

Equity and Representation in Cardiovascular Imaging: A Scientific Imperative, Not an Ideological One

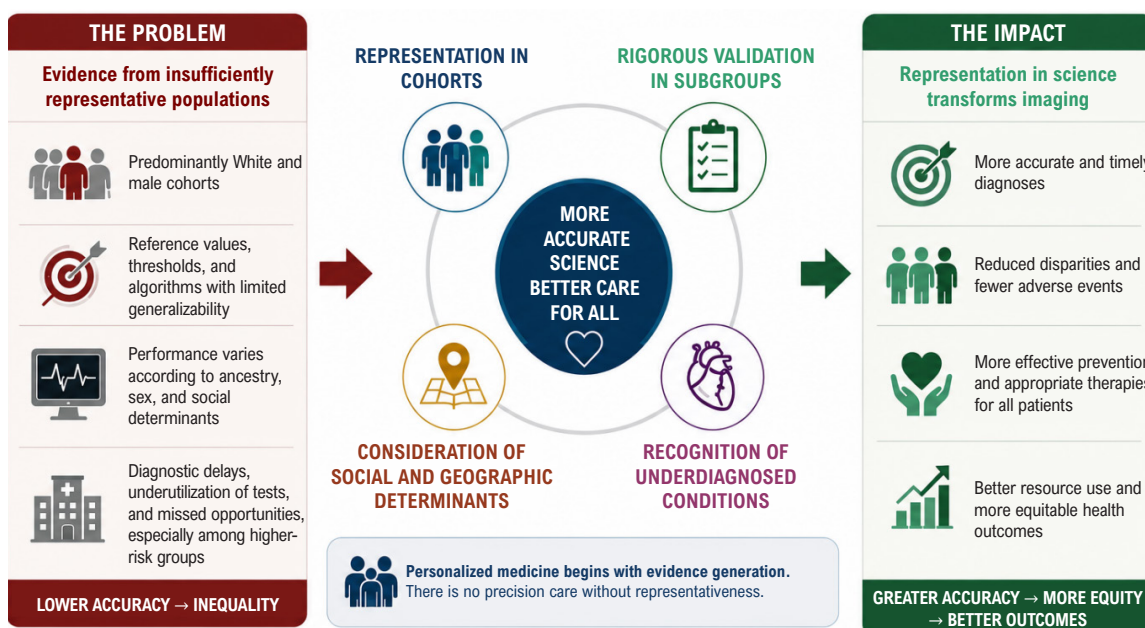
Enzo Crispino Calheiros,¹ Julia Schettini Veloso,¹ Antonildes Nascimento Assunção Junior,^{1,2} José Arimateia Batista Araujo-Filho^{1,3}

Hospital Sírio-Libanês,¹ São Paulo, SP – Brazil

Universidade de São Paulo, Instituto do Coração,² São Paulo, SP – Brazil

Grupo Fleury,³ São Paulo, SP – Brazil

Central Illustration: Equity and Representation in Cardiovascular Imaging: A Scientific Imperative, Not an Ideological One



Arq Bras Cardiol: Imagem cardiovasc. 2026;39(3):e20260094

Abstract

Much of cardiovascular medicine has been built on evidence derived from predominantly White, male cohorts that do not reflect the diversity of the patient population. Consequently, reference values, devices, and algorithms may exhibit variable accuracy across groups, thereby compromising diagnostic precision. From the perspective

of cardiovascular imaging, this review examines how underrepresentation in research translates into diagnostic inequities. We discuss scenarios where representation alters what imaging reveals: transthyretin amyloidosis associated with the Val142Ile variant in older adults of African ancestry, cardiopulmonary manifestations of sickle cell disease, and conditions that predominantly affect women, including ischemia with non-obstructive coronary arteries (INOCA) and takotsubo syndrome. We also address bias in devices and algorithms, exemplified by pulse oximetry and artificial intelligence models trained on datasets lacking diversity. Finally, we propose an agenda centered on ensuring representation in normative cohorts, subgroup validation, and the equitable implementation of novel technologies.

Keywords

Equity; Diagnostic Imaging; Bias; Algorithms

Mailing Address: José Arimateia Batista Araujo-Filho •

Hospital Sírio-Libanês. Adma Jafet. Postal code: 01308-050. São Paulo, SP – Brazil

E-mail: ariaraujocg@gmail.com

Manuscript received July 26, 2026; revised July 27, 2026;

accepted July 27, 2026

Editor responsible for the review: Marcelo Tavares

DOI: <https://doi.org/10.36660/abcimg.20260094>

Introduction

Although changes in the therapeutic and diagnostic landscape of contemporary cardiology have brought

undeniable advances, they have also exposed a structural limitation in the knowledge upon which we have historically built our practice. Many of the reference values, diagnostic thresholds, algorithms, and even the devices at our disposal were calibrated based on predominantly White, male cohorts, which do not reflect the diversity of patients we treat. A test whose accuracy varies according to a patient's sex, ancestry, or race is, first and foremost, a less precise test, and this imprecision harms everyone.

