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Review Article

Comparative Analysis of Surgical Treatments for Extracranial Carotid Atherosclerotic Disease in Brazil in the Last 2 Decades: Angioplasty x Endarterectomy.

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1. Introduction

The condition known as extracranial carotid atherosclerosis occurs when atheromatous plaques (composed of necrotic cells, lipids, cholesterol crystals and other constituents) accumulate on the walls of the carotid artery outside the skull, obstructing blood flow. This can lead to stenosis of the artery, which can directly affect the cerebral vascular system, through cerebral embolism, hypoperfusion secondary to critical stenosis, intracranial extension of a carotid thrombus due to an atheromatous plaque or dissection of the arterial wall. This affects the blood supply to the brain and increases the risk of events such as cerebrovascular accident (CVA) or transient ischemic attack (TIA), which are important causes of death in Brazil [1-3].

The clinical picture can be varied and depends on the location and extent of the ischemia, as well as the time, however, when symptomatic it usually manifests amaurosis, hemi or monoplegia, hemi or monoparesis, dyslalia and contralateral motor or sensory deficits. Patients with suspected neurological problems related to probable ischemia should undergo imaging tests to detect possible extracranial carotid disease, with vascular ultrasonography (USV) being the most used method and recommended as the first choice for the evaluation of carotid diseases by the Society American Society of Vascular Surgery [4-7].

Surgical treatment can be performed using two main techniques: angioplasty or endarterectomy. Angioplasty is a minimally invasive endovascular procedure performed via catheterization and involves opening the narrowed artery with a balloon or removing atheromatous plaques, while endarterectomy is the surgical removal of plaques from the walls of the carotid artery. The choice between these procedures depends on several factors, such as age, sex, pre-existing health conditions and anatomical characteristics of the patient, as elderly patients, for example, may be at greater risk of complications during angioplasty, due to more intense calcification of the arteries, while women may be more likely to experience restenosis after endarterectomy [8, 9].

Historically, research into various surgical treatment methods began when Fisher discovered the relationship between neurological events and carotid atherosclerotic disease in 195110. Then in the same decade, the first carotid endarterectomies were performed, making this procedure one of the main treatments of choice, together with clinical treatment. Until the 1980s, there was only discussion about the effectiveness and side effects of the procedure, when percutaneous transluminal balloon angioplasty emerged. Thus, a debate began to assess whether this procedure would be viable and whether it would have superior results to endarterectomy, until, currently, angioplasty has evolved enough to have results similar to open surgery. Thus, nowadays the debate prevails as to which procedure would

be most appropriate, with the use of each one determined by the individual context of each patient [10-21].

Following the trend, in some aspects, of other countries in North America and Europe, Brazil maintains carotid endarterectomy as the main indication for the treatment of carotid stenosis due to atherosclerotic disease, with angioplasty being reserved for cases in which there are contraindications for the first treatment (from 2008 to 2013, according to DATASUS data in relation to cerebrovascular disease, there was an absolute frequency of 7461 endarterectomies and 783 angioplasties performed) [22].

According to the Brazilian Society of Angiology and Vascular Surgery, the indications for different revascularization methods are as follows: "for patients with low or moderate surgical risk, who have presented non-disabling ischemic stroke or transient ischemic cerebral symptoms, endarterectomy should be performed, if the ipsilateral internal carotid artery presents stenosis greater than 70% on non-invasive imaging exams, or greater than 50% on catheter angiography, when the anticipated rate of stroke or preoperative mortality is less than 6%. In these same diagnostic imaging conditions, angioplasty is recommended as an alternative to endarterectomy for symptomatic patients with a low or moderate risk of complications secondary to endovascular procedures" [23].

Regarding a comparison between each procedure and its probable advantages and disadvantages, studies from the 2000s and 2010s in the United States (The Carotid Revascularization Endarterectomy vs. Stenting Trial was the main one - CREST) and in Europe (The International Carotid Stenting Study – ICSS) , among others, were able to elucidate this issue. They were conflicting in some ways, being that: the CREST conclusions showed similar results of both endarterectomy and angioplasty and stenting in preventing future cerebral ischemic events. The primary outcome of death, myocardial infarction or stroke within 30 days plus ipsilateral stroke up to 4 years was similar between CAS (carotid angioplasty) and CEA (carotid endarterectomy) 7.2% vs. 6.8% 2 4-, a good number of European studies concluded that angioplasty and stenting were inferior to endarterectomy – according to the ICCS, at 4 months, the composite outcome of death, stroke or procedural myocardial infarction occurred in 8 .5% of the stent group versus 5.2% of the endarterectomy group. Similarly, any stroke occurred in 7.7% versus 4.1%, any stroke or death in 8.5% versus 4.7%, any stroke or procedural death in 8.0% versus 4.2%, disabling stroke or death 4.0% versus 3.2%, and death from all causes 2.3% versus 0.8%, respectively for stent versus endarterectomy25 -, especially in the case of strictures symptomatic carotid arteries [9].

