

## Overview of Professional Practice in Computed Tomography and Cardiac Magnetic Resonance Imaging in Brazil

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### Abstract

**Background:** Non-invasive imaging for cardiovascular disease diagnosis has grown in volume and relevance in recent years, and it is important for early detection of cardiovascular diseases. There is a lack of data from Brazil on the availability of methods such as computed tomography (CT) and cardiac magnetic resonance imaging (CMR).

**Objective:** This study assessed the regional distribution of professional practice and the exams performed, correlating these factors with population data and the number of active professionals.

**Methods:** A nationwide survey was conducted by means of an online questionnaire applied to professionals who perform CT and CMR, compared with demographic data and the number of scans performed within Brazilian public and private healthcare systems.

**Results:** A total of 219 professionals filled out the questionnaire, 139 (63.8%) male, 161 (73.9%) cardiologists, and 46 (21.1%) radiologists. Regarding regional distribution, the Southeast had 125 professionals (57.3%), the Northeast 35 (16.1%), the South 30 (13.8%), the Central-West 22 (10.1%), and the North 6 (2.8%). The profile of these professionals in Brazilian regions was similar, with no statistical differences observed regarding the proportion of men ( $p = 0.2451$ ), cardiologists ( $p = 0.1325$ ), radiologists ( $p = 0.4564$ ), or training time  $> 2$  years ( $p = 0.8519$ ). The Southeast had the highest absolute number of exams, and the North had the lowest.

**Conclusion:** The data revealed structural disparities in access to cardiovascular imaging throughout Brazil, in terms of both number of professionals and number of exams performed. The regional discrepancies observed in this study reflect distinct demographic and economic circumstances in Brazilian regions.

**Keywords:** X-Ray Computed Tomography; Magnetic Resonance Imaging; Cardiovascular Diseases; Unified Health System; Supplemental Health.

### Introduction

Cardiovascular diseases remain the leading cause of mortality worldwide.<sup>1,2</sup> A study conducted in the United States based on data from the National Center for Health Statistics (NCHS) showed a total of 10,951,403 cardiovascular deaths

in adults over 35 years of age from 2010 to 2022.<sup>3</sup> Brazilian data are similar, with cardiovascular mortality accounting for approximately 30% of all deaths in the country.<sup>4</sup> Early and accurate diagnosis is a fundamental part of cardiovascular disease investigation, and it assists in decision-making regarding the most appropriate treatment, thus preventing cardiovascular complications such as infarction, stroke, revascularization, and cardiovascular mortality. Accordingly, advanced imaging methods such as computed tomography (CT) and cardiac magnetic resonance imaging (CMR) have gained prominence worldwide, with exponential growth in recent years.<sup>5</sup>

Advances in devices, contrast media, organization of services, increased clinical applicability of exams, and greater availability have created an extremely favorable scenario for growth in this field. In Brazil, there is a lack of available data

