

Coronary artery bypass graft surgery in Brazil from 2008 to 2017

Kalil Hussein Khalil¹, MD*

Michel Pompeu B. O. Sá^{2,3}, MD, MSc, PhD*

Dominique Vervoort⁴, MD

Leonardo Roevers⁵ MSc, PhD

Marcos Alfredo de Andrade Pires¹, MD

Jaqueline Maria de Oliveira Lima¹, MD

Felipe Borsu de Salles⁶, MD

Giovana Munhoz Khalil¹, MD

Pedro Felipe Gomes Nicz⁷, MD

Omar Asdrúbal Vilca Mejía⁷, PhD

Arnaldo Akio Okino¹, MD

Ricardo de Carvalho Lima, MD, MSc, PhD, ChM^{2,3}

INSTITUTIONS

¹Department of Cardiovascular Surgery, Hospital Norte Paranaense, Arapongas, Paraná, Brazil.

²Department of Cardiovascular Surgery, PROCAPE, University of Pernambuco, Recife, Brazil

³Nucleus of Postgraduate and Research in Health Sciences, Faculty of Medical Sciences and Biological Sciences Institute – FCM/ICB, Recife, Pernambuco, Brazil.

⁴Department of Health Policy and Management, Johns Hopkins Bloomberg School of Public Health, Baltimore, Maryland, United States

⁵Department of Cardiovascular Surgery, Federal University of Uberlândia, Uberlândia, MG, Brazil

⁶Department of Cardiovascular Surgery, Institute of Cardiology - Fundação Universitária de Cardiologia, Porto Alegre, RS, Brazil

⁷Department of Cardiology, Heart Institute - INCOR-HCFM-USP, São Paulo, SP, Brazil

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*These authors contributed equally to this paper.

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Correspondence Address:

Kalil Hussein Khalil

HONPAR - Hospital Norte Paranaense

Rodovia PR-218, Km 01, S/n - Jardim Universitário, Arapongas - PR, CEP 86702-670

E-mail: kalilkhil@hotmail.com

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53 Abbreviations, Acronyms and Symbols

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55 AC= State of Acre

56 AIH= Hospital Admission Authorization Form

57 AL= State of Alagoas

58 ALOS= average length of hospital stay

59 AM= State of Amazonas

60 AP= State of Amapá

61 BA= State of Bahia

62 BRL= Brazilian Real

63 CABG= coronary artery bypass graft

64 CE= State of Ceará

65 CAD= coronary artery disease

66 CVD= cardiovascular disease

67 DR= death rate

68 DF= Federal District

69 ES= State of Espírito Santo

70 GO= State of Goiás

71 ICD= international classification of disease

72 MA= State of Maranhão

73 MG= State of Minas Gerais

74 MT= State of Mato Grosso

75 MS= State of Mato Grosso do Sul

76 PA= State of Pará

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77 PB= State of Paraíba

78 PCI= percutaneous coronary intervention

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79 PE= State of Pernambuco

80 PI = State of Piauí

81 PR= State of Paraná

82 RJ= State of Rio de Janeiro

83 RN= State of Rio Grande do Norte

84 RO= State of Rondônia

85 RR= State of Roraima

86 RS= State of Rio Grande do Sul

87 SBCCV= Brazilian Society of Cardiovascular Surgery

88 SC = State of Santa Catarina

89 SE = State of Sergipe

90 SIH = Hospital Information System

91 SP = State of São Paulo

92 SUS = Brazilian Health Care System

93 TO = State of Tocantins

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Central message:

Brazil is a country of continental dimensions with a universal public health system. This paper describes outcomes and trends for more than 220,000 coronary artery bypass grafts performed over 10 years.

Perspective:

Analyzing a high volume of coronary artery bypass graft surgery and producing a national database with risk-adjusted mortality may help improve Brazilian results and enable policymakers to adopt appropriate health care policies, for greater transparency and accountability.

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 in the public health system in 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. Chi-square test was used to compare death rates. A p-value of <0.05 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.

157 INTRODUCTION

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

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

179 Private sector participation is structured by legislation to be either complementary or
180 supplementary to the SUS [7]. As a complementary measure, private institutions can be hired by the
181 SUS where the public system is insufficient, in general, for secondary or tertiary care. The

182 supplementary sector is regulated by the National Agency of Supplementary Health, linked to the
 183 Ministry of Health [7].

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

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194 *Some Details about SUS: Supplementary versus Complementary system*

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

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

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

206 To our knowledge, no study has reported on the volume of CABG procedures in Brazil over the
 207 last decade in the public health system. Here, we aim to give an overview of the volume, outcomes,

208 and trends of CABG surgery in Brazil's public health system in order to shed light on the situation of
209 CABG procedures as a public health issue in the country.

