10.1016/S2542-5196(22)00303-5

105. Loccoh EC, Joynt MKE, Wang Y, Kazi DS, Yeh RW, Wadhera RK. Rural-urban disparities in outcomes of myocardial infarction, heart failure, and stroke in the United States. *J Am Coll Cardiol*. 2022;79(3):267–279. https://doi.org/10.1016/j.jacc.2021.10.045

106. Greenwood-Ericksen MB, D'Andrea S, Findley S. Transforming the rural health care paradigm. *JAMA Health Forum*. 2020;1(9):e200987. https://doi.org/10.1001/jamahealthforum.2020.0987

107. Lunde ED, Joensen AM, Lundbye-Christensen S, et al. Socioeconomic position and risk of atrial fibrillation: a nationwide Danish cohort study. *J Epidemiol Commun Health*. 2020;74(1):7–13. https://doi.org/10.1136/jech-2019-212720

108. Johnson AE, Herbert BM, Stokes N, Brooks MM, Needham BL, Magnani JW. Educational attainment, race, and ethnicity as predictors for ideal cardiovascular health: from the national health and nutrition examination survey. *J Am Heart Assoc*. 2022;11(2):e023438. https://doi.org/10.1161/JAHA.121.023438

109. Magnani JW, Ning H, Wilkins JT, Lloyd-Jones DM, Allen NB. Educational attainment and lifetime risk of cardiovascular disease. *JAMA Cardiol*. 2024;9(1):45–54. https://doi.org/10.1001/jamacardio.2023.3990

110. Yan LL, Liu K, Daviglus ML, et al. Education, 15-year risk factor progression, and coronary artery calcium in young adulthood and early middle age: the coronary artery risk development in young adults study. *JAMA*. 2006;295(15):1793–1800. https://doi.org/10.1001/jama.295.15.1793

111. Kelli HM, Mehta A, Tahhan AS, et al. Low educational attainment is a predictor of adverse outcomes in patients with coronary artery disease. *J Am Heart Assoc*. 2019;8(17):e013165. https://doi.org/10.1161/JAHA.119.013165

112. Liu C, Ma Y, Hofman A, et al. Educational attainment and dementia: mediation by mid-life vascular risk factors. *Ann Neurol*. 2023;94(1):13–26. https://doi.org/10.1002/ana.26647

113. Graf GHJ, Aiello AE, Caspi A, et al. Educational mobility, pace of aging, and lifespan among participants in the Framingham heart study. *JAMA Netw Open*. 2024;7(3):e240655. https://doi.org/10.1001/jamanetworkopen.2024.0655

114. Hamad R, Nguyen TT, Bhattacharya J, Glymour MM, Rehkopf DH. Educational attainment and cardiovascular disease in the United States: a quasi-experimental instrumental variables analysis. *PLoS Med*. 2019;16(6):e1002834. https://doi.org/10.1371/journal.pmed.1002834

115. Krousel-Wood M, Joyce C, Holt E, et al. Predictors of decline in medication adherence: results from the cohort study of medication adherence among older adults. *Hypertension*. 2011;58(5):804–810. https://doi.org/10.1161/HYPERTENSIONAHA.111.176859

116. Jain B, Bajaj SS, Paguio JA, et al. Socioeconomic disparities in healthcare utilization for atherosclerotic cardiovascular disease. *Am Heart J*. 2022;246:161–165. https://doi.org/10.1016/j.ahj.2022.01.011

117. Muñoz D, Uzoije P, Reynolds C, et al. Polypill for cardiovascular disease prevention in an underserved population. *N Engl J Med*. 2019;381(12):1114–1123. https://doi.org/10.1056/NEJMoa1815359

118. Hassen HY, Ndejjo R, Van Geertruyden JP, Musinguzi G, Abrams S, Bastiaens H. Type and effectiveness of community-based interventions in improving knowledge related to cardiovascular diseases and risk factors: a systematic review. *Am J Prev Cardiol*. 2022;10:100341. https://doi.org/10.1016/j.ajpc.2022.100341

119. Flores SM. How states can put equity at the center of educational policy. MDRC. September 1, 2022. Accessed May 30, 2025. https://www.mdrc.org/work/publications/how-states-can-put-equity-center-educational-policy

120. Pak TY, Kim G. Association of food insecurity with allostatic load among older adults in the US. *JAMA Netw Open*. 2021;4(12):e2137503. https://doi.org/10.1001/jamanetworkopen.2021.37503

121. Liu Y, Eicher-Miller HA. Food insecurity and cardiovascular disease risk. *Curr Atheroscler Rep*. 2021;23(6):24. https://doi.org/10.1007/s11883-021-00923-6

122. O'Connor EA, Webber EM, Martin AM, Henninger ML, Eder ML, Lin JS. Preventive services for food insecurity: evidence report and systematic review for the US preventive services task force. *JAMA*. 2025;333(15):1340–1351. https://doi.org/10.1001/jama.2024.22805

123. Wennberg AM, Ek S, Na M. Food insecurity, vision impairment, and longitudinal risk of frailty and falls in the national health and aging trends study. *J Frailty Aging*. 2024;13(3):285–292. https://doi.org/10.14283/jfa.2024.21

124. Gondi KT, Larson J, Sifuentes A, et al. Health of the food environment is associated with heart failure mortality in the United States. *Circ Heart Fail*. 2022;15(12):e009651. https://doi.org/10.1161/CIRCHEARTFAILURE.122.009651

125. Markson F, Akuna E, Asemota I, et al. Protein-energy malnutrition is associated with worse outcomes in patients with atrial fibrillation: a nationwide analysis. *J Innov Card Rhythm Manag*. 2023;14(8):5538–5545. https://doi.org/10.19102/icrm.2023.14082