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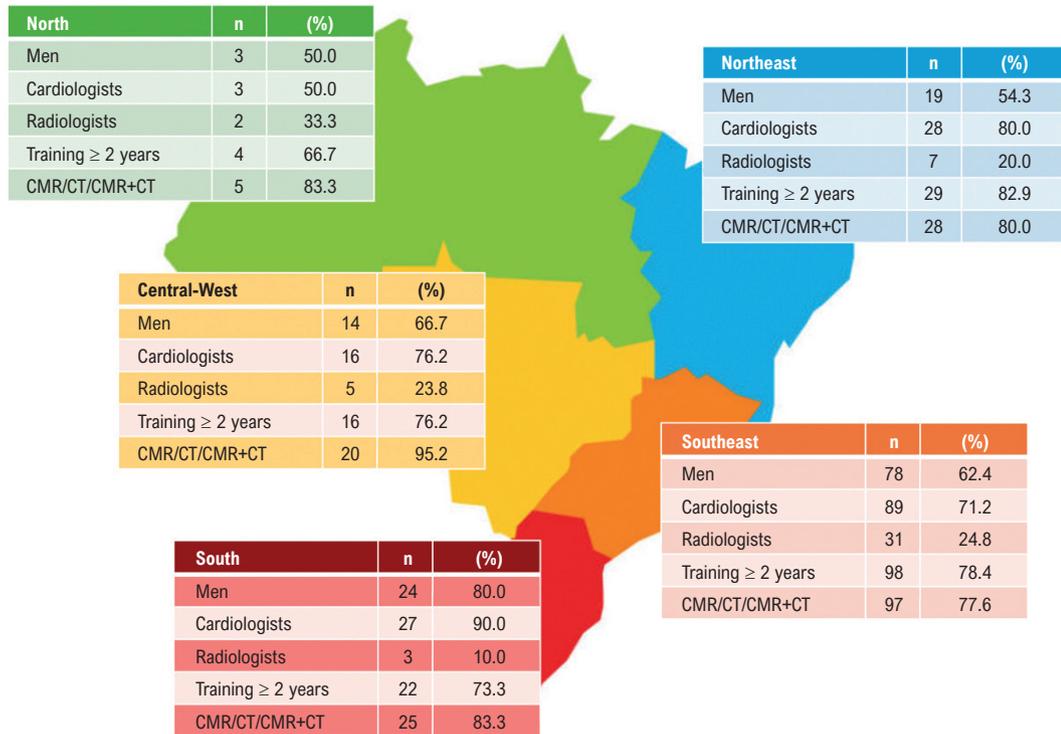
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**Central Illustration: Overview of Professional Practice in Computed Tomography and Cardiac Magnetic Resonance Imaging in Brazil**



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Professional profile by Brazilian region. CMR: cardiac magnetic resonance imaging; CT: computed tomography.

on these exams in the literature. Given Brazil's continental size and population and the heterogeneous nature of healthcare access within both the Brazilian Unified Health System (SUS, acronym in Portuguese) and private health insurance (PHI), it is important to understand distinct Brazilian realities. To this end, a survey of professionals involved in Brazilian cardiovascular imaging was designed.

We believe that this survey makes it possible to identify regions with a shortage of professionals, which will allow for targeted policies to encourage training and qualification, in addition to facilitating the planning of infrastructure investments, for example, installation of advanced equipment in areas with higher demand. Moreover, the survey can help identify gaps in the training profile of professionals, indicating the need to enhance academic curricula and training programs to further align them with current technological and clinical requirements, in accordance with the guidelines of the field, thus developing a comprehensive overview of the Brazilian situation.<sup>6</sup>

## Methods

The objectives of this survey were to identify the profile of medical professionals working in cardiovascular imaging, in 2024, with a focus on CT and CMR; to assess their geographic

distribution in Brazil; to assess the length of training in cardiovascular imaging; and to correlate the data obtained with the number of exams performed through the SUS and PHI in the same year.

This cross-sectional study was conducted by means of an online questionnaire applied to healthcare professionals who perform CT and CMR scans in Brazil. This survey is a partnership between the Department of Cardiovascular Imaging (DIC) of the Brazilian Society of Cardiology (SBC) and the Radiological and Diagnostic Imaging Society of São Paulo (SPR).

The questionnaire consists of the following four questions:

### What is/are your medical specialty/ies (multiple choice):

1. Cardiologist
2. Radiologist
3. Pediatrician
4. Heart surgeon

### Where do you practice?

1. Southeast
2. Northeast

3. Central-West
4. North
5. South

#### How many years of training did you complete in CT/CMR?

1. < 1 year
2. 1 year
3. 2 years
4. > 2 years

#### What methods do you work with (multiple choice)?

1. Computed tomography
2. Magnetic resonance imaging
3. Echocardiography
4. Nuclear medicine

The questionnaire was posted on the websites of participating medical societies, in message boards, medical conferences, and webinars whose target audience was healthcare professionals who perform CT/CMR in Brazil. The questionnaire was available from October 2024 to January 2025 at: [https://docs.google.com/forms/d/e/1FAIpQLSchvk0lti\\_TbezPstpC9PK3Qz\\_KuU5zyd79MwYama2M6vbDng/viewform?usp=sf\\_link](https://docs.google.com/forms/d/e/1FAIpQLSchvk0lti_TbezPstpC9PK3Qz_KuU5zyd79MwYama2M6vbDng/viewform?usp=sf_link).