210

211 **METHODS**

212 *The DATASUS System*

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

222 DATASUS encompasses the Hospital Information System (SIH) as one of its elements. The
223 SIH is based on filling out the Hospital Admission Authorization Form (AIH). SUS/SIH resorts to a
224 codification system for every surgical procedure. The current codes for CABG are 0406010927,
225 04060010935, 0406010943, and 0406010951. All isolated CABG procedures performed in the public
226 health care system were included in our study, regardless of the hospital or city and whether they were
227 on-pump or off-pump. Cases performed in the private sector are not captured in the database and
228 therefore not included in this analysis. In Brazil, all cardiac surgical units contribute to DATASUS,
229 with the exception of the subset of cardiac surgical units that only provide care in the Private Practice
230 model and do not participate in the public health system. CABG with concomitant procedures was
231 excluded. We used the TabNet software [8] from the DATASUS website to generate reports.

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234 *Outcomes*

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

242

243 *Statistical Analysis*

244 The chi-square test was used to compare death rates. Odds ratio (OR) and 95% confidence
 245 intervals were calculated. The macro region with the lowest mortality rate was used as reference in
 246 comparisons. Statistical analysis was performed using PASW version 18.0 (SPSS, Chicago, IL). A p-
 247 value of <0.05 was considered to indicate a statistically significant result.

248

249 **RESULTS**

250 *Mortality Rates and Surgical Volumes*

251 We identified 226,697 CABG procedures performed from January 2008 to December 2017. No
 252 studies have addressed why the rate of CABG in Brazil is lower than that of other Western countries.
 253 The overall in-hospital mortality over the 10-year period was 5.7%. We observed statistically
 254 significant differences in death rates between the five Brazilian macro regions (see Table 1). On the
 255 one hand, using the Northeast as reference (since it presented the lowest death rate), there was no
 256 statistically significant difference in comparison with the Southeast. On the other hand, we observed
 257 significantly higher death risks in the South, North, and Central-West (see Table 1). Figures 1A and 1B
 258 display the trends between 2008 and 2017, showing increasing numbers of cases from 2008 to 2012
 259 and decreasing numbers of cases from 2012 and 2017. Nearly all of the decrease in case volume 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 only three states were responsible for almost 55% of all CABGs (Supplemental Figure 1). 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). 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 hospital where CABG procedures could be performed. Death rates by state ranged from 2.6% to 13.1% (Supplemental Figure 2).

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272 *Distribution of Hospitals and Costs Related to CABG*

273 Brazil has 239 accredited hospitals that perform CABG, located in 142 of the nation's 5,570
 274 cities. There is a wide range of surgical volume between these hospitals (one hospital had nine
 275 surgeries over the 10-year period; another had more than 25,000) and the cities in which they are
 276 located (one city had 12 surgeries over the 10-year period; another had more than 42,000).

277 Five states of the South-Southeast axis (Paraná, Rio Grande do Sul, Rio de Janeiro, São Paulo,
 278 and Minas Gerais) are home to 60.6% of the hospitals, whereas the North and Central-West regions
 279 (with a total of 10 states) are home to 4.2% and 7.9%, respectively (Supplemental Figure 3).
 280 Interestingly, the Northeast has almost double the population of the South and nearly the same number
 281 of hospitals (50 and 51, respectively). Nevertheless, the South performs 61.1% more surgical
 282 procedures than the Northeast. There are 30 hospitals with a death rate lower than 3.0% located in 14
 283 states (BA, CE, DF, ES, MA, MG, MT, PE, PI, PR, RN, RJ, RS, SC, SP) plus the DF. Table 2
 284 describes population standardized number of hospitals and rates of CABG overall and by region.

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

287

288 *Comparative death and HDI rates*

289 The Southeast and South regions performed more than 70% of all surgeries and are also the
 290 richest regions of Brazil, with a gross domestic product (GPD) of over three trillion BRL (730 billion
 291 US\$). Although the Northeast is a poorer region with a lower HDI (0.659) than the South (0.756) and
 292 Southeast (0.753), it has the lowest death rate associated with CABG (along with the Southeast region;
 293 see Table 1). Federal District has the highest HDI: 0.824. The HDI of the North and Central-West is
 294 0.690 and 0.729, respectively (see Figure 3).