1.1. Goals

Primary objective: To evaluate the statistical behavior of hospital data regarding hospitalization for carotid endarterectomy compared with carotid angioplasty in Brazil between 2003 and 2023. Secondary objective: To compare the distribution of hospital data on the performance of each procedure by region and describe the statistical trend of carotid endarterectomy and carotid angioplasty over the period.

2. Methodology

It is an observational, retrospective and descriptive study of secondary data, extracted from the SUS Hospital Information System (SIH/SUS), available in the DataSUS database, referring to patients hospitalized in Brazil between the years 2003 and 2023, by place of residence, according to ICD-10-I 65: Occlusion and stenosis of pre-cerebral arteries that do not result in cerebral infarction. Thus, a parallel can be drawn between surgical treatments for extracarotid atherosclerotic disease: bypass thromboendarterectomy of the aorta and intraluminal angioplasty of vessels in the neck/supra aortic trunks without stent and with uncovered stent.

The data obtained was processed in Microsoft Excel, where tables and graphs were created relating to the information collected. This data can be verified through the Tabet portal, at the following access link: https://datasus.saude.gov.br/.

To describe the comparison between surgical treatments, the number of deaths and AIH (hospital admission authorization) approved, average value of hospitalization, total value, mortality rate, average length of stay, value of professional services and value of services were analyzed. hospitals. All of these analyzes were carried out by procedure, year of service (2003-2023) and by demographic regions of Brazil (North, Northeast, Center-West, Southeast, South), excluding the Federative Unit. We also collected, through Demographic and Socioeconomic information, on the DataSUS portal, in the "Resident Population" tab, the study of population estimates by municipality, sex and age, collecting data referring to the population in each Brazilian region (South, Southeast, North, Northeast, Central-West) between the years 2003 and 2023, with the aim of carrying out statistical treatment, in order to calculate the prevalence rate and lethality rate.

To calculate hospital lethality due to angioplasty and thromboendarterectomy between the years 2003 and 2023, the ratio between the number of deaths and the number of hospitalized patients for these diseases was calculated, the data for which was collected on the DataSUS portal by the SUS Hospital Information System. (SIH/SUS). To calculate the prevalence rate, the ratio was made between the total number of people who underwent the surgical procedure between 2003 and 2023 - data collected through the number of AIH - and the population residing in the region in that year. Furthermore, to convert the real currency to the US dollar currency, the value of the dollar was used following the exchange rate on 06/11/2024, in which US$1 dollar was worth R$5.3664 reais. We also highlight that for some variables analyzed there was a considerable lack of data, mainly with regard to the mortality rate, in both the North and Central-West regions in which there were more than 10 years without data. Furthermore, with regard to variables related to the nature of service, no information was recorded prior to 2008, creating a gap in information regarding the years 2003, 2004, 2005, 2006 and 2007. As it is a public data

source, authorization from the Ethics Committee was not required.

3. Results

Initially, in relation to the number of AIH approved between 2003-2023, the average number of AIH for performing angioplasties (343.12 procedures) is 1.5 times higher than the average for performing endarterectomies (220.64 procedures). Regarding approvals for angioplasties, a higher average number is noted in the Southeast region (742.76 procedures), followed, respectively, by the South (727.05 procedures), Northeast (121.48 procedures), Midwest (79.48 procedures) and North (13.47 procedures). In relation to authorized hospitalizations for endarterectomy, we also have the highest prevalence in the Southeast region (639.52 procedures), followed by the South (343.95 procedures), Northeast (69.43 procedures), Central-West (43, 00 procedures) and North (7.33 procedures). In view of this, we can observe the linearity in relation to the states for AIH approved for angioplasty and endarterectomy with the Southeast occupying the first position and the North the last, in addition there is a predominance of the number of hospitalizations for angioplasties when compared to endarterectomy.