In this context, considering equity and representation in cardiovascular imaging research and practice is not a concession to any particular ideological agenda, but rather a requirement of ethical commitment and scientific rigor. After all, equity does not compete with scientific precision; it stems from it. Here, we review some of the key issues highlighted in the recent literature.

The documented burden of disparities

Disparities in cardiovascular disease outcomes have been widely documented and directly linked to persistent inequities in access to health care worldwide, affecting populations that have historically been underrepresented in various population-based studies (Central Illustration).

Black individuals experience higher cardiovascular mortality and a substantially elevated risk of recurrent events; these disparities persist after adjusting for clinical factors and have been largely attributed to social determinants and unequal access to health care.¹⁻³ For cardiologists and cardiovascular imaging specialists, these statistics are not merely a distant backdrop; they translate into diagnostic delays, underutilization of advanced imaging, and missed opportunities for prevention strategies, populations at greater risk and vulnerability.

Such disparities are likewise not randomly distributed geographically. Place of residence, imperfectly yet revealingly summarized by ZIP code, serves as a marker of environmental exposure, socioeconomic conditions, and access to health care, to the extent that ZIP code-based analyses can predict cardiovascular outcomes better than clinical data alone.^{4,5} In a population-based cohort, a neighborhood disadvantage index alone accounted for 32% of the variation in adverse coronary artery disease events across neighborhoods, compared with only 10% accounted for by the clinical risk model.⁴ Recognizing the relationship between where one lives and risk factors has led to the incorporation of geographic factors into risk stratification tools: the American Heart Association's PREVENT calculator includes an optional ZIP code-based component to capture neighborhood socioeconomic status and refine risk prediction beyond traditional biological factors.⁶ The lesson for cardiovascular imaging is analogous: The determinants that shape who falls ill and who has access to imaging must be considered during both the indication and interpretation phases; if we fail to do so, we run the risk of reproducing in our reports the inequalities that were established long before the images were acquired.

When representation changes diagnosis

Some practical scenarios illustrate how the representation of factors such as race, ancestry, and sex can influence what cardiovascular imaging methods are capable of revealing.

Hereditary transthyretin cardiac amyloidosis associated with the Val142Ile variant (formerly Val122Ile) is an underdiagnosed cause of heart failure in older Black adults; the allele is present in approximately 3% to 4% of people of African descent in the United States, but it is practically absent among White individuals.^{7,8} It is worth noting that the frequency of this variant tracks with genetic ancestry (specifically West African ancestry) rather than race as a social category; in this case, self-identified race serves as an imperfect marker of ancestry. For decades, these patients were labeled as having hypertensive heart failure or heart failure with preserved ejection fraction of undetermined origin, precisely because this specific condition was not considered. Imaging has changed this landscape, as bone-seeking radiotracer scintigraphy, subendocardial late gadolinium enhancement, and elevated extracellular volume on T1 mapping (via cardiac magnetic resonance imaging) now enable noninvasive diagnosis. In this context, the SCAN-MP study was intentionally designed to screen for cardiac amyloidosis using nuclear imaging in Black and Hispanic populations with heart failure, an explicit recognition that representativeness in imaging research is essential for diagnosing conditions that previously went undetected.⁹ Ignoring these population did not by any means make the disease rare; instead, it merely kept it invisible.

Sickle cell disease provides a second example. Among patients with this disease, which predominantly affects individuals of African descent, cardiopulmonary complications, such as pulmonary hypertension, diastolic dysfunction, and sudden death, are the leading causes of mortality in adulthood.^{10,11} Here, too, imaging has played a decisive role in clinical decision-making, since cardiac magnetic resonance imaging studies have shown that these patients develop a distinctive restrictive cardiomyopathy characterized by atrial dilation and restrictive physiology. This phenotype was only understood once the population was studied using appropriate imaging tools.^{12,13} Cardiovascular research historically neglected these patients; had it continued to do so, we would still lack the valuable diagnostic framework needed to interpret these findings to this day.