295

296 **DISCUSSION**

297 *Comparing Brazil with the United States of America*

298 The rate of CABG in Brazil is approximately one-tenth that of the United States of America. In
 299 2016, the United States performed nearly as many surgeries as were performed over seven years in
 300 Brazil [10]. It has already been reported that the funds transferred from SUS do not cover all the
 301 hospital costs and that this mismatch can cause financial losses to health care institutions, which are
 302 contracted with SUS throughout the country, compromising their market survival and their ability to
 303 meet the population's demand [11]. This would explain why the cost of CABG in Brazil is very low
 304 compared to the cost of CABG in other western countries.

305 The Society of Thoracic Surgeons (STS) Adult Cardiac Surgery Database (ACSD) was
 306 established in 1989 to address the shortcomings of CABG mortality data published by the federal
 307 government three years earlier [12]. STS leaders recognized that these mortality results, derived from
 308 administrative data, did not adjust for the differences in the inherent risk of patients, and that to do so
 309 would require a far more comprehensive clinical data set than was then available. As of September
 310 2018, the ACSD includes 1,111 participant groups comprising 3,137 surgeons from all 50 United

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

318 The DATASUS does not provide information about surgical risk profile. The publicly available
319 database used in this manuscript does not contain data about preoperative risk factors, and it is
320 therefore not possible to document risk-adjusted mortality, as is documented in STS-ACSD. The
321 DATASUS does not contain information regarding important outcomes related to the procedures such
322 as reoperation, deep sternal wound infection, stroke, prolonged ventilation, renal failure, and
323 postoperative atrial fibrillation – data which are necessary to document a complete picture of outcomes
324 and quality of care. As with the United States in the past, administrative data lack the robustness,
325 consistency, and completeness needed to study how Brazilian patients evolve postoperatively.
326 Therefore, data is not available on risk-adjusted mortality; on the reasons for choosing CABG as the
327 treatment for these patients; or on the extent to which local differences in the makeup of surgical teams
328 may have affected mortality outcomes.

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

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337 *The BYPASS Project*

338 The Brazilian Registry of Adult Patients Undergoing Cardiovascular Surgery – the BYPASS
339 Project – is an ongoing database [15] established by the Brazilian Society of Cardiovascular Surgery
340 and aimed to collect perioperative and postoperative data from patients undergoing cardiac surgery in
341 Brazil. The first report of the BYPASS revealed that CABG is the most frequently performed cardiac
342 surgery in Brazil, encompassing 54.1% of the cases [16]. CABG remains the standard of care for
343 management of patients with coronary artery disease, particularly in high-risk patients with multi-
344 vessel disease, diabetics, aged 65 years or more, with left main stem or with impaired left ventricular
345 function. Recent international guidelines recommend that national societies establish their own
346 database on the practice and results of CABG [17].

347 The BYPASS registry was only recently introduced (in 2015), and has gathered data on only
348 2,292 patients from 17 institutions. On the one hand, this newly established database is as yet unable to
349 give a representative overview. On the other hand, it provides more data granularity. First results
350 revealed the following: patients referred to CABG in Brazil are predominantly male (71%), with prior
351 myocardial infarction in 41.1% of cases, diabetes in 42.5%, and ejection fraction lower than 40% in
352 9.7%; most patients underwent cardiopulmonary bypass (87%) and cardioplegia was the strategy of
353 myocardial protection chosen in 95.2% of the cases; the left internal thoracic artery was used as a graft
354 in 91% of the cases, the right internal thoracic artery in 5.6% and the radial artery in 1.1%; the
355 saphenous vein graft was used in 84.1% of the patients, being the only graft employed in 7.7% of the
356 patients; the median number of coronary vessels treated was three; the incidence of cerebrovascular
357 accident was 1.2%; operative mortality was 2.8%.

358 Any ability to better understand the significance of these differences requires a more extensive
359 risk-adjusted dataset. The focus then should be less on the finer differences and more on the need to
360 implement a more detailed and widespread data collection system. This might be achieved by the
361 BYPASS registry depending on the adherence of the cardiac centers.

362

363 *Limitations of this Study*

364 Despite including all CABG procedures performed over the past 10 years, there is lack of a
 365 national database that gathers information on risk-adjusted mortality. Even though the DATASUS is
 366 open to the public and 100% of all public cardiac units contribute data to the database under
 367 government surveillance, there is no granularity on the quality and surgical outcomes of CABG in the
 368 recent era, nor why the treatment of choice was CABG. The lack of data granularity of DATASUS is a
 369 major concern since even basic characteristics such as patients' age and sex are unavailable.

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

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375 **CONCLUSION**

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

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FIGURE LEGEND

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 vs Off-Pump procedures.

Figure 3. Brazilian Human development index by county layer (<http://atlasbrasil.org.br/2013/pt>)

Supplementary figure 1. Number of procedures by state.