The total number of exams performed within the SUS in outpatient and inpatient settings by Brazilian region was obtained by consulting DATASUS (<https://datasus.saude.gov.br/home/tabnet>) in May 2025, searching for code 0207020019 (magnetic resonance imaging of the heart/aorta w/ cine). It was not possible to estimate the number of cardiac CT scans for calcium score assessment or coronary computed tomography angiography (CCTA) due to the lack of specific codes for these exams in the SUS.

The total number of exams performed through PHI in outpatient and inpatient settings by Brazilian region was obtained by consulting the website of the National Supplementary Health Agency (ANS), the regulatory body responsible for private health plans in Brazil. The website (<https://www.gov.br/ans/pt-br/aceso-a-informacao/perfil-do-setor/dados-e-indicadores-do-setor/d-tiss-painel-dos-dados-do-tiss>) was accessed in May 2025 to search for the following codes:

- 41101138 MRI – heart – morphological and functional
- 41101146 MRI – heart – morphological and functional + perfusion + stress
- 41101154 MRI – heart – morphological and functional + perfusion + myocardial viability
- 41001087 CT – heart – for coronary calcium score assessment
- 41001230 CT – coronary computed tomography angiography

Codes 41101138, 41101146, and 41101154 were grouped under the classification CMR.

This survey did not include out-of-network exams.

Brazilian demographic data were obtained from the last census, available at: <https://www.ibge.gov.br/estatisticas/todos-os-produtos-estatisticas.html> (see Supplementary Material).

The information collected by the questionnaire was analyzed in conjunction with data on the number of exams performed in Brazil by region and demographic data.

#### Statistical Analysis

Normally distributed continuous variables were presented as mean and standard deviation, and non-normally distributed continuous variables were presented as median and interquartile range. Categorical variables were presented as absolute and relative frequencies (percentages). Continuous variables were analyzed using Student's t test or Mann-Whitney U test, and categorical variables were analyzed using the chi-squared test or Fisher's exact test. P values < 0.05 were considered significant, and SPSS (Statistical Package for the Social Sciences), version 18.0 (SPSS Inc., Chicago, IL, USA) was used to analyze the data.

#### Results

A total of 219 professionals responded to the questionnaire, 139 (63.8%) male and 80 (36.7%) female. In relation to medical specialty, 161 (73.9%) were cardiologists, and 46 (21.1%) were radiologists. The distribution of these professionals was heterogeneous throughout Brazilian regions. There were 125 (57.3%) professionals in the Southeast, 35 (16.1%) in the Northeast, 30 (13.8%) in the South, 22 (10.1%) in the Central-West, and 6 (2.8%) in the North. The majority of professionals had completed 2 or more years of training in cardiovascular imaging (169 professionals, 77.5%), and they worked with CT (219 professionals; 100%) and CMR (210 professionals; 96.3%). A minority also worked with echocardiography (39 professionals; 17.9%) or nuclear medicine (12 professionals; 5.5%). Table 1 summarizes the baseline data described.

Regarding sex, women and men were similar in their medical specialty of origin, but differed in the length of training in cardiac imaging (Table 2). The proportion of men who responded that they had 2 or more years of training was lower than that of women (100 [72.5%] versus 69 [86.3%], respectively;  $p = 0.029$ ).

Proportional analysis of the number of professionals in relation to the percentage distribution of the Brazilian population showed that, in the North and Northeast regions, the proportion of professionals was lower than the percentage distribution of the Brazilian population, suggesting a shortage of professionals in those regions. In the Southeast region, the concentration of professionals was higher than the distribution of the Brazilian population (Figure 1). The profile of these professionals in the different regions of the country was similar, with no statistical differences observed regarding the proportion of men ( $p = 0.2451$ ), cardiologists ( $p = 0.1325$ ), radiologists ( $p = 0.4564$ ), training time greater than or equal to 2 years ( $p = 0.8519$ ), and additional imaging methods ( $p = 0.4361$ ) (Central Figure).

