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Coronary artery bypass graft surgery in Brazil from 2008 to 2017

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Abstract

Background: Brazil is an upper middle-income country in South America with the world's sixth largest population. Despite great advances in health-care services and cardiac surgical care in both its public and private health systems, little is known on the volume, outcomes, and trends of coronary artery bypass grafting (CABG) in Brazil's public health system.

Objective: The aim of this study was to evaluate the outcome of CABG on the public health system from January 2008 to December 2017 through the database DATASUS.

Methods: This study is based on publicly available material obtained from DATASUS, the Brazilian Ministry of Health's data processing system, on numbers of surgical procedures, death rates, length of stay, and costs. Only isolated CABG

procedures were included in our study. We used the TabNet software from the DATASUS website to generate reports. The χ^2 test was used to compare death rates. A $p < .05$ was considered statistically significant.

Results: We identified 226,697 CABG procedures performed from January 2008 to December 2017. The overall in-hospital mortality over the 10-year period was 5.7%. We observed statistically significant differences in death rates between the five Brazilian macro-regions. Death rates by state ranged from 2.6% to 13.1%. The national average mortality rate remained stable over the course of time.

Conclusion: Over 10 years, a high volume of CABG was performed in the Brazilian Public Health System, with significant differences in mortality, number of procedures, and distribution of surgeries by region. Future databases involving all centers that perform CABG and carry out risk-adjusted analysis will help improve Brazilian results and enable policymakers to adopt appropriate health-care policies for greater transparency and accountability.

1 | INTRODUCTION

Brazil is a country of continental dimensions, with significant differences in climate, genetic ancestry, and lifestyle in its distinct regions. It occupies 47% of South America's area, mainly in the tropical region, and has more than 200 million inhabitants.[1] Brazil is the fifth largest country in land area and sixth in population size, and it is currently the seventh largest economy in the world.[2] However, on the basis of income distribution, Brazil remains one of the world's most unequal countries.[2] The racial composition of the Brazilian population stems from a mixture of ethnic groups that include descendants of initial Portuguese settlers, native Brazilians, additional European immigrants and their descendants, descendants of African slaves, and a small proportion of Asians.[3] Brazil is divided into five regions: North, Northeast, Central-west, Southeast, and South. The Northeast population is approximately 53 million, and the North, South, Southeast, and Central-west population is 15 million, 27 million, 80 million, and 16 million, respectively. Whereas the northeastern and northern regions (the latter sparsely populated) have the worst socioeconomic indicators, the southeastern region has 42% of the population and is responsible for 56% of the gross domestic product (GDP).[4]

The Brazilian national health system has two branches: a universal public health system (Sistema Único de Saúde [SUS]), which covers around 70% of the population, and a supplementary health sector, which comprises private health plans, insurance, and private health professionals. To have access to the supplementary sector, patients must either pay out of pocket or obtain coverage from their employer. SUS is one of the largest public health-care systems in the world, financed by the Brazilian government, and it was responsible for over 113 million hospitalizations with an overall mortality of 3.8% between January 2008 and February 2018. Over the same period, cardiovascular diseases accounted for over 11 million hospital admissions with mortality rates of 7.7%.[5,6]

Private sector participation is structured by legislation to be either complementary or supplementary to the SUS.[7] As a complementary measure, private institutions can be hired by the SUS where the public system is insufficient, in general, for secondary or tertiary care. The supplementary sector is regulated by the National Agency of Supplementary Health, linked to the Ministry of Health.[7]

According to Ribeiro et al.,[6] in 2011, after correcting for underreporting and ill-defined causes, 384,615 deaths were attributed to cardiovascular disease (*International Statistical Classification of Diseases and Related Health Problems, 10th Revision* [ICD-10] codes I00–I99), corresponding to 31.0% of all deaths and 42.0% of all noncommunicable disease deaths. Coronary artery disease (ICD-10 I20–25) is now the leading cause of cardiovascular death, accounting for 31% of cardiovascular mortality in Brazil. More recently, according to the GBD results tool (based on the Global Burden of Disease Study; http://ghdx.healthdata.org/gbd-results-tool), 388,268 deaths occurred in Brazil due to cardiovascular disease (CVD) in 2017 (or 28.8% of total mortality) and coronary artery disease made up 45.3% of all CVD deaths in Brazil in 2017.