Supplementary figure 2. Death rate by state.

Supplementary figure 3. Number of hospitals by state.

Figure 4. Brazil is a country of continental dimensions with a universal public health system. Over 220,000 coronary artery bypass graft were performed over a 10-year period with significant differences in mortality, number of procedures and distribution of surgeries by region. There is 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 to improve Brazilian results and enable policy makers to adopt appropriate health care policies, for greater transparency and accountability.

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Table 1. Data by region in Brazil for CABG over 10 years (from January 2008 to December 2017).

Region	Number of Procedures (%) - Deaths (%)	OR (95% CI)	P-value
Northeast	37,186 (16.4) - 1,901 (5.1)	1.00*	- - -
Southeast	108,347 (47.8) - 5,603 (5.2)	1.01 (0.95-1.06)	0.6560
South	59,906 (26.4) - 3,617 (6.0)	1.19 (1.22-1.26)	<0.0001
Central-West	14,921 (6.6) - 1,175 (7.9)	1.58 (1.47-1.71)	<0.0001
North	6,337 (2.8) - 513 (8.1)	1.63 (1.47-1.80)	<0.0001
Total	226,697 (100.0) - 12,809 (5.7)		

*The Northeast was used as reference since it presented the lowest mortality rate.
OR: odds ratio; CI: confidence interval

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	10697	122.9	5.2
South	29	51	17.6	5893	203.2	6.0
Total	206	239	11.6	22356	108.5	5.7

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

	Costs (BRL)	Costs (US\$)	Cost per case (US\$)
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Region			
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

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498 *US\$ to BRL exchange of January 10th 2020

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509 FIGURE 1

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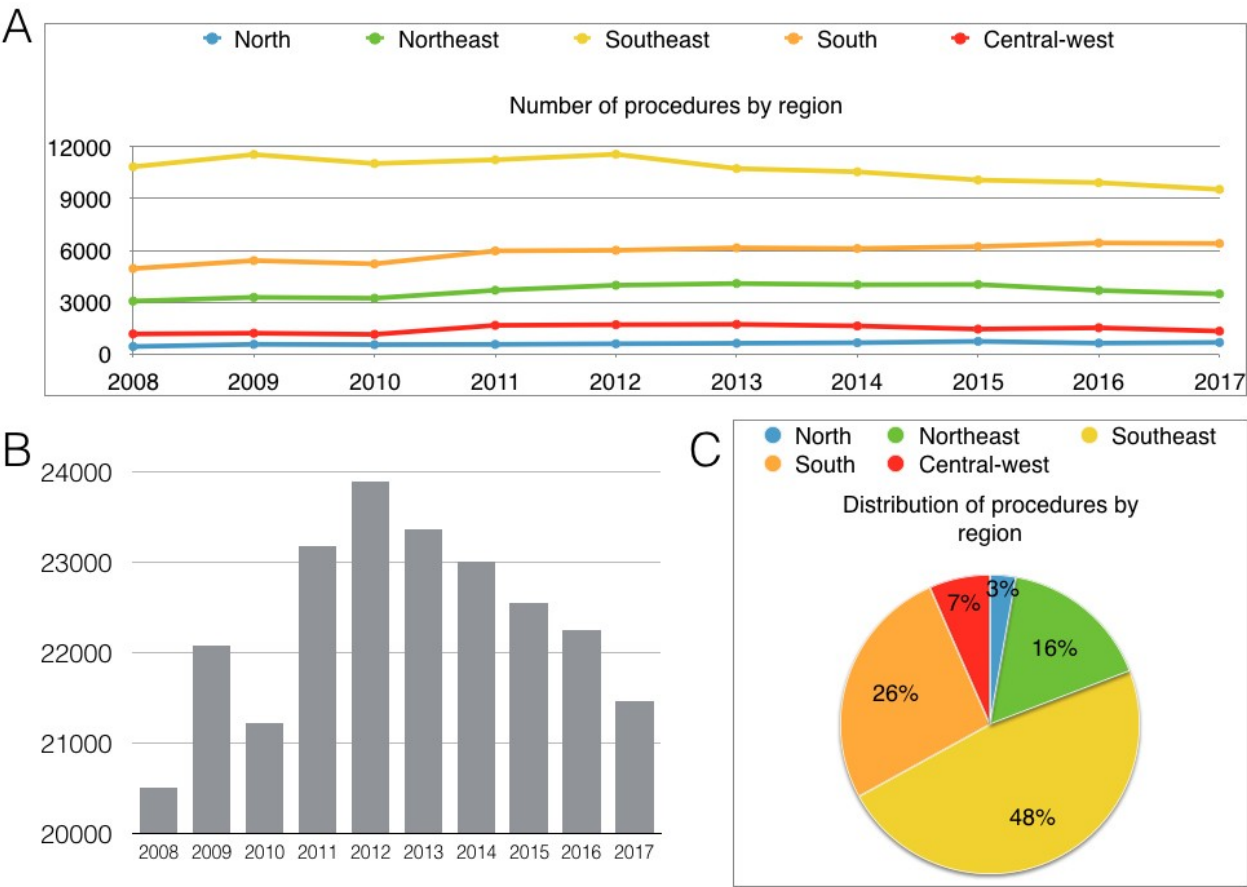