In relation to the volume of exams in Brazil in 2024, 14,966 CMR scans were performed within the SUS. Within

**Table 1 – Profile of professionals who perform computed tomography and cardiac magnetic resonance imaging in Brazil**

Variables	n	%
<b>Sex</b>		
Male	139	63.8
Female	80	36.7
<b>Medical training</b>		
Cardiologist	161	73.9
Radiologist	46	21.1
Pediatric cardiologist	8	3.7
Heart surgeon	1	0.5
Cardiologist/radiologist	2	0.9
<b>Brazilian region</b>		
North	6	2.8
Northeast	35	16.1
Central-West	22	10.1
Southeast	125	57.3
South	30	13.8
<b>Training time</b>		
< 1 year	12	5.5
1 year	37	17.0
2 years	130	59.6
> 2 years	39	17.9
<b>Imaging methods</b>		
Computed tomography	219	100
Magnetic resonance imaging	210	96.3
Nuclear medicine	12	5.5
Echocardiography	39	17.9

**Table 2 – Professional profile according to sex**

Category	Women (n, %)	Men (n, %)	P value
Cardiologist	58 (72.5%)	104 (75.4%)	0.7601
Radiologist	14 (17.5%)	32 (23.2%)	0.4123
Training ≥ 2 years	69 (86.3%)	100 (72.5%)	0.0291
CMR/CT/CMR+CT	63 (78.8%)	110 (79.7%)	1.0

CMR: cardiac magnetic resonance imaging; CT: computed tomography.

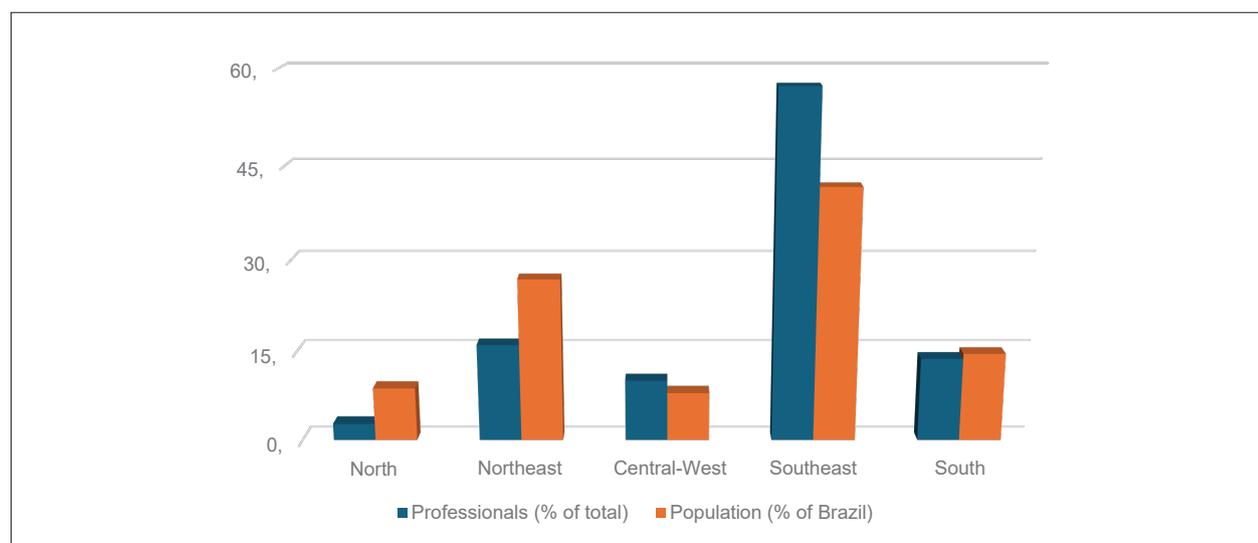
private healthcare, there were 44,382 CMR scans, 130,189 CCTA exams, and 2,629 calcium score assessments. Table 3 displays the distribution of exams by region. Analysis of the distribution of cardiovascular imaging exams in Brazil revealed significant disparities between regions and between the public and private healthcare systems. Considering the CMR exams performed within the SUS, a pronounced concentration was observed in the Southeast region, with 9,404 exams, followed by the Northeast (2,855), South (1,759), Central-West (849), and North (99).