126. Kelli HM, Hammadah M, Ahmed H, et al. Association between living in food deserts and cardiovascular risk. *Circ Cardiovasc Qual Outcomes*. 2017;10(9):e003532. https://doi.org/10.1161/CIRCOUTCOMES.116.003532

127. Zierath R, Claggett B, Hall ME, et al. Measures of food inadequacy and cardiovascular disease risk in black individuals in the US from the Jackson heart study. *JAMA Netw Open*. 2023;6(1):e2252055. https://doi.org/10.1001/jamanetworkopen.2022.52055

128. Palakshappa D, Ip EH, Berkowitz SA, et al. Pathways by which food insecurity is associated with atherosclerotic cardiovascular disease risk. *J Am Heart Assoc*. 2021;10(22):e021901. https://doi.org/10.1161/JAHA.121.021901

129. Lane MM, Gamage E, Du S, et al. Ultra-processed food exposure and adverse health outcomes: umbrella review of epidemiological meta-analyses. *BMJ*. 2024;384:e077310. https://doi.org/10.1136/bmj-2023-077310

130. Hager K, Du M, Li Z, et al. Impact of produce prescriptions on diet, food security, and cardiometabolic health outcomes: a multisite evaluation of 9 produce prescription programs in the United States. *Circ Cardiovasc Qual Outcomes*. 2023;16(9):e009520. https://doi.org/10.1161/CIRCOUTCOMES.122.009520

131. Liu M, Johnson DY, Bleich SN, et al. Changes in physical and mental health after the end of SNAP emergency allotments. *JAMA*. 2025;334(2):175–177. https://doi.org/10.1001/jama.2025.6010

132. Choi SE, Seligman H, Basu S. Cost effectiveness of subsidizing fruit and vegetable purchases through the supplemental nutrition assistance program. *Am J Prev Med*. 2017;52(5):e147–e155. https://doi.org/10.1016/j.amepre.2016.12.013

133. Troy AL, Ahmad I, Zheng Z, Wadhera RK. Food insecurity among low-income U.S. adults during the COVID-19 pandemic. *Ann Intern Med*. 2024;177(2):260–262. https://doi.org/10.7326/M23-2282

134. Mozaffarian D, Aspry KE, Garfield K, et al. "Food Is Medicine" strategies for nutrition security and cardiometabolic health equity. *J Am Coll Cardiol*. 2024;83(8):843–864. https://doi.org/10.1016/j.jacc.2023.12.023

135. Early J, Hernandez A. Digital disenfranchisement and COVID-19: broadband internet access as a social determinant of health. *Health Promot Pract*. 2021;22(5):605–610. https://doi.org/10.1177/15248399211014490

136. Powell-Wiley TM, Brewer LC, Burke LE, et al. Role of technology in promoting heart healthy behavior change to increase equity in optimal cardiovascular health: a scientific statement from the American Heart Association. *Circulation*. 2025;151(18):e972–e985. https://doi.org/10.1161/CIR.0000000000001314

137. Klaiman T, Iannotte LG, Josephs M, et al. Qualitative analysis of a remote monitoring intervention for managing heart failure. *BMC Cardiovasc Disord*. 2023;23(1):440. https://doi.org/10.1186/s12872-023-03456-9

138. Mehta SJ, Volpp KG, Troxel AB, et al. Remote blood pressure monitoring with social support for patients with hypertension: a randomized clinical trial. *JAMA Netw Open*. 2024;7(6):e2413515. https://doi.org/10.1001/jamanetworkopen.2024.13515

139. Dodson JA, Adhikari S, Schoenthaler A, et al. Rehabilitation at home using mobile health for older adults hospitalized for ischemic heart disease: the RESILIENT randomized clinical trial. *JAMA Netw Open*. 2025;8(1):e2453499. https://doi.org/10.1001/jamanetworkopen.2024.53499

140. Mathews L, Brewer LC. A review of disparities in cardiac rehabilitation: evidence, drivers and solutions. *J Cardiopulm Rehabil Prev*. 2021;41(6):375–382. https://doi.org/10.1097/HCR.0000000000000659

141. Johnson T, Chilazi M, Isakadze N, et al. Bridging the digital divide: applying digital tools to improve cardiovascular health in underrepresented communities. *JACC: Adv*. 2023;2(7):100587. https://doi.org/10.1016/j.jacadv.2023.100587

142. The $42 billion internet program that has connected 0 people » Publications » Washington Policy Center. Accessed May 30, 2025. https://www.washingtonpolicy.org/publications/detail/the-42-billion-internet-program-that-has-connected-0-people

143. Hanlon P, Politis M, Wightman H, et al. Frailty and socioeconomic position: a systematic review of observational studies. *Ageing Res Rev*. 2024;100:102420. https://doi.org/10.1016/j.arr.2024.102420

144. Doom JR, Mason SM, Suglia SF, Clark CJ. Pathways between childhood/adolescent adversity, adolescent socioeconomic status, and long-term cardiovascular disease risk in young adulthood. *Soc Sci Med*. 2017;188:166–175. https://doi.org/10.1016/j.socscimed.2017.06.044

145. Hamad R, Penko J, Kazi DS, et al. Association of low socioeconomic status with premature coronary heart disease in US adults. *JAMA Cardiol*. 2020;5(8):899–908. https://doi.org/10.1001/jamacardio.2020.1458

146. Mathews L, Ding N, Mok Y, et al. Impact of socioeconomic status on mortality and readmission in patients with heart failure with reduced ejection fraction: the ARIC study. *J Am Heart Assoc*. 2022;11(18):e024057. https://doi.org/10.1161/JAHA.121.024057

147. Misialek JR, Rose KM, Everson-Rose SA, et al. Socioeconomic status and the incidence of atrial fibrillation in whites and blacks: the atherosclerosis risk in communities (ARIC) study. *J Am Heart Assoc*. 2014;3(4):e001159. https://doi.org/10.1161/JAHA.114.001159