1.1 | Some details about SUS: Supplementary versus complementary system

SUS is intended to serve as a universal health-care system provided by the government, which can be accessed by every citizen. Patients who are well-off may also pay for private health insurance and, thus, have access to the private system as well.

In states in which the public health system is equipped to provide complete coverage for the population, the private system serves as a *supplementary system* for patients who can afford it. In states in which the public system does not fully meet the population's needs, less well-off patients can access the private system through quotas provided by the government; in this case, the private system serves as *complementary system*.

Both complementary and supplementary systems are a part of SUS. Unfortunately, there are no available comparative data for the number of cases and related outcomes for CABG procedures carried out within the private system, because these data are not under public surveillance in the country.

To the best of authors' knowledge, no study has reported on the volume of CABG procedures in Brazil over the last decade in the public health system. Here, we aim to give an overview of the volume, outcomes, and trends of CABG surgery in Brazil's public health system to shed light on the situation of CABG procedures as a public health issue in the country.

2 | METHODS

2.1 | The DATASUS system

The material was obtained from DATASUS, the data processing system of the Brazilian Ministry of Health, which collects information from every patient who needs in-hospital care and was admitted to a public hospital, gathering and auditing data with relation to number of surgical procedures, death rates, and costs. Whereas SUS contains verified patient identifiers to track individuals across hospital admissions within and across the states, DATASUS contains completely deidentified data (i.e., no social security numbers or patient-specific identifiers) using unique patient keys that are tracked by the state. As DATASUS is a publicly available deidentified database, this study was exempt from patients' consent to have their data included in this report by our Institutional Review Board.

DATASUS encompasses the Hospital Information System (SIH) as one of its elements. The SIH is based on filling out the Hospital Admission Authorization Form (AIH). SUS/SIH resorts to a codification system for every surgical procedure. The current codes for CABG are 0406010927, 04060010935, 0406010943, and 0406010951. All isolated CABG procedures performed in the public health-care system were included in our study, regardless of the hospital or city and whether they were on-pump or off-pump. Cases performed in the private sector are not captured in the database, and therefore not included in this analysis. In Brazil, all cardiac surgical units contribute to DATASUS, with the exception of the subset of cardiac surgical units that only provide care in the Private Practice model and do not participate in the public health system. CABG with concomitant procedures was excluded. We used the TabNet software[8] from the DATASUS website to generate reports.

2.2 | Outcomes

Death rates were the main outcome of interest. The system records in-hospital mortality, which means any intraoperative death or postoperative death before discharge. To assess a possible link between outcomes and local development, we assessed the Human Development Index (HDI), a comparative measure that uses three aspects: wealth, education, and average life expectancy. The HDI is a standardized means of assessment and a measure of the population's well-being. We used the latest HDI value assigned to each Brazilian county as a means to express the socioeconomic conditions of the respective local populations.[9]

2.3 | Statistical analysis

The χ^2 test was used to compare death rates. Odds ratio and 95% confidence intervals were calculated. The macro-region with the lowest mortality rate was used as a reference in comparisons. Statistical analysis was performed using PASW version 18.0 (SPSS). A $p < .05$ was considered to indicate a statistically significant result.

3 | RESULTS

3.1 | Mortality rates and surgical volumes

We identified 226,697 CABG procedures performed from January 2008 to December 2017. No studies have addressed the cause for the lower rate of CABG in Brazil than that of other Western countries. The overall in-hospital mortality over the 10-year period was 5.7%. We observed statistically significant differences in death rates between the five Brazilian macro-regions (see Table 1). On the one hand, using the Northeast as a reference (as it presented the lowest death rate), there was no statistically significant difference in comparison with the Southeast. On the other hand, we observed significantly higher death risks in the South, North, and Central-west (see Table 1). Figure 1A,B displays the trends between 2008 and 2017, showing increasing numbers of cases from 2008 to 2012 and decreasing numbers of cases from 2012 to 2017. Nearly all of the decrease in the number of procedures over the study time frame occurred in the Southeast Region. The Southeast was responsible for almost 50% of CABG surgeries. Together, the Southeast and South were responsible for almost 75% of all surgeries (see Figure 1C). The state of São Paulo was responsible for approximately 30.3% of all surgeries, followed by the state of Paraná with 14.9% and the state of Minas Gerais with 9.4%, meaning that only three states were responsible for almost 55% of all CABGs (Figure S1). The national average death rate remained stable over time (see Figure 2A), as did the national average length of stay (see Figure 2B). Off-pump CABG accounted for only 11.0% of CABG surgeries (see Figure 2C).