In data on PHI, regional inequality persists, but with considerably higher absolute numbers in all regions. The Southeast region stood out again with 22,492 CMR scans, representing greater availability through PHI. The South (13,955) and Central-West (3,318) also had significant volumes, in contrast to the North (1,130) and Northeast (3,487), which continued to have lower access, although higher than that observed within the SUS.

CCTA exams were also largely concentrated in the Southeast (66,304) and South (35,152) regions, with much lower numbers in the North (3,209), Northeast (10,902), and Central-West (14,622). Calcium score assessments followed a similar pattern, with emphasis on the South (1,095) and Southeast (1,041), demonstrating the greater presence of these cardiovascular risk stratification tools in areas with a higher density of specialized services.

The Southeast region, with 36% of the population using the SUS and 59.7% using PHI, disproportionately accounted for 62.8% of CMR scans performed within the SUS and 50.7% of CCTA and CMR scans within PHI, as well as 57.3% of professionals specializing in cardiovascular imaging. Conversely, the North region, with 10.4% of the population using the SUS and 3.7% using PHI, accounted for only 0.7% of CMR scans performed within the SUS, 2.4% of CCTA exams within PHI, and 2.8% of professionals in this field, representing a scenario of significant healthcare shortages. Meanwhile, the South, with approximately 14% of the population in each system, accounted for 27.3% of CT scans and 31.4% of CMR scans within PHI, although it concentrated only 13.8% of specialized professionals. This suggests a high density of exams per professional in this region. These data are detailed in Figure 2.

Table 4 shows the relationship between the total number of cardiovascular imaging exams performed and regional structural variables, such as population, gross domestic product (GDP),



**Figure 1** – Proportion of cardiovascular imaging professionals in Brazil and percentage distribution of the Brazilian population.

**Table 3** – Number of cardiac magnetic resonance and computed tomography scans by region and healthcare system

Exams	Number by Brazilian region				
	North	Northeast	Central-West	Southeast	South
<b>SUS</b>					
CMR	99	2,855	849	9,404	1,759
<b>PHI</b>					
CMR	1,130	3,487	3,318	22,492	13,955
CCTA	3,209	10,902	14,622	66,304	35,152
Calcium score	12	363	118	1,041	1,095

*CCTA: coronary computed tomography angiography; CMR: cardiac magnetic resonance imaging; PHI: private health insurance; SUS: Brazilian Unified Health System.*