Regarding the prevalence rate of carotid endarterectomy, relatively increasing values were observed throughout the period analyzed in all regions. The South region has the highest prevalence (1.20%), as well as the greatest variation in values, increasing until 2010, reaching (1.68%), decreasing until 2020 (0.78%) and increasing until 2023, when reaches 1.31%, followed, respectively, by the Southeast (0.76%), Central-West (0.28%), Northeast (0.12) and North (0.04%) regions, which have the lowest values and the lower variability of these. Tables 1 and 2 demonstrate the prevalence rates for thromboendarterectomy and carotid angioplasty, respectively, observed during the period analyzed.

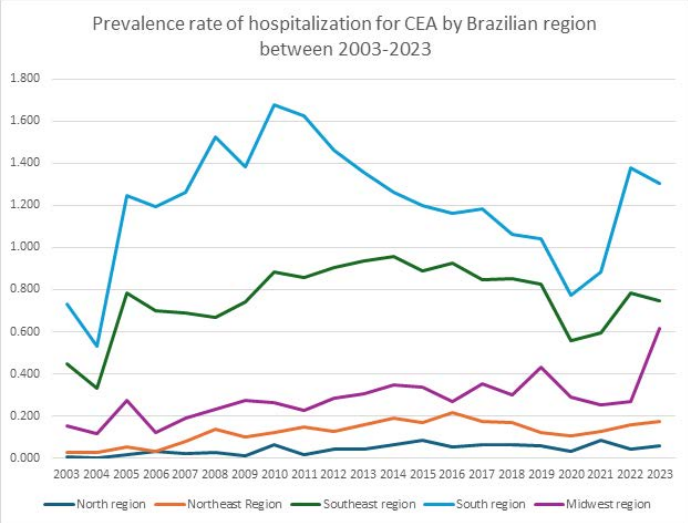

Figure 1: Prevalence Rate for CAS by Brazilian Region 2003-2023

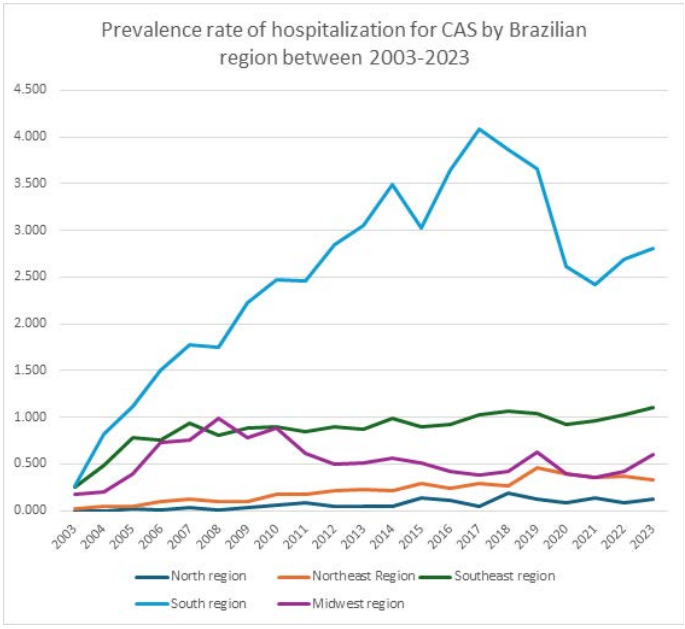

Figure 2: Prevalence Rate of Hospitalization for Cea by Brazilian Region 2003-2023

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Regarding the prevalence of angioplasty in the period analyzed by Regions, it is also possible to observe a higher average rate in the South region (2.5%), with increasing values until 2017, reaching a peak of 4.1%, which decrease until 2023, when reach 2.8%. The decreasing comparison of the prevalence rate values follows the same profile of endarterectomies, with the South region followed, respectively, by the Southeast (0.88%), Central-West (0.53%), Northeast (0. 22%) and North (0.08%), which also occupies the profile with the lowest average and lowest variability of values. Thus, from the calculation of the averages of these state values, it is observed that, in a comparative way, there is a prevalence of angioplasty (0.84%) when compared to endarterectomy (0.48%). Table 3 expresses the relationship between angioplasty and carotid endarterectomy according to Brazilian region between 2003-2023.