Region	Number of procedures (%)—deaths (%)	OR (95% CI)	p value
Northeast	37,186 (16.4)—1901 (5.1)	1.00[a]	–
Southeast	108,347 (47.8)—5603 (5.2)	1.01 (0.95–1.06)	.6560
South	59,906 (26.4)—3617 (6.0)	1.19 (1.22–1.26)	<.0001
Central-west	14,921 (6.6)—1175 (7.9)	1.58 (1.47–1.71)	<.0001
North	6337 (2.8)—513 (8.1)	1.63 (1.47–1.80)	<.0001
Total	226,697 (100.0)–12,809 (5.7)		

Abbreviations: CI, confidence interval; OR, odds ratio.
[a]The Northeast was used as a reference, as it presented the lowest mortality rate.

The North was the region with the highest mortality rate and the lowest number of procedures. It is important to mention that the state of Roraima (in the North) has no accredited hospitals where CABG procedures could be performed. Death rates by state ranged from 2.6% to 13.1% (Figure S2).

## 3.2 | Distribution of hospitals and costs related to CABG

Brazil has 239 accredited hospitals that perform CABG, located in 142 of the nation's 5570 cities. There is a wide range of surgical volume between these hospitals (one hospital had 9 surgeries over the 10-year period and another had more than 25,000) and the cities in which they are located (one city had 12 surgeries over the 10-year period and another had more than 42,000).