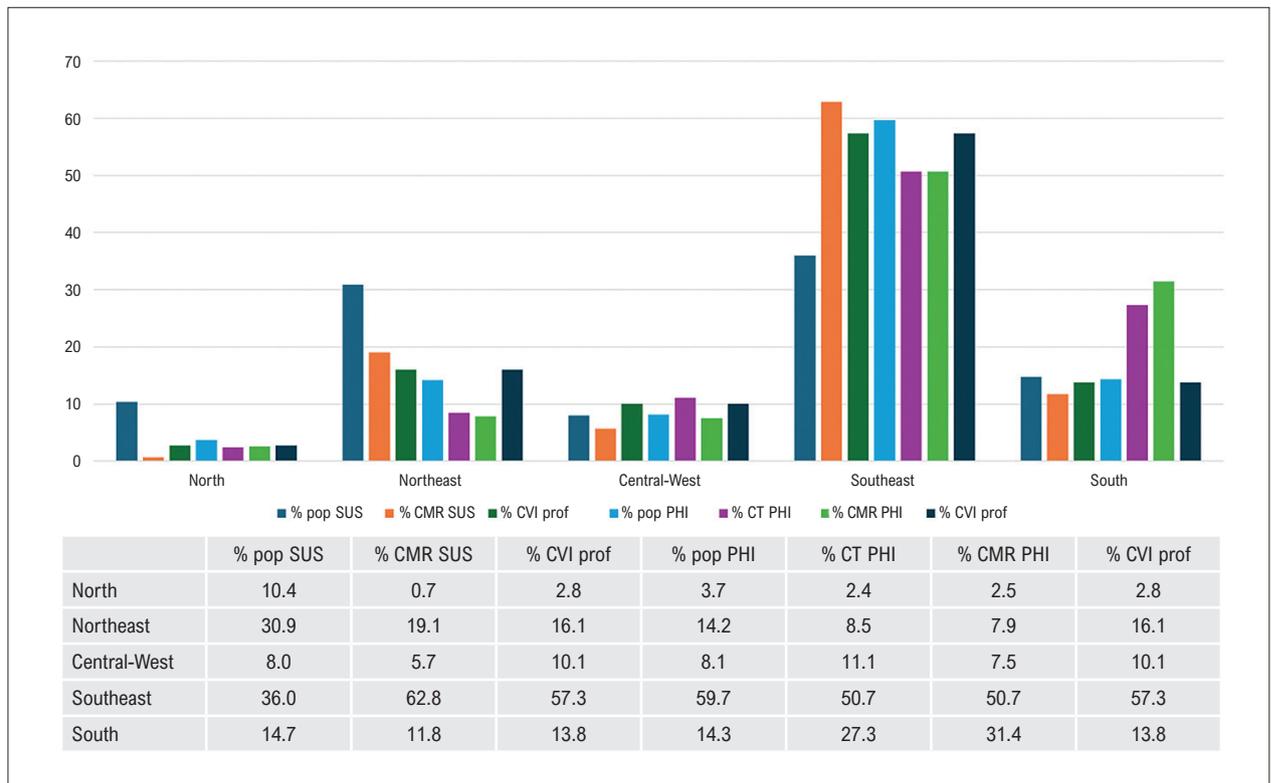
and number of active professionals. The South region, with 31.1 million inhabitants and a GDP of 1.56 trillion Brazilian reais (BRL), had the highest rate of exams per 100,000 inhabitants (167,007) and the highest productivity relative to GDP (33,312 exams per billion BRL), despite a moderate number of professionals (n = 30). The Southeast region, with a larger population (88.6 million), higher GDP (4.71 trillion BRL), and absolute number of professionals (n = 125), had the second-highest rate of exams per 100,000 inhabitants (111,988) and high efficiency relative to GDP (21,056.94 exams/billion BRL). In contrast, the North region, with only 6 professionals and the lowest GDP, performed the lowest absolute and proportional number of exams (22,275/100,000 inhabitants; 7,889.17 exams/billion BRL), demonstrating significant underutilization of diagnostic resources. The Northeast and Central-West regions had intermediate results, with increasing rates of exams per inhabitant and per billion BRL of GDP, consistent with their respective professional density. These findings should certainly be analyzed with caution, but they demonstrate the influence

of economic infrastructure on regional access to cardiovascular imaging methods in Brazil. Regional economic capacity and population size appear to influence the availability and use of exams; these data may indirectly reflect the population's access to PHI, not just the availability of professionals in a given region.

## Discussion

The growth of non-invasive diagnostic methods in cardiology assessment has become a global reality.<sup>5</sup> This increase has resulted from the growing body of scientific evidence published in the literature, reinforcing the importance of these methods in cardiovascular disease diagnosis.<sup>7</sup> The main national and international guidelines on the subject highlight the role of CCTA, calcium score, and CMR in the diagnosis of cardiovascular disease and cardiovascular involvement in systemic diseases.<sup>6,8-10</sup>

The incorporation of CCTA as the initial approach for investigating patients with coronary artery disease in the United Kingdom has yielded noticeable results more than half a decade



**Figure 2** – Percentage distribution of the number of exams, population served by the Unified Health System and private health insurance, and proportion of cardiovascular imaging professionals in Brazil. % CMR PHI: percentage of cardiac magnetic resonance imaging scans performed through private health insurance; % CMR SUS: percentage of cardiac magnetic resonance imaging scans performed within the Unified Health System; % CT PHI: percentage of cardiac computed tomography scans performed through private health insurance; % CVI prof: percentage of cardiovascular imaging professionals in the region; % pop PHI: percentage of the population served by private health insurance; % pop SUS: percentage of the population served by the Unified Health System.