FIGURE 2

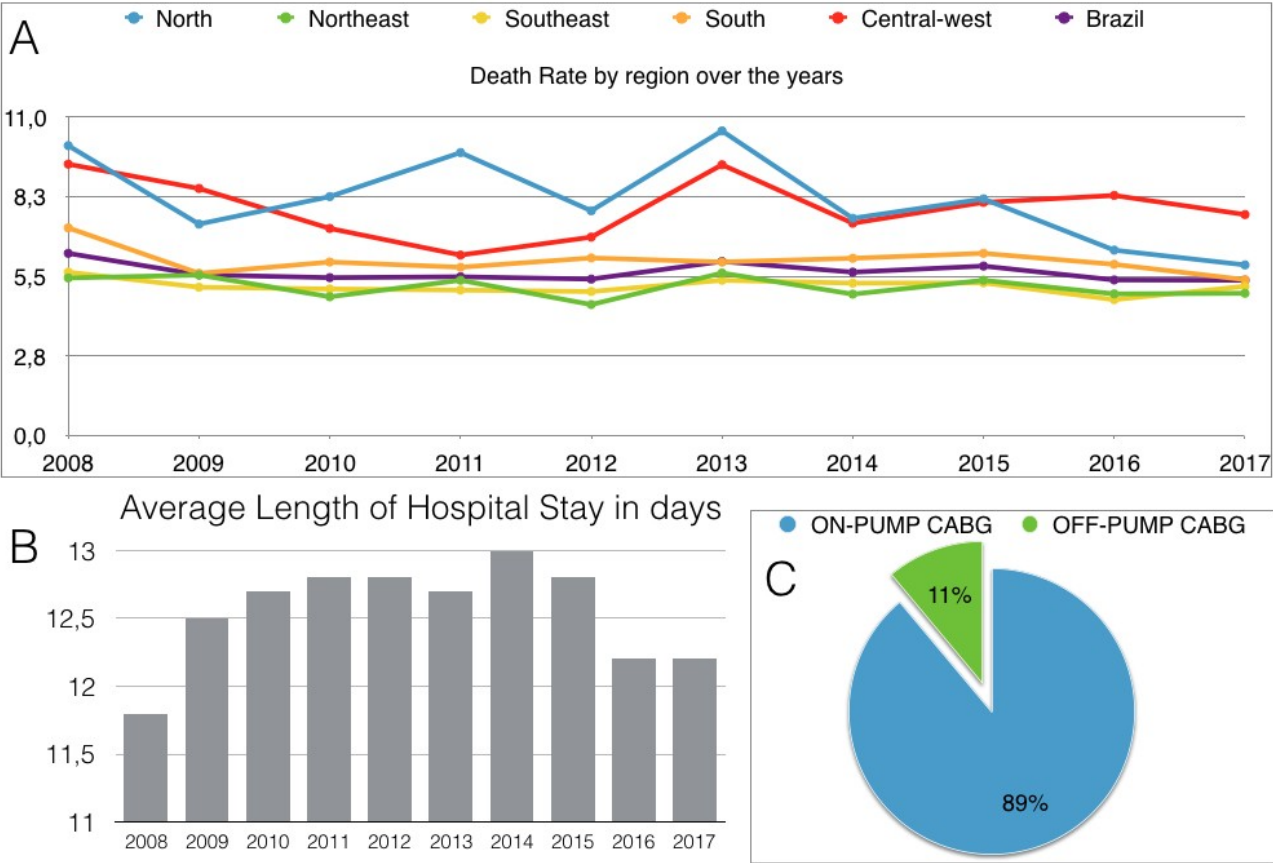
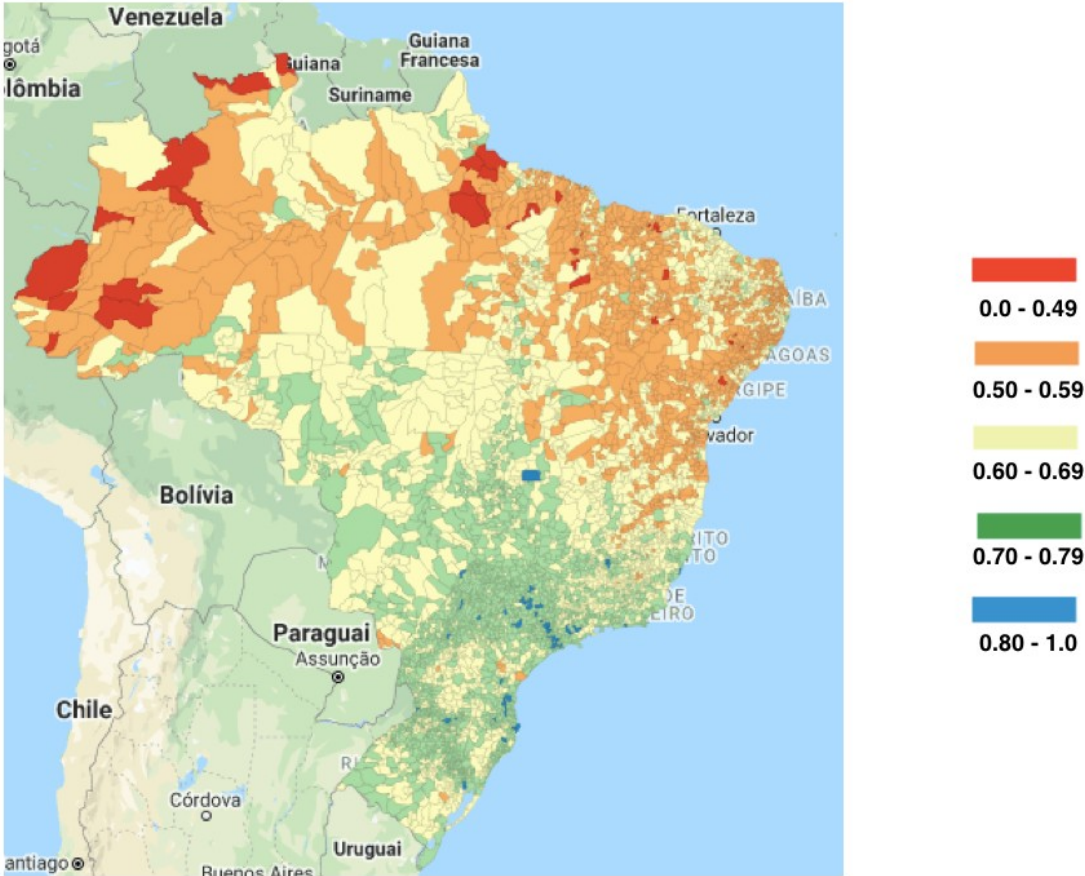