Five states of the South–Southeast axis (Paraná, Rio Grande do Sul, Rio de Janeiro, São Paulo, and Minas Gerais) are home to 60.6% of the hospitals, whereas the North and Central-west regions (with a total of 10 states) are home to 4.2% and 7.9%, respectively (Figure S3). Interestingly, the Northeast has almost double the population of the South and nearly the same number of hospitals (50 and 51, respectively). Nevertheless, the South performs 61.1% more surgical procedures than the Northeast. There are 30 hospitals with a death rate lower than 3.0% located in 14 states (BA, CE, DF, ES, MA, MG, MT, PE, PI, PR, RN, RJ, RS, SC, and SP) plus the DF. Table 2 describes population standardized number of hospitals and rates of CABG overall and by region.
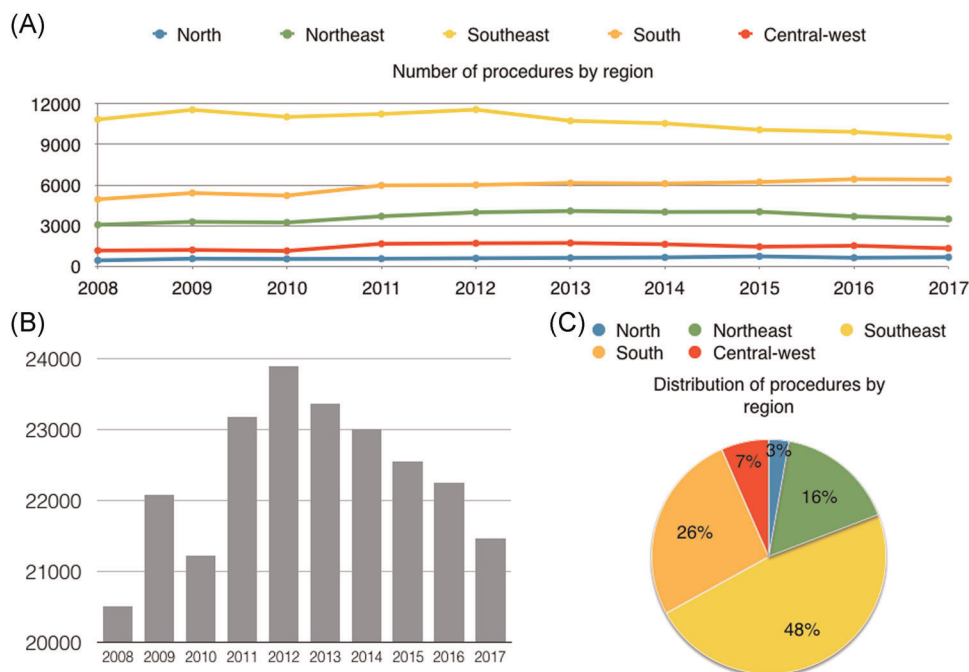
FIGURE 1 Coronary artery bypass graft over a period of 10 years in Brazil. (A) Number of procedures by region over the years. (B) Number of procedures by year. (C) Distribution of procedures by region
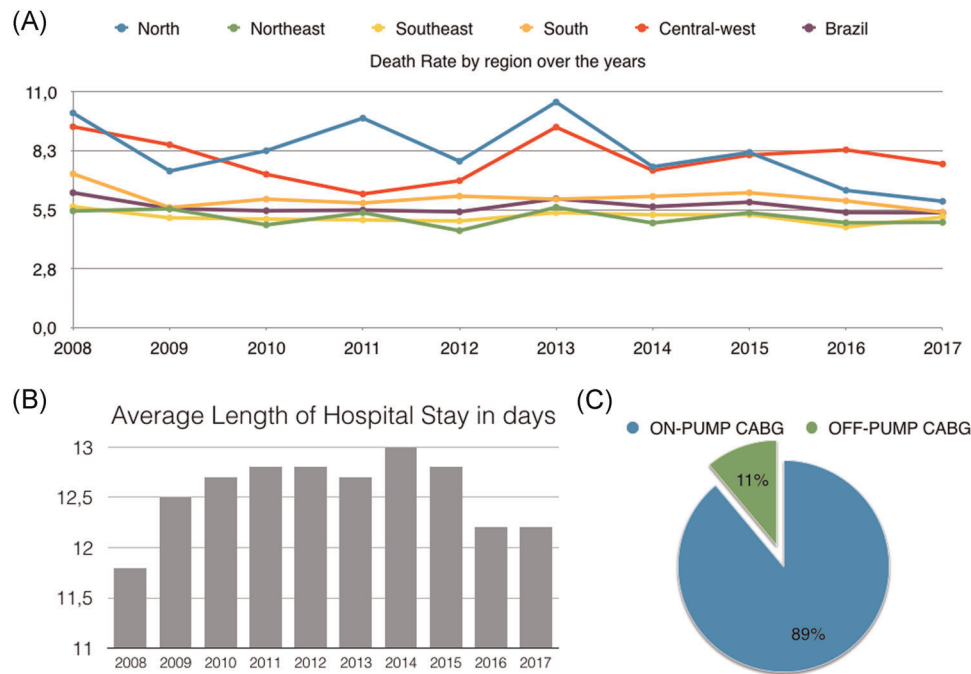
FIGURE 2 Coronary artery bypass graft over a period of 10 years in Brazil. (A) Death rate by region over the years. (B) National average length of hospital stay. (C) Distribution of on-pump versus off-pump procedures

The costs of CABG procedures over the 10 years amounted to over 2.6 billion BRL (634 million US$), as seen in Table 3.

3.3 | Comparative death and HDI rates

The Southeast and South regions performed more than 70% of all surgeries and are also the richest regions of Brazil, with a GDP of over three trillion BRL (730 billion US$). Although the Northeast is a poorer region with a lower HDI (0.659) than the South (0.756) and Southeast (0.753), it has the lowest death rate associated with CABG (along with the Southeast region; see Table 1). The Federal District has the highest HDI: 0.824. The HDI of the North and Central-west is 0.690 and 0.729, respectively (see Figure 3).