148. Gerber Y, Weston SA, Killian JM, Therneau TM, Jacobsen SJ, Roger VL. Neighborhood income and individual education: effect on survival after myocardial infarction. *Mayo Clin Proc*. 2008;83(6):663–669. https://doi.org/10.4065/83.6.663

149. Minhas AMK, Jain V, Li M, et al. Family income and cardiovascular disease risk in American adults. *Sci Rep*. 2023;13(1):279. https://doi.org/10.1038/s41598-023-27474-x

150. Sukumar S, Wasfy JH, Januzzi JL, Peppercorn J, Chino F, Warraich HJ. Financial toxicity of medical management of heart failure: JACC review topic of the week. *J Am Coll Cardiol*. 2023;81(20):2043–2055. https://doi.org/10.1016/j.jacc.2023.03.402

151. Yong CM, Abnousi F, Asch SM, Heidenreich PA. Socioeconomic inequalities in quality of care and outcomes among patients with acute coronary syndrome in the modern era of drug eluting stents. *J Am Heart Assoc*. 2014;3(6):e001029. https://doi.org/10.1161/JAHA.114.001029

152. Houweling TAJ, Grünberger I. Intergenerational transmission of health inequalities: towards a life course approach to socioeconomic inequalities in health - a review. *J Epidemiol Commun Health*. 2024;78(10):641–649. https://doi.org/10.1136/jech-2022-220162

153. Arno PS, House JS, Viola D, Schechter C. Social security and mortality: the role of income support policies and population health in the United States. *J Public Health Policy*. 2011;32(2):234–250. https://doi.org/10.1057/jphp.2011.2

154. Albert MA, Durazo EM, Slopen N, et al. Cumulative psychological stress and cardiovascular disease risk in middle aged and older women: rationale, design, and baseline characteristics. *Am Heart J*. 2017;192:1–12. https://doi.org/10.1016/j.ahj.2017.06.012

155. Sandhu S, Liu M, Wadhera RK. Hospitals and health equity—translating measurement into action. *N Engl J Med*. 2022;387(26):2395–2397. https://doi.org/10.1056/NEJMp2211648

156. Matthews S, Qureshi N, Levin JS, Eberhart NK, Breslau J, McBain RK. Financial interventions to improve screening in primary care: a systematic review. *Am J Prev Med*. 2024;67(1):134–146. https://doi.org/10.1016/j.amepre.2024.03.003

157. Butt SA, Retamales MT, Javed Z, et al. Multidimensional poverty and risk of atherosclerotic cardiovascular disease: a U.S. national study. *JACC: Adv*. 2024;3(7):100928. https://doi.org/10.1016/j.jacadv.2024.100928

158. Miller S, Rhodes E, Bartik AW, Broockman DE, Krause PK, Vivalt E. *Does Income Affect Health? Evidence From a Randomized Controlled Trial of a Guaranteed Income*. National Bureau of Economic Research; 2024. https://doi.org/10.3386/w32711

159. Aggarwal R, Yeh RW, Dahabreh IJ, Robertson SE, Wadhera RK. Medicare eligibility and healthcare access, affordability, and financial strain for low- and higher-income adults in the United States: a regression discontinuity analysis. *PLOS Med*. 2022;19(10):e1004083. https://doi.org/10.1371/journal.pmed.1004083

160. Jiang GY, Urwin JW, Wasfy JH. Medicaid expansion under the affordable care act and association with cardiac care: a systematic review. *Circ Cardiovasc Qual Outcomes*. 2023;16(6):e009753. https://doi.org/10.1161/CIRCOUTCOMES.122.009753

161. Wadhera RK, Joynt Maddox KE, Fonarow GC, et al. Association of the affordable care act's medicaid expansion with care quality and outcomes for low-income patients hospitalized with heart failure. *Circ: Cardiovasc Qual Outcomes*. 2018;11(7):e004729. https://doi.org/10.1161/CIRCOUTCOMES.118.004729

162. Troy A, Anderson TS. National trends in use of and spending on oral anticoagulants among US medicare beneficiaries from 2011 to 2019. *JAMA Health Forum*. 2021;2(7):e211693. https://doi.org/10.1001/jamahealthforum.2021.1693

163. Narasimmaraj PR, Oseran A, Tale A, et al. Out-of-pocket drug costs for medicare beneficiaries with cardiovascular risk factors under the inflation reduction act. *J Am Coll Cardiol*. 2023;81(15):1491–1501. https://doi.org/10.1016/j.jacc.2023.02.002

164. *Social Isolation and Loneliness in Older Adults: Opportunities for the Health Care System*. National Academies Press (US); 2020. Accessed May 30, 2025. http://www.ncbi.nlm.nih.gov/books/NBK557974/

165. Cené CW, Beckie TM, Sims M, et al. Effects of objective and perceived social isolation on cardiovascular and brain health: a scientific statement from the American Heart Association. *J Am Heart Assoc*. 2022;11(16):e026493. https://doi.org/10.1161/JAHA.122.026493

166. Liang YY, Chen Y, Feng H, et al. Social isolation, loneliness and subsequent risk of major adverse cardiovascular events among individuals with type 2 diabetes mellitus. *Gen Psychiatr*. 2023;36(6):e101153. https://doi.org/10.1136/gpsych-2023-101153

167. Davies K, Maharani A, Chandola T, Todd C, Pendleton N. The longitudinal relationship between loneliness, social isolation, and frailty in older adults in England: a prospective analysis. *Lancet Healthy Longev*. 2021;2(2):e70–e77.