**Table 4** – Relationship between number of exams performed according to local population, gross domestic product, and number of professionals per Brazilian region

	Population	GDP (bi)	Professionals	Total exams	Exams/100,000 inhabitants	Exams/bi PIB
North	19,977,877	0.564064	6	4,450	22.275	7,889.17
Northeast	57,112,096	1.243104	35	17,607	30.829	14,163.74
Central-West	16,289,538	0.932166	22	18,907	60.769	20,282.86
Southeast	88,617,693	4.712982	125	99,241	111.988	21,056.94
South	31,113,021	1.559828	30	51,961	167.007	33,312.00

bi: billion Brazilian reais; GDP: gross domestic product.

after implementation. The National Institute for Health and Care Excellence (NICE), the body responsible for quality, evidence-based decision-making in the National Health Service (NHS), recommended the use of CCTA as the preferred diagnostic test for evaluating chest pain.<sup>11</sup> The study revealed that, in regions that fully adopted the recommendation, there was a significant reduction in the number of myocardial scintigraphy tests. The change in

investigation strategy was also associated with a slight reduction in invasive coronary angiography and a reduction in cardiovascular mortality. Moreover, a decreasing trend in all-cause mortality was identified, reinforcing the effectiveness of the proposed model. These data confirm the central role of CCTA, not only in improving clinical outcomes, but also its potential to optimize resources within the United Kingdom’s public health system.<sup>11</sup>

In Brazil, circumstances are different, as this test is not widely available with the Brazilian SUS. Even when available, we are not able to quantify its use due to the lack of coding. In the context of PHI, prior evaluation is frequently requested due to positive ischemia tests, in addition to criteria that often limit its use, which should be reviewed. The data presented reveal important inequality in the provision and use of advanced cardiovascular imaging tests in Brazil, both between the different regions of the country and between the SUS and PHI. The concentration of tests in the Southeast and South regions, especially in the private sector, contrasts with the low provision observed in the North, Northeast, and Central-West regions, highlighting structural and healthcare limitations in these areas.

These regional inequalities in access to cardiovascular imaging exams indicate structural limitations and historical asymmetries in the distribution of resources within the Brazilian healthcare system. Although most exams are concentrated in the most economically developed regions, the high relative productivity observed in the South suggests a possible optimization of the existing infrastructure, or even a more consolidated private market, with greater access to PHI. On the other hand, the limited performance observed in the North region, even when adjusted for GDP and number of inhabitants, highlights additional barriers, such as a lack of equipment, low PHI coverage, and shortage of trained professionals. The discrepancy between regions reinforces the need for specific public policies that promote development of professional training in interior regions, investment in diagnostic infrastructure in the SUS, and more equitable regulation of access to imaging methods, in order to ensure minimum fair coverage in all Brazilian regions.

The findings of this analysis dialogue with those presented by Monti et al.,<sup>12</sup> in a survey conducted by the CMR working group of the Italian Society of Cardiology. The study identified structural and operational barriers similar to those observed in Brazil, including limited access to CMR, regional disparities, and underutilization of the technique, even in centers with installed capacity. Furthermore, the study highlighted the shortage of professionals with specific training as one of the main obstacles to expanding the clinical use of CMR. These challenges, shared across different health systems, reinforce the importance of coordinated strategies to expand specialist training, optimize the use of available resources, and integrate CMR into care guidelines more broadly and equitably.