4 | DISCUSSION

4.1 | Comparing Brazil with the United States of America

The rate of CABG in Brazil is approximately one-tenth that of the United States of America. In 2016, the United States performed nearly as many surgeries as were performed over 7 years in Brazil.[10] It has already been reported that the funds transferred from SUS do not cover all the hospital costs, and that this mismatch can cause financial losses to health-care institutions, which are contracted with SUS throughout the country, compromising their market survival and their ability to meet the population's demand.[11] This would explain why the cost of CABG in Brazil is

TABLE 2 Population standardized number of hospitals and rates of CABG overall and by region

Region	Population (millions)	Number of hospitals	Number of hospitals per 10 million people	Average number of CABG per year	Average number of CABG per year per 1 million people	CABG mortality
North	18	9	5	625	34.7	8.1
Northeast	56	50	8.9	3668	65.5	5.1
Central-west	16	19	11.9	1471	91.9	7.9
Southeast	87	110	12.6	10,697	122.9	5.2
South	29	51	17.6	5893	203.2	6.0
Total	206	239	11.6	22,356	108.5	5.7

Abbreviation: CABG, coronary artery bypass graft.
*US$ to BRL exchange of January 10th 2020.

TABLE 3 Costs with isolated CABG procedures from January 2008 to December 2017

| Region	Costs (BRL)	Costs (US$)	Cost per case (US$)
Northeast	399,769,709.60	97,504,807.10	2622
Southeast	1,240,404,513.14	302,537,686.13	2792
South	788,510,757.06	192,319,652.45	3210
Central-west	169,377,954.55	41,311,696.23	2768
North	75,567,924.20	18,431,201.03	2908
Total	2,673,630,858.55	652,105,087.45	2876

[a]US$ to BRL exchange of January 10th 2020.

very low as compared with the cost of CABG in other Western countries.

The Society of Thoracic Surgeons (STS) Adult Cardiac Surgery Database (ACSD) was established in 1989 to address the shortcomings of CABG mortality data published by the federal government 3 years earlier.[12] STS leaders recognized that these mortality results, derived from administrative data, did not adjust for the differences in the inherent risk of patients, and that a far more comprehensive clinical data set, compared with the one that was then available, was required to do so. As of September 2018, the

ACSD includes 1111 participant groups comprising 3137 surgeons from all 50 United States, 10 sites in Canada, and 22 participants in 9 other countries. The volume of isolated CABG in the STS National Database was 160,160 operations in 2017 with a mortality rate of 1.8%, which means that isolated CABG in Brazil is associated with a threefold higher mortality rate. Whereas the STS-ACSD contains nearly 6.6 million cumulative patient records, and it is estimated that it currently contains information on more than 95% of the adult cardiac operations performed each year in the United States,[13,14] the DATASUS only allows the retrieval of the following data: outcome (death), length of stay, and cost.