https://doi.org/10.1016/S2666-7568(20)30038-6

168. Qiao Y, Wang Y, Ge T, et al. Association of social disconnection with the incidence and prognosis of atrial fibrillation: a multistate analysis. *J Am Heart Assoc*. 2025;14(9):e039885. https://doi.org/10.1161/JAHA.124.039885

169. Barefoot JC, Grønbaek M, Jensen G, Schnohr P, Prescott E. Social network diversity and risks of ischemic heart disease and total mortality: findings from the Copenhagen city heart study. *Am J Epidemiol*. 2005;161(10):960-967. https://doi.org/10.1093/aje/kwi128

170. Freak-Poli R, Ryan J, Neumann JT, et al. Social isolation, social support and loneliness as predictors of cardiovascular disease incidence and mortality. *BMC Geriatr*. 2021;21(1):711. https://doi.org/10.1186/s12877-021-02602-2

171. Golaszewski NM, LaCroix AZ, Godino JG, et al. Evaluation of social isolation, loneliness, and cardiovascular disease among older women in the US. *JAMA Netw Open*. 2022;5(2):e2146461. https://doi.org/10.1001/jamanetworkopen.2021.46461

172. Yarish NM, Posis AIB, Nguyen S, et al. Loneliness, social isolation, and cardiovascular disease among nonveteran and veteran women. *J Women Aging*. 2024;36(6):492-503. https://doi.org/10.1080/08952841.2024.2336655

173. Cené CW, Leng XI, Faraz K, et al. Social isolation and incident heart failure hospitalization in older women: women's health initiative study findings. *J Am Heart Assoc*. 2022;11(5):e022907. https://doi.org/10.1161/JAHA.120.022907

174. Gronewold J, Engels M, van de Velde S, et al. Effects of life events and social isolation on stroke and coronary heart disease. *Stroke*. 2021;52(2):735-747. https://doi.org/10.1161/STROKEAHA.120.032070

175. Holt-Lunstad J, Smith TB. Loneliness and social isolation as risk factors for CVD: implications for evidence-based patient care and scientific inquiry. *Heart*. 2016;102(13):987-989. https://doi.org/10.1136/heartjnl-2015-309242

176. Silverman MN, Sternberg EM. Glucocorticoid regulation of inflammation and its functional correlates: from HPA axis to glucocorticoid receptor dysfunction. *Ann N Y Acad Sci*. 2012;1261:55-63. https://doi.org/10.1111/j.1749-6632.2012.06633.x

177. Shankar A, McMunn A, Banks J, Steptoe A. Loneliness, social isolation, and behavioral and biological health indicators in older adults. *Health Psychol*. 2011;30(4):377-385. https://doi.org/10.1037/a0022826

178. Valtorta NK, Kanaan M, Gilbody S, Hanratty B. Loneliness, social isolation and risk of cardiovascular disease in the English longitudinal study of ageing. *Eur J Prev Cardiol*. 2018;25(13):1387-1396. https://doi.org/10.1177/2047487318792696

179. Roddick CM, Chen FS. Effects of chronic and state loneliness on heart rate variability in women. *Ann Behav Med*. 2021;55(5):460-475. https://doi.org/10.1093/abm/kaaa065

180. Brown EG, Gallagher S, Creaven AM. Loneliness and acute stress reactivity: a systematic review of psychophysiological studies. *Psychophysiology*. 2018;55(5):e13031. https://doi.org/10.1111/psyp.13031

181. Welch V, Ghogomu ET, Barbeau VI, et al. Digital interventions to reduce social isolation and loneliness in older adults: an evidence and gap map. *Campbell Syst Rev*. 2023;19(4):e1369. https://doi.org/10.1002/cl2.1369

182. Welch V, Ghogomu ET, Dowling S, et al. In-person interventions to reduce social isolation and loneliness: an evidence and gap map. *Campbell Syst Rev*. 2024;20(2):e1408. https://doi.org/10.1002/cl2.1408

183. Berkman LF, Blumenthal J, Burg M, et al. Effects of treating depression and low perceived social support on clinical events after myocardial infarction: the enhancing recovery in coronary heart disease patients (ENRICHD) randomized trial. *JAMA*. 2003;289(23):3106-3116. https://doi.org/10.1001/jama.289.23.3106

184. Svec J, Nemmers N, Lee JE, Hwang IJ. Connected but lonely? The role of social networking sites among older adults experiencing isolation and loneliness. *Aging Ment Health*. 2025;29:1-9. https://doi.org/10.1080/13607863.2025.2460089

185. Moody E, Phinney A. A community-engaged art program for older people: fostering social inclusion. *Can J Aging*. 2012;31(1):55-64. https://doi.org/10.1017/S0714980811000596

186. Aiba N, Hotta K, Yokoyama M, et al. Usefulness of pet ownership as a modulator of cardiac autonomic imbalance in patients with diabetes mellitus, hypertension, and/or hyperlipidemia. *Am J Cardiol*. 2012;109(8):1164-1170. https://doi.org/10.1016/j.amjcard.2011.11.055

187. Stasi MF, Amati D, Costa C, et al. Pet-therapy: a trial for institutionalized frail elderly patients. *Arch Gerontol Geriatr Suppl*. 2004;38(9):407-412. https://doi.org/10.1016/j.archger.2004.04.052

188. Gardiner C, Geldenhuys G, Gott M. Interventions to reduce social isolation and loneliness among older people: an integrative review. *Health Soc Care Commun*. 2018;26(2):147-157. https://doi.org/10.1111/hsc.12367

189. Rippon I, Victor CR, Martyr A, et al. Dyadic perspectives on loneliness and social isolation among people with dementia and spousal carers: findings from the IDEAL programme. *Aging Ment Health*. 2024;28(6):891-899. https://doi.org/10.1080/13607863.2023.2286618