Data from Germany's national certification program and the European Society of Cardiovascular Radiology (ESCR) registry revealed pronounced heterogeneity in the provision and use of cardiovascular imaging, among both institutions and medical specialties. The study underscored the need for standardization in training, certification, and quality control processes, indicating that, even in a country with broad technological availability, the lack of uniformity in professional qualifications and the incorporation of imaging into clinical workflows limits systematic use.<sup>13</sup> Similarly, a recent analysis on the use of CCTA in different regions of the United States and the United Kingdom revealed significant inequalities in access and adoption of the exam, associated with the availability of equipment, the presence of trained specialists, and variations in regional clinical guidelines.<sup>14</sup> These findings reinforce that, even in advanced healthcare

systems, the consolidation of cardiovascular imaging as a routine diagnostic tool requires structured policies for training, professional accreditation, and technical governance. These challenges are particularly critical in Brazil, where they are characterized by even more pronounced regional inequalities.

Based on the findings presented, it is possible to propose strategies to mitigate regional inequalities in access to cardiovascular imaging in Brazil. The creation of regional training and qualification centers dedicated to CCTA and CMR, especially in the North, Northeast, and Central-West regions, can promote the development of expertise in interior regions and contribute to the retention of professionals. Accordingly, retention scholarships linked to medical residency, master's, or doctoral programs, funded by Brazilian agencies such as the Coordination for the Improvement of Higher Education Personnel (CAPES) and the National Council for Scientific and Technological Development (CNPq), should be offered based on epidemiological and structural data obtained by means of national censuses in the field. Additionally, public-private partnerships for the acquisition and maintenance of advanced imaging equipment can be strategic for regions with low technological coverage, provided that they are accompanied by clear regulatory protocols that guarantee priority use by the SUS. These integrated measures can contribute to greater equity in the provision of exams, expanding the clinical and social impact of cardiovascular imaging in Brazil.

Our data have important limitations. We believe that the number of imaging professionals in this survey is an underestimate, especially regarding the participation of radiologists. International data have shown that radiologist participation is higher.<sup>5</sup> These limitations were due to the voluntary participation of the professionals involved, as well as the fact that the majority of radiologists represented are affiliated with the SPR, which operates in São Paulo. Lack of coding in the SUS prevented us from accessing the number of CCTA scans and calcium scores. The lack of data on out-of-network exams performed in Brazil was a limitation, whose impact was likely not significant on this survey, given their low proportion in the Brazilian context.

In conclusion, our results demonstrated pronounced inequality in the provision and use of cardiovascular imaging in Brazil, with a greater concentration of resources and procedures in the Southeast and South regions, and marked shortages in other regions. This asymmetry is not limited to technological and economic infrastructure; it also reflects a shortage of qualified professionals in the field, especially in more vulnerable regions. Given this scenario, there is an evident need for strategies focused on training, ongoing development, and retention of cardiovascular imaging specialists, as an essential component to expanding access and ensuring more equitable care. Investment in human capital development is an indispensable step toward consolidating cardiovascular imaging as a routine diagnostic tool and improving the quality of care nationwide.

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## Author Contributions

Conception and design of the research: Costa IBSS, Torreão JA, Fernandes JL, Trad H, Liberato G, Sasdelli Neto R, Pinto IM, Senra T. Acquisition of data: Costa IBSS, Torreão JA, Fernandes JL, Trad H, Liberato G, Sasdelli Neto R, Senra T. Analysis and interpretation of the data: Costa IBSS, Pinto IM, Senra T. Statistical analysis: Costa IBSS, Senra T. Writing of the manuscript: Costa IBSS, Torreão JA, Fernandes JL, Trad H, Liberato G, Sasdelli Neto R, Senra T. Critical revision of the manuscript for intellectual content: Barberato SH, Pinto IM, Senra T.

### Potential conflict of interest

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

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## Study association

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

## Ethics approval and consent to participate

This study was approved by the Ethics Committee of the Instituto Dante Pazzanese under the protocol number CAAE 85943025.6.0000.5462. All the procedures in this study were in accordance with the 1975 Helsinki Declaration, updated in 2013. Informed consent was obtained from all participants included in the study.

## Use of Artificial Intelligence

The authors did not use any artificial intelligence tools in the development of this work.

## Data Availability

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

## \*Supplemental Materials

For additional information, please click here.



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