Gender and sex provide an equally instructive perspective. For decades, ischemic heart disease was studied and defined based on the male pattern of epicardial obstruction, while mechanisms that are predominate in women were largely overlooked. Ischemia and myocardial infarction with non-obstructive coronary arteries (INOCA and MINOCA) clearly illustrate this issue. An analysis of the ISCHEMIA trial revealed that INOCA was approximately four times more common in women than in men (odds ratio of 4.2 [95% confidence interval 3.4–5.2] for women in the multivariable analysis).¹⁴ Because conventional angiography cannot visualize microcirculation, these conditions were long interpreted as non-cardiac chest pain. Today, functional imaging, including Positron Emission Tomography (PET)-based assessment of coronary flow and cardiac magnetic resonance perfusion and mapping, makes the underlying. In MINOCA, conversely, mechanisms such

as plaque rupture or erosion, spontaneous coronary artery dissection and spasm predominate, the elucidation of which relies on modalities such as cardiac magnetic resonance and intracoronary imaging.

A similar phenomenon is observed in Takotsubo syndrome, a condition predominantly affecting post-menopausal women, who account for nearly 90% of cases in an international registry.¹⁵ Recognition of this syndrome depends on patterns of ventricular ballooning identified via ventriculography, echocardiography, and cardiac magnetic resonance imaging; therefore, in this disease as well, what is observed depends on what we have decided to look for.

Bias in devices and algorithms

The third area of concern, perhaps the most urgent in the era of quantitative imaging and artificial intelligence, lies in bias embedded within devices and algorithms.

The case of pulse oximetry has become emblematic, as Black patients are approximately three times more likely to have undetected occult hypoxemia due to the interference of skin pigmentation with device readings.¹⁶ The parallel with cardiovascular imaging is direct. Artificial intelligence models trained on datasets lacking diversity tend to define what is “normal” and “abnormal” based on a narrow population and may exhibit systematic errors when applied to groups that were underrepresented in the training data.¹ Technically, these are classified as representation and aggregation biases, which have been described among the main mechanisms limiting the generalizability of artificial intelligence models in health care.¹⁷ Normative values for myocardial thickness, strain, extracellular volume, or coronary calcium scores derived from homogeneous cohorts risk misclassifying patients whose underlying physiology remains understudied. A prime example in cardiovascular imaging involves a deep learning model for cardiac magnetic resonance image segmentation that, having been trained predominantly on White individuals, exhibited consistently inferior performance in Black and mixed-race patients prior to bias-mitigation strategies.¹⁸

Diversity in training datasets is necessary, but not sufficient. Models also require external validation across distinct populations and continuous monitoring after implementation. An algorithm is only as equitable as the data on which it was trained and only as reliable as the population in which it was validated. Cardiovascular imaging, which is increasingly reliant on automated measurements, must address this limitation in a transparent manner.

From description to action: an agenda for cardiovascular imaging

It is worth clarifying a frequent misunderstanding here. Studying neglected populations is neither a favor to a specific group nor an exercise in political correctness, but rather a scientific strategy that expands knowledge applicable to all people.

It was only by investigating the Val142Ile variant in Black patients that our understanding of transthyretin amyloidosis as a whole was refined. Wild-type transthyretin amyloidosis is

now recognized as a condition affecting older patients across diverse ancestral backgrounds. The study of sickling led to the characterization of a restrictive cardiomyopathy phenotype whose relevance extends beyond that specific disease. Science that excludes populations does not become more neutral; it becomes poorer, less generalizable, and less precise. After all, personalized medicine begins before treatment: it begins with generating evidence.

Recognizing disparities is merely the first step; the contemporary challenge lies in moving from description to action. A recent joint editorial by the American College of Cardiology, the American Heart Association, the European Society of Cardiology, and the World Heart Federation proposes exactly this shift, framing health equity not as a politicized agenda, but as a scientific frontier in cardiovascular medicine that warrants the same rigor applied to any other field.¹⁹ For our cardiovascular imaging community, this framing translates into concrete commitments.

The first is ensuring the representativeness of the cohorts that define normal values. Whenever biologically plausible and clinically relevant, reference values for myocardial thickness, strain, T1 mapping, extracellular volume, coronary calcium scores, and echocardiographic parameters should be established and reported across diverse populations in terms of ancestry and sex, so that the concept of “normal” is not derived from a narrow sample.