190. Wolfe MK, McDonald NC, Holmes GM. Transportation barriers to health care in the United States: findings from the national health interview survey, 1997-2017. *Am J Public Health*. 2020;110(6):815-822. https://doi.org/10.2105/AJPH.2020.305579

191. Keeney T, Jette AM. Individual and environmental determinants of late-life community disability for persons aging with cardiovascular disease. *Am J Phys Med Rehabil*. 2019;98(1):30-34. https://doi.org/10.1097/PHM.0000000000001011

192. Ryvicker M, Bollens-Lund E, Ornstein KA. Driving status and transportation disadvantage among medicare beneficiaries. *J Appl Gerontol*. 2018;39(9):935. https://doi.org/10.1177/0733464818806834

193. Erskine NA, Gandek B, Tran HV, et al. Barriers to healthcare access and to improvements in health-related quality of life after an acute coronary syndrome (from TRACE-CORE). *Am J Cardiol*. 2018;122(7):1121-1127. https://doi.org/10.1016/j.amjcard.2018.06.043

194. Fukuei T, Akaida S, Taniguchi Y, et al. Associations between driving status, frequency of transport use after driving cessation, and social frailty among middle-aged and older adults. *Ann Geriatr Med Res*. 2024;28(4):437-444. https://doi.org/10.4235/agmr.24.0071

195. Syed ST, Gerber BS, Sharp LK. Traveling towards disease: transportation barriers to health care access. *J Commun Health*. 2013;38(5):976-993. https://doi.org/10.1007/s10900-013-9681-1

196. Labban M, Chen CR, Frego N, et al. Disparities in travel-related barriers to accessing health care from the 2017 national household travel survey. *JAMA Netw Open*. 2023;6(7):e2325291. https://doi.org/10.1001/jamanetworkopen.2023.25291

197. Acquah I, Hagan K, Valero-Elizondo J, et al. Delayed medical care due to transportation barriers among adults with atherosclerotic cardiovascular disease. *Am Heart J*. 2022;245:60-69. https://doi.org/10.1016/j.ahj.2021.11.019

198. Jahangir S, Bailey A, Hasan MU, Hossain S, Helbich M, Hyde M. "When I need to travel, I feel feverish": everyday experiences of transport inequalities among older adults in Dhaka, Bangladesh. *Gerontologist*. 2022;62(4):493-503. https://doi.org/10.1093/geront/gnab103

199. Remillard ET, Campbell ML, Koon LM, Rogers WA. Transportation challenges for persons aging with mobility disability: qualitative insights and policy implications. *Disabil Health J*. 2022;15(1S):101209. https://doi.org/10.1016/j.dhjo.2021.101209

200. Abdul Latiff AR, Mohd S. Transport, mobility and the wellbeing of older adults: an exploration of private chauffeuring and companionship services in Malaysia. *Int J Environ Res Public Health*. 2023;20(3):2720. https://doi.org/10.3390/ijerph20032720

201. Lin D, Cui J. Transport and mobility needs for an ageing society from a policy perspective: review and implications. *Int J Environ Res Public Health*. 2021;18(22):11802. https://doi.org/10.3390/ijerph182211802

202. Summers P, Chao E, McCoy P, Perry J, Rhodes SD. Influencing public transportation policy through community engagement and coalition building: process and preliminary outcomes. *Prog Commun Health Partnersh*. 2020;14(4):489-498. https://doi.org/10.1353/cpr.2020.0054

203. Onyekere C, Ross S, Namba A, Ross JC, Mann BD. Medical student volunteerism addresses patients' social needs: a novel approach to patient-centered care. *Ochsner J*. 2016;16(1):45-49.

204. American College of Cardiology. Older adults and heart disease - more information | CardioSmart—American college of cardiology. CardioSmart. Accessed June 27, 2025. https://www.cardiosmart.org/topics/older-adults-and-heart-disease/more-information

205. Ornstein KA, Leff B, Covinsky K, et al. The epidemiology of the homebound in the United States. *JAMA Intern Med*. 2015;175(7):1180–1186. https://doi.org/10.1001/jamainternmed.2015.1849

206. Ankuda CK, Leff B, Ritchie CS, Siu AL, Ornstein KA. Association of the COVID-19 pandemic with the prevalence of homebound older adults in the United States, 2011-2020. *JAMA Intern Med*. 2021;181(12):1658–1660. https://doi.org/10.1001/jamainternmed.2021.4456

207. Leff B, Ritchie C, Szanton S, et al. Epidemiology of homebound population among beneficiaries of a large national medicare advantage plan. *Ann Intern Med*. 2024;177(9):1199–1208. https://doi.org/10.7326/M24-0011

208. Choi NG, Sullivan JE, Marti CN. Low-income homebound older adults receiving home-delivered meals: physical and mental health conditions, incidence of falls and hospitalisations. *Health Soc Care Commun*. 2019;27(4):e406–e416. https://doi.org/10.1111/hsc.12741

209. Qiu WQ, Dean M, Liu T, et al. Physical and mental health of homebound older adults: an overlooked population. *J Am Geriatr Soc*. 2010;58(12):2423–2428. https://doi.org/10.1111/j.1532-5415.2010.03161.x

210. Sakurai R, Yasunaga M, Nishi M, et al. Co-existence of social isolation and homebound status increase the risk of all-cause mortality. *Int Psychogeriatr*. 2019;31(5):703–711. https://doi.org/10.1017/S1041610218001047

211. Soones T, Federman A, Leff B, Siu AL, Ornstein K. Two-year mortality in homebound older adults: an analysis of the national health and aging trends study. *J Am Geriatr Soc*. 2017;65(1):123–129. https://doi.org/10.1111/jgs.14467

212. Golden AG, Preston RA, Barnett SD, Llorente M, Hamdan K, Silverman MA. Inappropriate medication prescribing in homebound older adults. *J Am Geriatr Soc*. 1999;47(8):948–953. https://doi.org/10.1111/j.1532-5415.1999.tb01289.x