FIGURE 3



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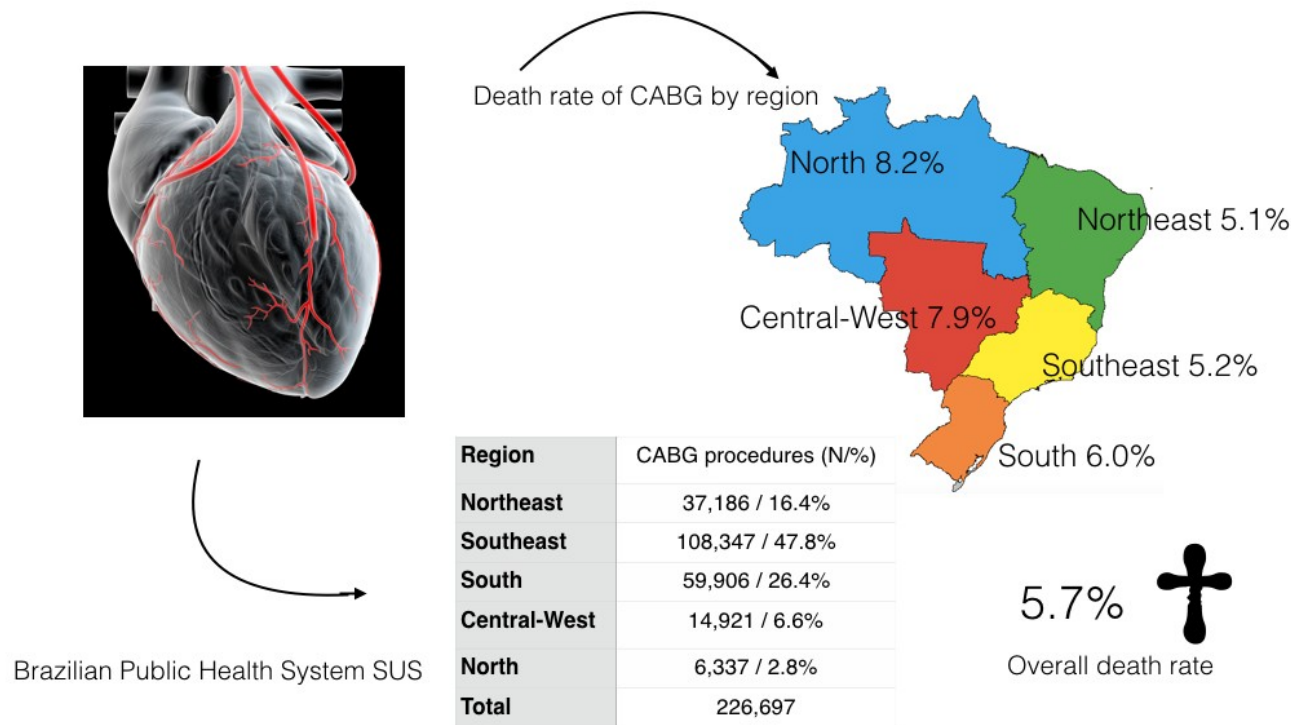
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548 FIGURE 4