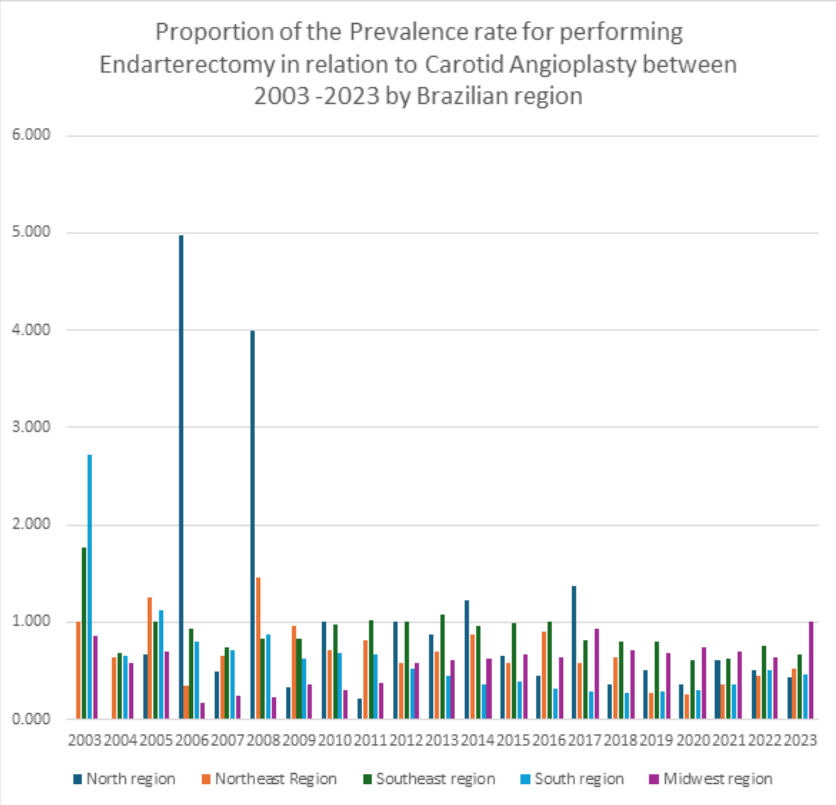

Figure 3: Proportion of CEA-CAS prevalence rate by Brazilian region 2003 - 2023

Furthermore, in relation to the number of deaths per procedure, we can observe a higher average number of deaths related to Angioplasty (8.25 deaths/year/state), when compared to Endarterectomy (7.52 deaths/year/state). In a better analysis of these values, initially in relation to Angioplasty, the highest occurrence of reported deaths occurred in the Southeast region (12.62 deaths/year), followed, and almost tied, by the South region (12.33 deaths / year), and, respectively, by the Northeast (2.80 deaths/year), Central-West (1.60 deaths/year) and North (1.00 deaths/year) regions. Regarding Endarterectomy, the analysis demonstrated that the region with the highest average number of deaths/year was also the Southeast region (12.48 deaths/year), followed, respectively, by the South regions (5.81 deaths/year), Central-West (1.45 deaths/year), Northeast (1.28 deaths/year) and North (0.25 deaths/year). When evaluating the relationship between the total number of deaths from angioplasty compared to endarterectomy according to Region, it was noted that the North leads with an increase in mortality associated with angioplasty at a rate 4 times higher, followed by the Northeast (2.18 times), the South with (2.12 times), Central-West (1.1 times) and Southeast (1.01 times). Therefore, it is possible to affirm a greater number of deaths related to angioplasty, with the Southeast Region leading when evaluating the total number of deaths for both procedures, but when we evaluate the relationship between the number of deaths compared to the two procedures, The North Region leads with a 4-fold increase.

When evaluating the days of stay between 2003 and 2023, the average number of days of hospitalization for the endarterectomy procedure was almost double that for angioplasty, with the first being 9.65 and the second 4.95 days. (1.95 times increase). For endarterectomies, the region with the highest average prevalence was the North (11.14 days), followed by the Central-West (11.04 days), Northeast (9.20 days), South (8.52 days) and Southeast (8.49 days). In the case of angioplasties, the trend was different, with the region with the highest average length of stay being the Central-West (5.14 days), followed by the Northeast (5.08 days), South (4.9 days) , Southeast (4.89 days) and finally the North (4.73 days).

Furthermore, still regarding the days of stay, it is noted that over the years, there was a great variation in days in the North region regarding endarterectomy, with in 2011 the highest average length of stay of all, 34.3 days, and in 2003 the lowest, 2 days (population standard deviation for the entire region: 8.28). This same pattern is repeated in angioplasty procedures, however in different years: the highest average was 13 days in 2006 and the lowest was 1.8 in 2018 (standard deviation for the entire region: 2.75).