The DATASUS does not provide information about surgical risk profile. The publicly available database used in this article does not contain data about preoperative risk factors, and it is therefore not possible to document risk-adjusted mortality, as is documented in STS-ACSD. The DATASUS does not contain information regarding important outcomes related to the procedures such as reoperation, deep sternal wound infection, stroke, prolonged ventilation, renal failure, and postoperative atrial fibrillation—data that are necessary to document a complete picture of outcomes and quality of care. As with the United States in the past, administrative data lack the robustness, consistency, and completeness needed to study how Brazilian patients evolve postoperatively. Therefore, data are not available on risk-adjusted mortality, on the reasons for choosing
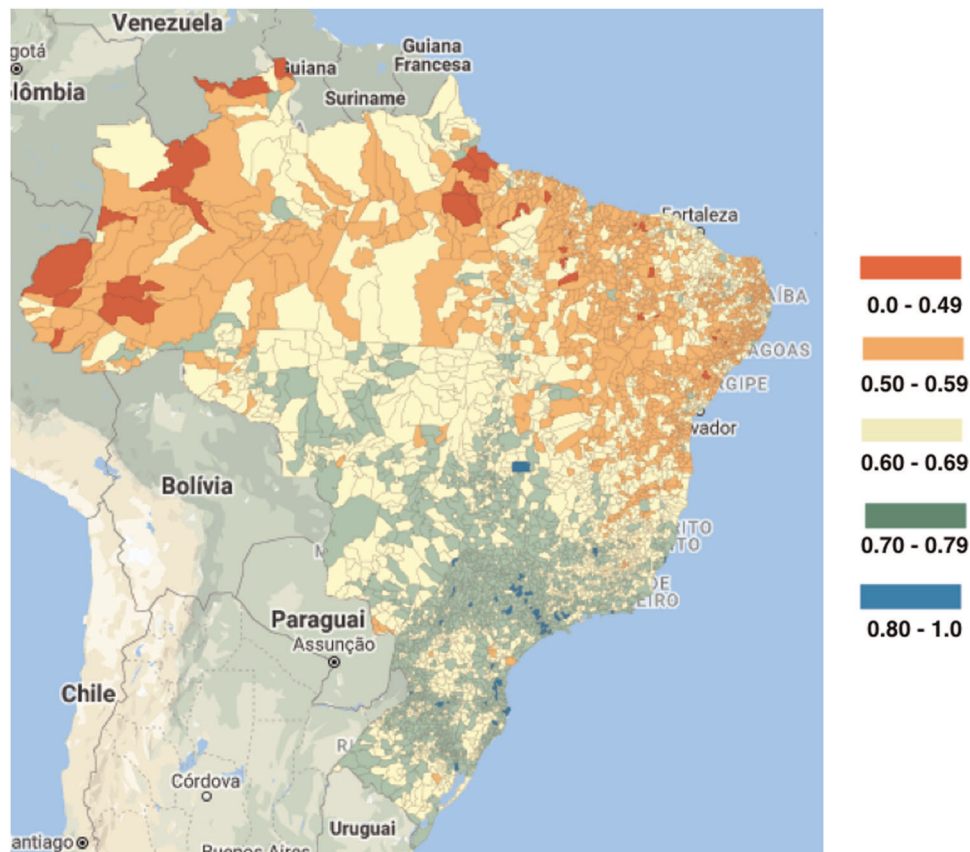
FIGURE 3 The Brazilian Human development index by county layer (http://atlasbrasil.org.br/2013/pt)

CABG as the treatment for these patients, or on the extent to which local differences in the makeup of surgical teams may have affected mortality outcomes.

Our findings have public health implications, as we identified high rates of mortality in isolated CABG (in comparison with high-income countries) and the lack of a system that enables us to study what actually happens to patients who undergo CABG in Brazil, which leads us to the necessity of improving the use of information technology in our public health system. As reported by the STS, surgery groups and/or hospitals that do not meet established data completeness thresholds during the reporting time period do not receive scores and star ratings and, therefore, are not publicly reported.

4.2 | The BYPASS project

The Brazilian Registry of Adult Patients Undergoing Cardiovascular Surgery—the BYPASS Project—is an ongoing database[15] established by the Brazilian Society of Cardiovascular Surgery, which aimed to collect perioperative and postoperative data from patients undergoing cardiac surgery in Brazil. The first report of the BYPASS revealed that CABG is the most frequently performed cardiac surgery in Brazil, encompassing 54.1% of the cases.[16] CABG remains the standard of care for the management of patients with coronary artery disease, especially in high-risk patients with multivessel disease,

diabetics, aged 65 years or more, with left main stem or with impaired left ventricular function. Recent international guidelines recommend that national societies establish their own database on the practice and results of CABG.[17]

The BYPASS registry was only recently introduced (in 2015), and it has gathered data on only 2292 patients from 17 institutions. On the one hand, this newly established database is as yet unable to give a representative overview. On the other hand, it provides more data granularity. First results revealed the following: patients referred to CABG in Brazil are predominantly males (71%), with prior myocardial infarction in 41.1% of cases, diabetes in 42.5%, and ejection fraction lower than 40% in 9.7%. Most patients underwent cardiopulmonary bypass (87%) and cardioplegia was the strategy of myocardial protection chosen in 95.2% of the cases. The left internal thoracic artery was used as a graft in 91% of the cases, the right internal thoracic artery in 5.6%, and the radial artery in 1.1%. The saphenous vein graft was used in 84.1% of the patients, being the only graft employed in 7.7% of the patients. The median number of coronary vessels treated was three. The incidence of cerebrovascular accident was 1.2% and operative mortality was 2.8%.