213. Musich S, Wang SS, Hawkins K, Yeh CS. Homebound older adults: prevalence, characteristics, health care utilization and quality of care. *Geriatr Nurs*. 2015;36(6):445–450. https://doi.org/10.1016/j.gerinurse.2015.06.013

214. Ornstein KA, Garrido MM, Bollens-Lund E, et al. The association between income and incident homebound status among older medicare beneficiaries. *J Am Geriatr Soc*. 2020;68(11):2594–2601. https://doi.org/10.1111/jgs.16715

215. Kalicki AV, Moody KA, Franzosa E, Gliatto PM, Ornstein KA. Barriers to telehealth access among homebound older adults. *J Am Geriatr Soc*. 2021;69(9):2404–2411. https://doi.org/10.1111/jgs.17163

216. Lindenfeld Z, Berry C, Albert S, et al. Synchronous home-based telemedicine for primary care: a review. *Med Care Res Rev*. 2023;80(1):3–15. https://doi.org/10.1177/10775587221093043

217. Zimbroff RM, Ornstein KA, Sheehan OC. Home-based primary care: a systematic review of the literature, 2010-2020. *J Am Geriatr Soc*. 2021;69(10):2963–2972. https://doi.org/10.1111/jgs.17365

218. DeCherrie LV, Wardlow L, Ornstein KA, et al. Hospital at home services: an inventory of fee-for-service payments to inform medicare reimbursement. *J Am Geriatr Soc*. 2021;69(7):1982–1992. https://doi.org/10.1111/jgs.17140

219. Reckrey JM, Zhao D, Stone RI, Ritchie CS, Leff B, Ornstein KA. Use of home-based clinical care and long-term services and supports among homebound older adults. *J Am Med Dir Assoc*. 2023;24(7):1002–1006.e2. https://doi.org/10.1016/j.jamda.2023.03.016

220. Brown L, Cambron C, Post WS, Brandt EJ. The role of social determinants of health in atherosclerotic cardiovascular disease. *Curr Atheroscler Rep*. 2024;26(9):451–461. https://doi.org/10.1007/s11883-024-01226-2

221. Tremblay JO, Nahodyl L, Mesa RA, Vilchez L, Elfassy T. Low income and education are associated with greater ASCVD risk scores among adults in the US. *Prev Med Rep*. 2024;41:102720. https://doi.org/10.1016/j.pmedr.2024.102720

222. Aggarwal R, Yeh RW, Joynt Maddox KE, Wadhera RK. Cardiovascular risk factor prevalence, treatment, and control in US adults aged 20 to 44 years, 2009 to March 2020. *JAMA*. 2023;329(11):899–909. https://doi.org/10.1001/jama.2023.2307

223. Lu Y, Liu Y, Dhingra LS, et al. National trends in racial and ethnic disparities in use of recommended therapies in adults with atherosclerotic cardiovascular disease, 1999-2020. *JAMA Netw Open*. 2023;6(12):e2345964. https://doi.org/10.1001/jamanetworkopen.2023.45964

224. Pinheiro LC, Reshetnyak E, Sterling MR, Levitan EB, Safford MM, Goyal P. Multiple vulnerabilities to health disparities and incident heart failure hospitalization in the REGARDS study. *Circ Cardiovasc Qual Outcomes*. 2020;13(8):e006438. https://doi.org/10.1161/CIRCOUTCOMES.119.006438

225. Logan JG, Barksdale DJ. Allostasis and allostatic load: expanding the discourse on stress and cardiovascular disease. *J Clin Nurs*. 2008;17(7B):201–208. https://doi.org/10.1111/j.1365-2702.2008.02347.x

226. Morris A, Shah KS, Enciso JS, et al. The impact of health care disparities on patients with heart failure. *J Card Fail*. 2022;28(7):1169–1184. https://doi.org/10.1016/j.cardfail.2022.04.008

227. Zhang DT, Onyebeke C, Nahid M, et al. Social determinants of health and cardiologist involvement in the care of adults hospitalized for heart failure. *JAMA Netw Open*. 2023;6(11):e2344070. https://doi.org/10.1001/jamanetworkopen.2023.44070

228. Levesque JF, Harris MF, Russell G. Patient-centred access to health care: conceptualising access at the interface of health systems and populations. *Int J Equity Health*. 2013;12:18. https://doi.org/10.1186/1475-9276-12-18

229. Jonkman NH, Westland H, Groenwold RHH, et al. Do self-management interventions work in patients with heart failure? An individual patient data meta-analysis. *Circulation*. 2016;133(12):1189–1198. https://doi.org/10.1161/CIRCULATIONAHA.115.018006

230. White-Williams C, Rossi LP, Bittner VA, et al. Addressing social determinants of health in the care of patients with heart failure: a scientific statement from the American Heart Association. *Circulation*. 2020;141(22):e841–e863. https://doi.org/10.1161/CIR.0000000000000767

231. Buck HG, Stromberg A, Chung ML, et al. A systematic review of heart failure dyadic self-care interventions focusing on intervention components, contexts, and outcomes. *Int J Nurs Stud*. 2018;77:232–242. https://doi.org/10.1016/j.ijnurstu.2017.10.007

232. Smith CE, Piamjariyakul U, Wick JA, et al. Multidisciplinary group clinic appointments: the self-management and care of heart failure (SMAC-HF) trial. *Circ Heart Fail*. 2014;7(6):888–894. https://doi.org/10.1161/CIRCHEARTFAILURE.113.001246

233. Dunbar SB, Clark PC, Reilly CM, et al. A trial of family partnership and education interventions in heart failure. *J Card Fail*. 2013;19(12):829–841. https://doi.org/10.1016/j.cardfail.2013.10.007