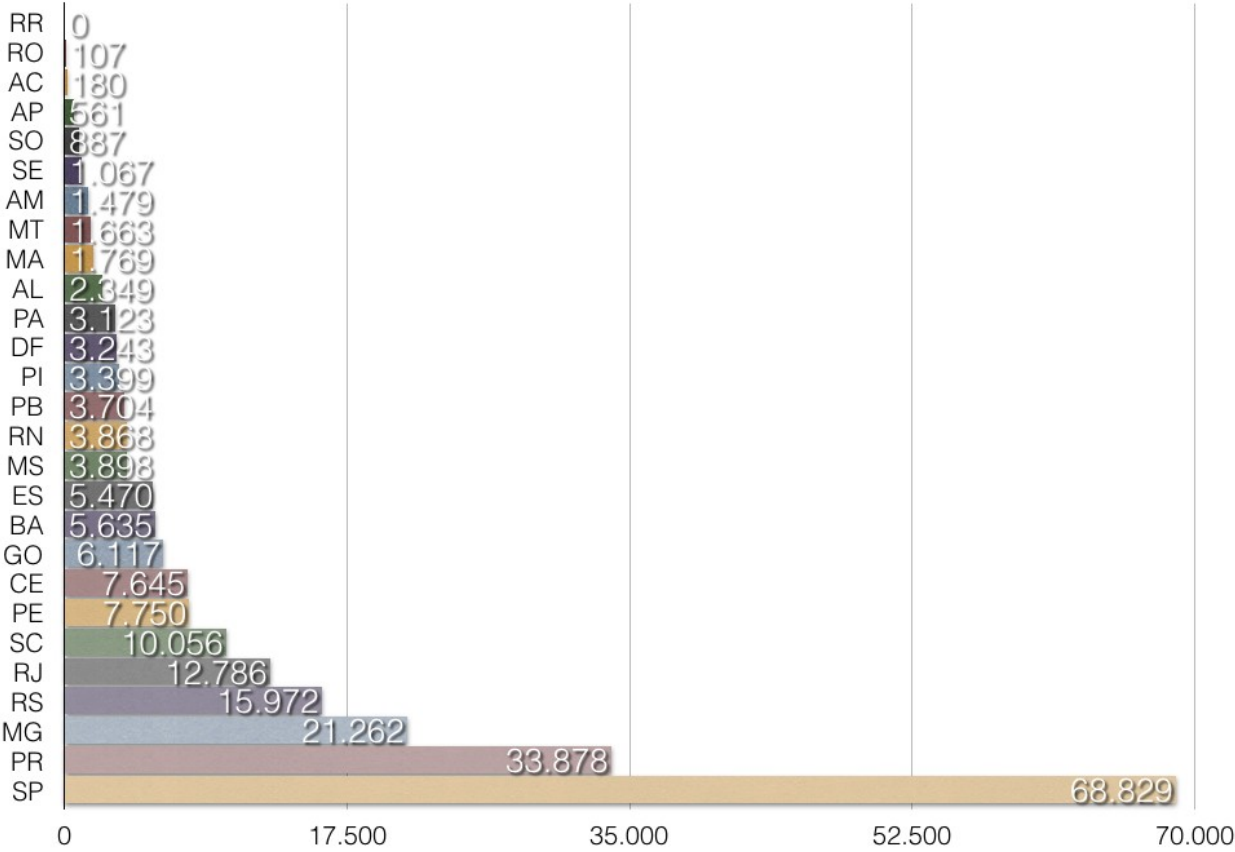
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Coronary Artery Bypass Graft in Brazil
from 2008 to 2017