Any ability to better understand the significance of these differences requires a more extensive risk-adjusted data set. The focus then should be less on the finer differences and more on the need to implement a more detailed and widespread data collection system. This might be achieved by the BYPASS registry, depending on the adherence of the cardiac centers.
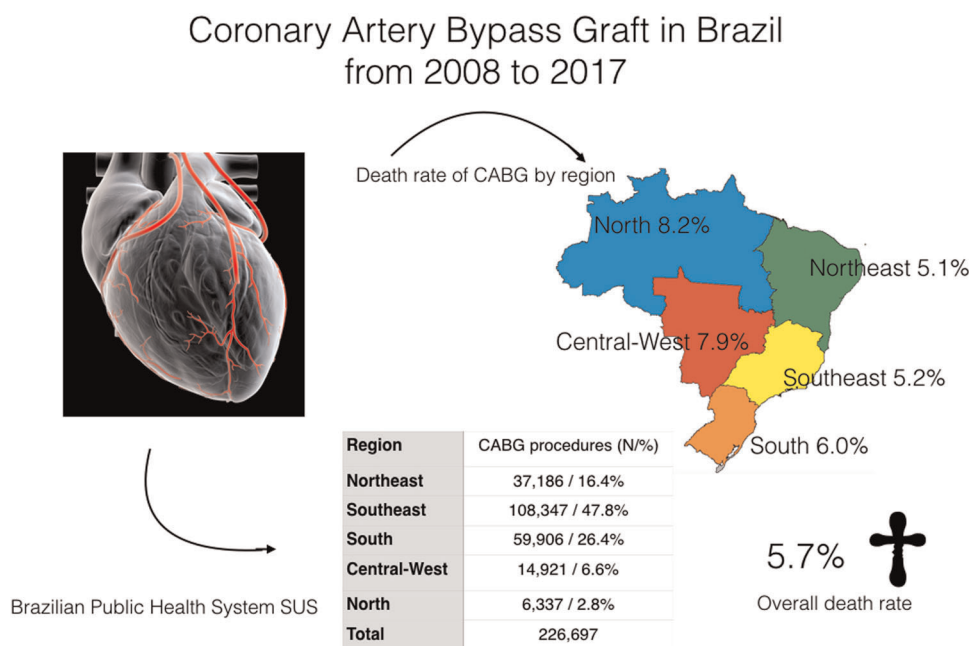
FIGURE 4 Brazil is a country of continental dimensions with a universal public health system. Over 220,000 coronary artery bypass graft (CABG) were performed over a 10-year period, with significant differences in mortality, number of procedures, and distribution of surgeries by region. There is a lack of a national database that gathers information on risk-adjusted mortality. Future databases involving all centers that perform CABG and carry out risk-adjusted analysis will help improve Brazilian results and enable policy makers to adopt appropriate health-care policies for greater transparency and accountability

5 | LIMITATIONS OF THIS STUDY

Despite including all CABG procedures performed over the past 10 years, there is lack of a national database that gathers information on risk-adjusted mortality. Although the DATASUS is open to the public and 100% of all public cardiac units contribute data to the database under government surveillance, there is no granularity on the quality and surgical outcomes of CABG in the recent era, or why the treatment of choice was CABG. The lack of data granularity of DATASUS is a major concern, as even basic characteristics such as patients' age and sex are unavailable.

In a universal public health system that performs a significant number of procedures and has already released public data, allowing patients to get access to risk-adjusted mortality is important, so that people are be able to compare cardiac surgical groups with national benchmarks for performance, survival, complications, and other outcomes (see Figure 4).

6 | CONCLUSION

Over 10 years, a high volume of CABG was performed in the Brazilian Public Health System, with significant differences in mortality, number of procedures, and distribution of surgeries by region. Future databases involving all centers that perform CABG and carry out risk-adjusted analysis will help improve Brazilian results and enable policy makers to adopt appropriate health-care policies for greater transparency and accountability.

CONFLICT OF INTERESTS
The authors declare that there are no conflict of interests.

DATA AVAILABILITY STATEMENT
The data that support the findings of this study are openly available in DataSUS at http://datasus1.saude.gov.br/

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SUPPORTING INFORMATION
Additional supporting information may be found online in the Supporting Information section.