234. DeWalt DA, Malone RM, Bryant ME, et al. A heart failure self-management program for patients of all literacy levels: a randomized, controlled trial [ISRCTN11535170]. *BMC Health Serv Res*. 2006;6:30. https://doi.org/10.1186/1472-6963-6-30

235. Naylor MD, Brooten DA, Campbell RL, Maislin G, McCauley KM, Schwartz JS. Transitional care of older adults hospitalized with heart failure: a randomized, controlled trial. *J Am Geriatr Soc*. 2004;52(5):675–684. https://doi.org/10.1111/j.1532-5415.2004.52202.x

236. Breathett K, Lewsey S, Brownell NK, et al. Implementation science to achieve equity in heart failure care: a scientific statement from the American Heart Association. *Circulation*. 2024;149(19):e1143–e1163. https://doi.org/10.1161/CIR.0000000000001231

237. Damluji AA, Bernacki G, Afilalo J, et al. TAVR in older adults: moving toward a comprehensive geriatric assessment and away from chronological age: JACC family series. *JACC Adv*. 2024;3(4):100877. https://doi.org/10.1016/j.jacadv.2024.100877

238. Myasoedova VA, Di Minno A, Songia P, et al. Sex-specific differences in age-related aortic valve calcium load: a systematic review and meta-analysis. *Ageing Res Rev*. 2020;61:101077. https://doi.org/10.1016/j.arr.2020.101077

239. Ilonze O, Free K, Shinnerl A, Lewsey S, Breathett K. Racial, ethnic, and gender disparities in valvular heart failure management. *Heart Fail Clin*. 2023;19(3):379–390. https://doi.org/10.1016/j.hfc.2023.02.009

240. Damluji AA, Fabbro M, Epstein RH, et al. Transcatheter aortic valve replacement in low-population density areas: assessing healthcare access for older adults with severe aortic stenosis. *Circ Cardiovasc Qual Outcomes*. 2020;13(8):

e006245. https://doi.org/10.1161/CIRCOUTCOMES.119.006245

241. Sleder A, Tackett S, Cerasale M, et al. Socioeconomic and racial disparities: a case-control study of patients receiving transcatheter aortic valve replacement for severe aortic stenosis. *J Racial Ethn Health Disparities*. 2017;4(6):1189-1194. https://doi.org/10.1007/s40615-016-0325-x

242. Kundi H, Cohen DJ, Leon MB, et al. Trends and late outcomes in elderly patients undergoing mitral valve interventions in the United States. *JACC: Cardiovasc Interv*. 2025;18(18):2241-2252. https://doi.org/10.1016/j.jcin.2025.06.041

243. Frost L, Johnsen SP, Benjamin EJ, Trinquart L, Vinter N. Social drivers in atrial fibrillation occurrence, screening, treatment, and outcomes: systematic-narrative hybrid review. *Eur Heart J Suppl*. 2024;26(Suppl 4):iv50-iv60. https://doi.org/10.1093/eurheartjsupp/suae073

244. Benjamin EJ, Thomas KL, Go AS, et al. Transforming atrial fibrillation research to integrate social determinants of health: a national heart, lung, and blood institute workshop report. *JAMA Cardiol*. 2023;8(2):182-191. https://doi.org/10.1001/jamacardio.2022.4091

245. Li H, Song X, Liang Y, et al. Global, regional, and national burden of disease study of atrial fibrillation/flutter, 1990-2019: results from a global burden of disease study, 2019. *BMC Public Health*. 2022;22(1):2015. https://doi.org/10.1186/s12889-022-14403-2

246. Wändell P, Carlsson AC, Li X, Gasevic D, Sundquist J, Sundquist K. The association between sociodemographic characteristics and dementia in patients with atrial fibrillation. *Aging Clin Exp Res*. 2020;32(11):2319-2327. https://doi.org/10.1007/s40520-019-01449-3

247. Essien UR, McCabe ME, Kershaw KN, et al. Association between neighborhood-level poverty and incident atrial fibrillation: a retrospective cohort study. *J Gen Intern Med*. 2022;37(6):1436-1443. https://doi.org/10.1007/s11606-021-06976-2

248. Mou L, Norby FL, Chen LY, et al. Lifetime risk of atrial fibrillation by race and socioeconomic status. *Circ: Arrhythm Electrophysiol*. 2018;11(7):e006350. https://doi.org/10.1161/CIRCEP.118.006350

249. Rodriguez CJ, Soliman EZ, Alonso A, et al. Atrial fibrillation incidence and risk factors in relation to race-ethnicity and the population attributable fraction of atrial fibrillation risk factors: the multi-ethnic study of atherosclerosis. *Ann Epidemiol*. 2015;25(2):71-76. https://doi.org/10.1016/j.annepidem.2014.11.024

250. Feinberg WM, Blackshear JL, Laupacis A, Kronmal R, Hart RG. Prevalence, age distribution, and gender of patients with atrial fibrillation. Analysis and implications. *Arch Intern Med*. 1995;155(5):469-473.