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SUPPLEMENTARY FIGURE 1



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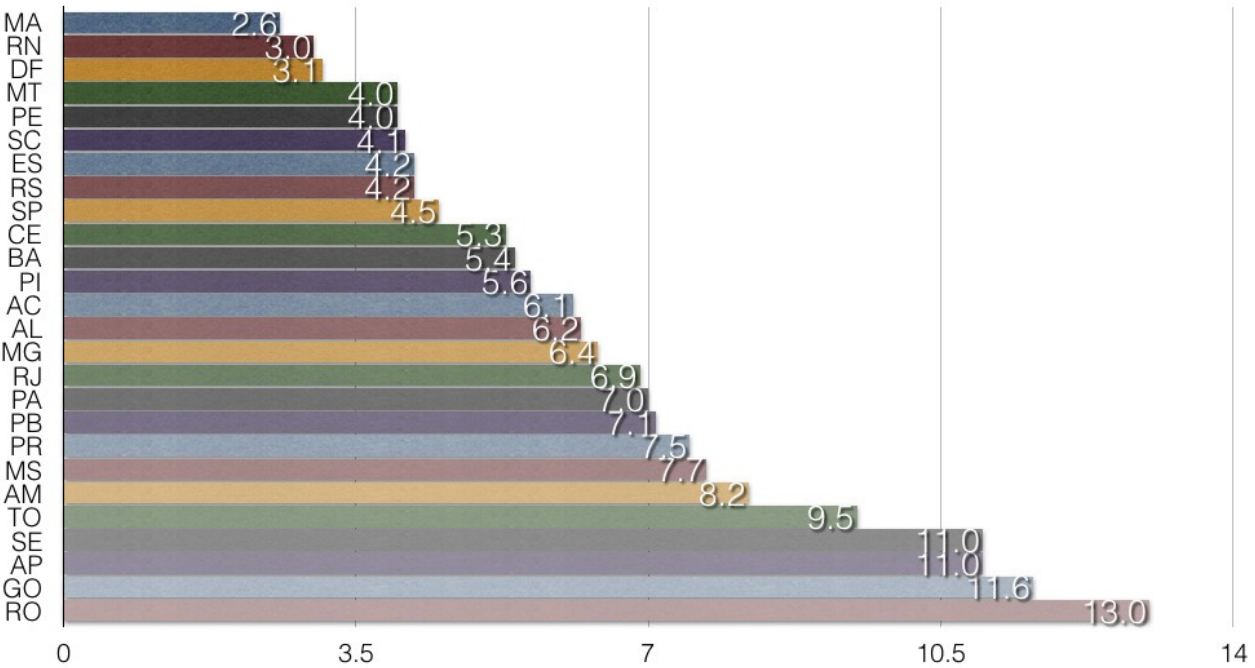
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574 SUPPLEMENTARY FIGURE 2

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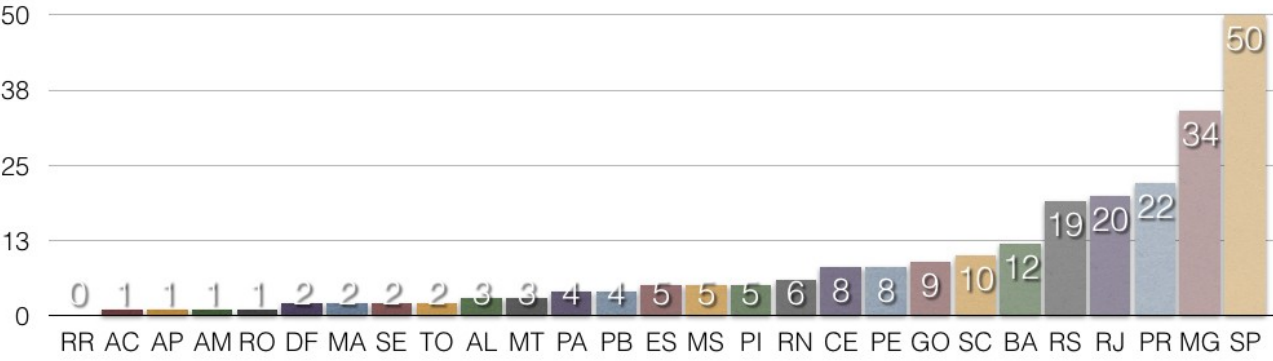
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587 SUPPLEMENTARY FIGURE 3

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