The second is validation of devices and algorithms across subgroups. Much like the lessons learned from pulse oximetry, imaging tools and artificial intelligence models should demonstrate consistent performance across groups prior to adoption, with explicit reporting of accuracy based on relevant variables such as race, ancestry, sex, and skin tone, rather than assuming generalizability based on homogeneous training data. This assessment must include external validation and post-implementation monitoring, as performance observed in one cohort does not guarantee reproducibility in another. This effort should be structured throughout the model's lifecycle, spanning conception and data collection, preprocessing, validation, deployment, and post-deployment monitoring. Furthermore, subgroup performance must always be evaluated using explicit fairness metrics, such as demographic parity and equal opportunity.¹⁷

The third encompasses education and diagnostic vigilance. It is crucial to incorporate into the training of cardiologists and radiologists the recognition of conditions that historical homogeneity has kept in the shadows, such as transthyretin amyloidosis in older Black adults and the cardiac manifestations of sickle cell disease, as well as the routine consideration of geographic and social determinants of access when ordering and interpreting tests.

Last comes implementation. Strategies such as telemedicine, abbreviated protocols, and lower-cost technologies have the potential to bring advanced imaging closer to historically underserved populations, provided they are designed with equity in mind, so that innovation will narrow, rather than widen, the gap between those who benefit and those who remain marginalized.¹⁹ A caveat regarding scope is warranted: the framework of disparities discussed herein relies largely on

evidence from North America. Both epidemiological profiles and sociodemographic categories vary across health care systems and populations. In Brazil, for example, the high degree of genetic admixture limits the direct extrapolation of normative values and allele frequencies derived from other cohorts. Moreover, this viewpoint is a perspective article and does not constitute a systematic review of the literature.

Take-home message

Cardiovascular imaging is uniquely positioned to lead the necessary change, as it operates at the frontier between measurable physiology and clinical decision-making. The true measure of its excellence lies not only in the increasing sophistication of its methods but also in its ability to maintain accuracy across the entire population it aims to serve. Better representing human diversity does not mean tailoring science to an external agenda; it means aligning it more closely with the biological and social realities that science seeks to describe. The more diverse the evidence underpinning our methods, the more generalizable the resulting knowledge becomes, and the more precise the care offered to each patient. In this sense, equity is not at odds with scientific excellence; it is one of its most tangible expressions.

Author Contributions

Writing of the manuscript: Calheiros EC, Veloso JS; critical revision of the manuscript for intellectual content: Assunção Junior AN, Araujo-Filho JAB.

References

1. Akinmolayemi O, Sun Y, McClelland RL, Bancks MP, Post WS, Szklo M, et al. Racial Disparities in Incident and Recurrent Cardiovascular Events: The Multi-Ethnic Study of Atherosclerosis. *Am J Epidemiol*. 2025;194(8):2144-9. doi: 10.1093/aje/kwae399.
2. Garcia M, Almuwaqqat Z, Moazzami K, Young A, Lima BB, Sullivan S, et al. Racial Disparities in Adverse Cardiovascular Outcomes after a Myocardial Infarction in Young or Middle-Aged Patients. *J Am Heart Assoc*. 2021;10(17):e020828. doi: 10.1161/JAHA.121.020828.
3. Bayne J, Garry J, Albert MA. Brief Review: Racial and Ethnic Disparities in Cardiovascular Care with a Focus on Congenital Heart Disease and Precision Medicine. *Curr Atheroscler Rep*. 2023;25(5):189-95. doi: 10.1007/s11883-023-01093-3.
4. Musaogullari A, Moorhead J, Plana A, Johnson A. Space for Improvement: ZIP Codes Should Not Determine Cardiovascular Longevity, a Scoping Review. *Trends Cardiovasc Med*. 2025;35(4):214-8. doi: 10.1016/j.tcm.2024.12.005.
5. Dalton JE, Perzynski AT, Zidar DA, Rothberg MB, Coulton CJ, Milinovich AT, et al. Accuracy of Cardiovascular Risk Prediction Varies by Neighborhood Socioeconomic Position: A Retrospective Cohort Study. *Ann Intern Med*. 2017 Oct 3;167(7):456-64. doi: 10.7326/M16-2543.
6. Khan SS, Matsushita K, Sang Y, Ballew SH, Grams ME, Surapaneni A, et al. Development and Validation of the American Heart Association's PREVENT Equations. *Circulation*. 2024;149(6):430-49. doi: 10.1161/CIRCULATIONAHA.123.067626.
7. Quarta CC, Buxbaum JN, Shah AM, Falk RH, Claggett B, Kitzman DW, et al. The Amyloidogenic V122I Transthyretin Variant in Elderly Black Americans. *N Engl J Med*. 2015;372(1):21-9. doi: 10.1056/NEJMoa1404852.
8. Buxbaum JN, Ruberg FL. Transthyretin V122I (pV142I)* Cardiac Amyloidosis: An Age-Dependent Autosomal Dominant Cardiomyopathy too Common to be Overlooked as a Cause of Significant Heart Disease in Elderly African Americans. *Genet Med*. 2017;19(7):733-42. doi: 10.1038/gim.2016.200.
9. Ruberg FL, Blaner WS, Chiuhan C, Connors LH, Einstein AJ, Fine D, et al. Design and Rationale the SCAN-MP (Screening for Cardiac Amyloidosis with Nuclear Imaging in Minority Populations) Study. *J Am Heart Assoc*. 2023;12(8):e028534. doi: 10.1161/JAHA.122.028534.
10. Ilonze C, Echefu GC, Broadnax AL, Johnson A, Etuk A, Ilonze OJ. Cardiovascular Complications of Sickle Cell Disease: A Primer for the General Clinician. *J Natl Med Assoc*. 2024;116(5):517-25. doi: 10.1016/j.jnma.2023.11.010.
11. Gladwin MT, Sachdev V, Jison ML, Shizukuda Y, Plehn JF, Minter K, et al. Pulmonary Hypertension as a Risk Factor for Death in Patients with Sickle Cell Disease. *N Engl J Med*. 2004;350(9):886-95. doi: 10.1056/NEJMoa035477.
12. Niss O, Quinn CT, Lane A, Daily J, Khoury PR, Bakeer N, et al. Cardiomyopathy with Restrictive Physiology in Sickle Cell Disease. *JACC Cardiovasc Imaging*. 2016;9(3):243-52. doi: 10.1016/j.jcmg.2015.05.013.
13. Wood KC, Gladwin MT, Straub AC. Sickle Cell Disease: At the Crossroads of Pulmonary Hypertension and Diastolic Heart Failure. *Heart*. 2020;106(8):562-8. doi: 10.1136/heartjnl-2019-314810.
14. Reynolds HR, Diaz A, Cyr DD, Shaw LJ, Mancini GBJ, Leipsic J, et al. Ischemia with Nonobstructive Coronary Arteries: Insights from the ISCHEMIA Trial. *JACC Cardiovasc Imaging*. 2023;16(1):63-74. doi: 10.1016/j.jcmg.2022.06.015.