251. Engdahl J, Holmén A, Svennberg E, et al. Geographic and socio-demographic differences in uptake of population-based screening for atrial fibrillation: the STROKESTOP I study. *Int J Cardiol*. 2016;222:430-435. https://doi.org/10.1016/j.ijcard.2016.07.198

252. Gudmundsdottir KK, Holmen A, Fredriksson T, et al. Decentralising atrial fibrillation screening to overcome socio-demographic inequalities in uptake in STROKESTOP II. *J Med Screen*. 2021;28(1):3-9. https://doi.org/10.1177/0969141320908316

253. Savickas V, Stewart AJ, Rees-Roberts M, et al. Opportunistic screening for atrial fibrillation by clinical pharmacists in UK general practice during the influenza vaccination season: a cross-sectional feasibility study. *PLOS Med*. 2020;17(7):e1003197. https://doi.org/10.1371/journal.pmed.1003197

254. Guo Y, Wang H, Zhang H, et al. Mobile photoplethysmographic technology to detect atrial fibrillation. *J Am Coll Cardiol*. 2019;74(19):2365-2375. https://doi.org/10.1016/j.jacc.2019.08.019

255. Ravvaz K, Weissert JA, Jahangir A, Ruff CT. Evaluating the effects of socioeconomic status on stroke and bleeding risk scores and clinical events in patients on oral anticoagulant for new onset atrial fibrillation. *PLOS ONE*. 2021;16(3):e0248134. https://doi.org/10.1371/journal.pone.0248134

256. Essien UR, Chiswell K, Kaltenbach LA, et al. Association of race and ethnicity with oral anticoagulation and associated outcomes in patients with atrial fibrillation: findings from the get with the guidelines-atrial fibrillation registry. *JAMA Cardiol*. 2022;7(12):1207-1217. https://doi.org/10.1001/jamacardio.2022.3704

257. Dalmau Llorca MR, Aguilar Martín C, Carrasco-Querol N, et al. Gender and socioeconomic inequality in the prescription of direct oral anticoagulants in patients with non-valvular atrial fibrillation in primary care in Catalonia (Fantas-TIC study). *Int J Environ Res Public Health*. 2021;18(20):10993. https://doi.org/10.3390/ijerph182010993

258. Reynolds KR, Khosrow-Khavar F, Dave CV. Racial and ethnic disparities in initiation of direct oral anticoagulants among medicare beneficiaries. *JAMA Netw Open*. 2024;7(5):e249465. https://doi.org/10.1001/jamanetworkopen.2024.9465

259. Reddy KP, Eberly LA, Halaby R, et al. Racial, ethnic, and socioeconomic inequities in access to left atrial appendage occlusion. *J Am Heart Assoc*. 2023;12(5):e028032. https://doi.org/10.1161/JAHA.122.028032

260. Troy AL, Herzig SJ, Trivedi S, Anderson TS. Initiation of oral anticoagulation in US older adults newly diagnosed with atrial fibrillation during hospitalization. *J Am Geriatr Soc*. 2023;71(9):2748-2758. https://doi.org/10.1111/jgs.18375

261. Cressman AM, Macdonald EM, Yao Z, et al. Socioeconomic status and risk of hemorrhage during warfarin therapy for atrial fibrillation: a population-based study. *Am Heart J*. 2015;170(1):133-140. https://doi.org/10.1016/j.ahj.2015.03.014

262. Isakadze N, Horstman NA, Ding J, et al. Patient centered mobile health technology enabled atrial fibrillation management (mTECH afib): a pilot randomized controlled trial. *JACC: Clin Electrophysiol*. 2025;11(6):1251-1262. https://doi.org/10.1016/j.jacep.2025.02.015

263. Boursiquot BC, Jackson LR II, Essien UR. Advancing pharmacoequity in atrial fibrillation—the case for direct oral anticoagulants. *JAMA Netw Open*. 2024;7(5):e249403. https://doi.org/10.1001/jamanetworkopen.2024.9403

264. Navar-Boggan AM, Rymer JA, Piccini JP, et al. Accuracy and validation of an automated electronic algorithm to identify patients with atrial fibrillation at risk for stroke. *Am Heart J*. 2015;169(1):39-44.e2. https://doi.org/10.1016/j.ahj.2014.09.014

265. Guo Y, Lane DA, Wang L, et al. Mobile health technology to improve care for patients with atrial fibrillation. *J Am Coll Cardiol*. 2020;75(13):1523-1534. https://doi.org/10.1016/j.jacc.2020.01.052

266. Satti DI, Chan JSK, Weinstein R, et al. Social determinants of health and disparities in diagnosis-to-ablation time for atrial fibrillation. *JACC Clin Electrophysiol*. 2025. https://doi.org/10.1016/j.jacep.2025.07.006

267. Zörner CR, Tønnesen J, Riis-Vestergaard LD, et al. Disparities in the access to atrial fibrillation ablation in Denmark: who gets ablated, who neglected? *EP Europace*. 2024;26(9):euae231. https://doi.org/10.1093/europace/euae231

268. Olsen F, Uleberg B, Jacobsen BK, et al. Socioeconomic and geographic differences in ablation of atrial fibrillation in Norway - a national cohort study. *BMC Public Health*. 2022;22(1):303. https://doi.org/10.1186/s12889-022-12628-9

269. Duke JM, Muhammad LN, Song J, et al. Racial disparity in referral for catheter ablation for atrial fibrillation at a single integrated health system. *J Am Heart Assoc*. 2022;11(18):e025831. https://doi.org/10.1161/JAHA.122.025831

270. Hagengaard L, Andersen MP, Polcwiartek C, et al. Socioeconomic differences in outcomes after hospital admission for atrial fibrillation or flutter. *Eur Heart J Qual Care Clin Outcomes*. 2021;7(3):295-303. https://doi.org/10.1093/ehjqcco/qcz053

271. Garg K, Satti DI, Yadav R, et al. Global health inequities in electrophysiology care. *JACC: Adv*. 2024;3(12_Part_2):101387. https://doi.org/10.1016/j.jacadv.2024.101387

272. Thomas KL, Garg J, Velagapudi P, et al. Racial and ethnic disparities in arrhythmia care: a call for action. *Heart Rhythm*. 2022;19(9):1577-1593. https://doi.org/10.1016/j.hrthm.2022.06.001

KEY WORDS atherosclerotic cardiovascular disease, atrial fibrillation, cardiovascular aging, geriatric cardiology, health policy, heart failure, implementation science, population health, preventive cardiology, social determinants of health, valvular heart disease