Potential Conflict of Interest

No potential conflict of interest relevant to this article was reported.

Sources of Funding

There were no external funding sources for this study.

Study Association

This study is not associated with any thesis or dissertation work.

Ethics Approval and Consent to Participate

This article does not contain any studies with human participants or animals performed by any of the authors.

Use of Artificial Intelligence

During the preparation of this work, the author(s) used ChatGPT for elaboration of Figure 1. After using this tool/service, the author(s) reviewed and edited the content as needed and take full responsibility for the content of the published article.

Availability of Research Data

The underlying content of the research text is contained within the manuscript.

Review Article

15. Templin C, Ghadri JR, Diekmann J, Napp LC, Bataiosu DR, Jaguszewski M, et al. Clinical Features and Outcomes of Takotsubo (Stress) Cardiomyopathy. *N Engl J Med*. 2015;373(10):929-38. doi: 10.1056/NEJMoa1406761.
16. Sjoding MW, Dickson RP, Iwashyna TJ, Gay SE, Valley TS. Racial Bias in Pulse Oximetry Measurement. *N Engl J Med*. 2020;383(25):2477-8. doi: 10.1056/NEJMc2029240.
17. Hasanzadeh F, Josephson CB, Waters G, Adedinsewo D, Azizi Z, White JA. Bias Recognition and Mitigation Strategies in Artificial Intelligence Healthcare Applications. *NPJ Digit Med*. 2025;8(1):154. doi: 10.1038/s41746-025-01503-7.
18. Puyol-Antón E, Ruijsink B, Piechnik SK, Neubauer S, Petersen SE, Razavi R, et al. Fairness in cardiac MR image analysis: an investigation of bias due to data imbalance in deep learning-based segmentation. *Proceedings of the Medical Image Computing and Computer Assisted Intervention 24th International Conference*; 2021 Sep 27-Oct 1; Strasbourg, France. Part III. Cham: Springer; 2011.
19. Itchhaporia D, Yancy CW, Rosen SE, Mbakwem AC, Münzel T, Timmis A, et al. Cardiovascular Health Equity: Time for a New Era of Science, Sociology, and Interventions: Joint Editorial on Behalf of the American College of Cardiology, the American Heart Association, the European Society of Cardiology, and the World Heart Federation. *J Am Coll Cardiol*. 2026;S0735-1097(26)05225-3. doi: 10.1016/j.jacc.2026.02.4871.



This is an open-access article distributed under the terms of the Creative Commons Attribution License