Furthermore, the Central-West region presented the highest average length of stay in the most recent data, both for endarterectomy and angioplasty, equivalent to 11.5 days for the first (so that the average for the other regions was: 5.8 in the North; 8.5 in the Northeast; 6.8 in the Southeast; 6 in the South), and 9.3 for the second (with the average for the other regions being: 3.9 in the North; 5.5 in the Northeast; 4. 4 in the Southeast; 6.6 in the South) in 2023.

When analyzing the mortality rate, between 2003 and 2023, the average value associated with endarterectomy procedures at the Brazilian level was higher (2.20%) than that of angioplasty (1.62%). In the case of the first treatment, the analysis of the average mortality rate during the period highlighted the Center-West (3.76%), followed by the Southeast (1.95%), Northeast (1.90%), North (1.70%) and, finally, the South (1.67%). In carotid angioplasty, the Northeast led the mortality rate (2.46%), followed by the South (1.84%), Southeast (1.72%), North (1.12%) and Central-West (0.96%). It is noted that the Midwest is in opposite positions in the two procedures, having a mortality rate 3.96 times higher for endarterectomies in relation to angioplasties, however this disparity is associated with the gap in existing data regarding the mortality rate for angioplasty in the Analysis Region. Figure 4 expresses the proportion of mortality rate according to each procedure.

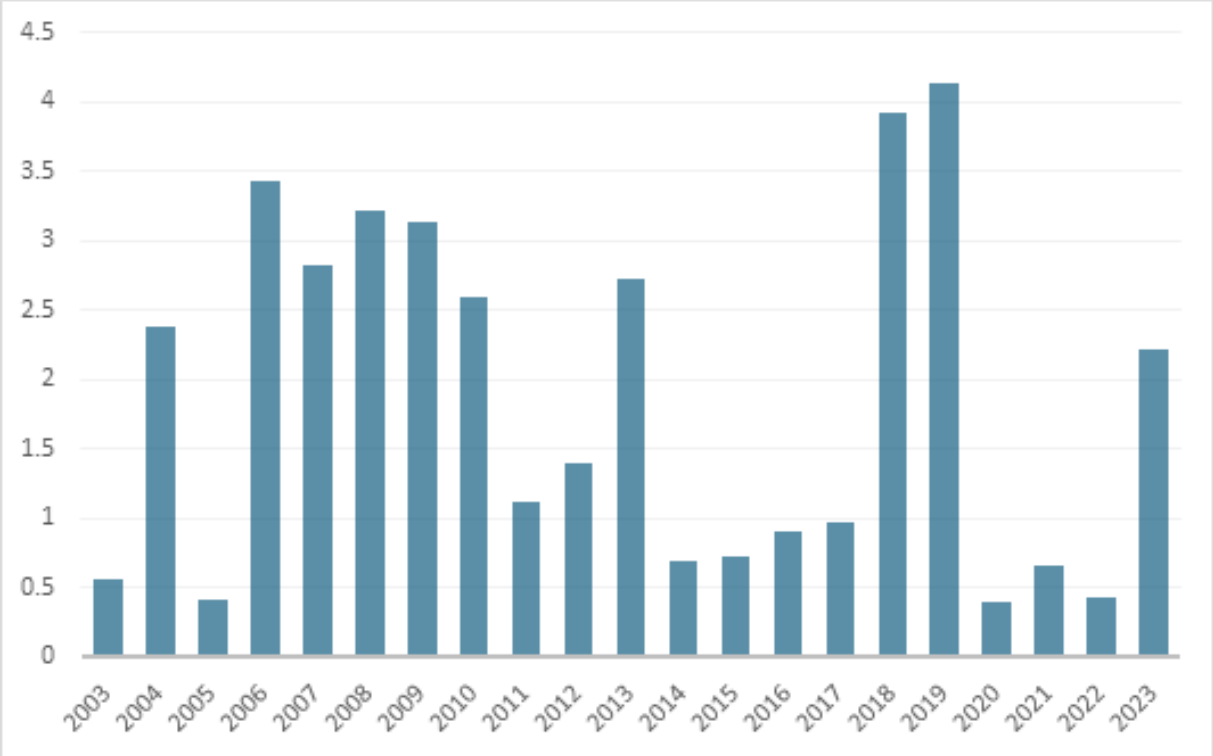

Figure 4:

As for the total value of services, the average expenses for carrying out Angioplasty are approximately four times greater than the total values used for carrying out Endarterectomies, which are, respectively, $1,986,723.40 and $536,529.95. Regarding the analysis of the performance of Angioplasties, we have that, in descending order, the average expenses in reais per state in each year are: South (937,387.02), Southeast (821,635.56), Northeast (130,338.31), Center -West (84,644.86) and North (11,827.28). Even so, the average expenses with Endarterectomies, using the same analysis prism, are: Southeast (322,122.31), South (151,008.62), Northeast (36467.64), Central-West (23,288.03) and North (3,825.52). In a comparative way, relating to the total amounts spent on open surgery/closed surgery, we have that the South and Central-West regions have the highest comparative values, being, respectively, 6.44 and 5.24, followed by the other regions with relatively equal relationships : Northeast (3.94), North (3.44) and Southeast (3.04). The disposition of total expenses according to procedure per year in Brazil in the analyzed period is represented in Figure 5.

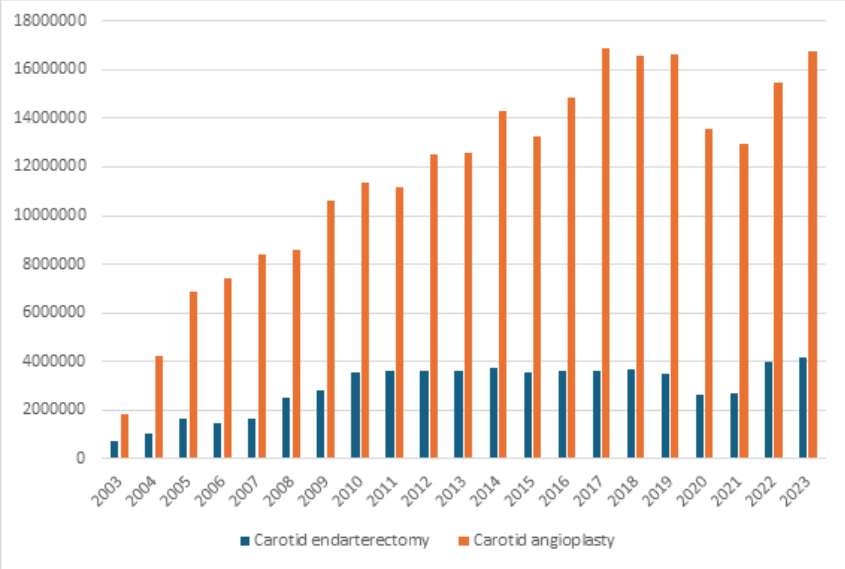

Figure 5: Amount spent on thromboendarterectomy vs. angioplasty by region 2003 - 2023

Analyzing the value of health professionals' services between 2003 and 2023, it is noted that endarterectomies cost 28.19% less than angioplasties, recording $2,541,438.35 and $3,538,943.94 in expenses, respectively. Regarding regions specifically, the region with the highest costs overall was the Southeast with a total of $144,214.41, followed by the South ($110,147.94), Northeast ($19,700.71), Midwest ($13,483.48) , and North ($2,159.61). Regarding each procedure evaluated according to Regions, specifically the region with the highest cost per professional for angioplasty procedures was the Southeast ($75,105.85) and the lowest was the North ($1,287.18) and the region with the highest cost for endarterectomy was the South ($71,921.71) and the smallest the North ($872.43), with no variation in the position of the other Regions.

When examining the prices of hospital services over the same period, endarterectomies cost 77.14% less than angioplasties, recording $8,720,444.06 and $38,144,131.01 in expenses, respectively. Regarding regions specifically, the region with the highest costs overall was the Southeast with a total of $20,979,228.23, followed by the South ($20,532,558.75), Northeast ($3,087,578.78), Central- West ($1,982,382.25), and North ($282,827.07). Regarding each procedure individually, it is noted that for endarterectomy the region with the highest cost was the Southeast ($5,251,062.70) and the lowest was the North ($59,026.21), while in the values associated with angioplasty the South stood out with the highest values ($18,098,738.27) and the North with the lowest ($223,800.85) again, without changing the spending position of the other Regions.

It is important to highlight that the value of the hospital service added to the value of the professional service corresponds to the total value. During the period evaluated, a constant pattern was noted in relation to the cost of endarterectomy in relation to Brazilian regions, with the Southeast leading the expenditure on hospital, professional and, therefore, total services, followed by the South, Northeast, Central-West and North . In terms of angioplasty, the South led the expenditure on hospital, professional and, therefore, total services, followed by the Southeast, Northeast, Central-West and North. Furthermore, when evaluating the nature of care, between 2008 and 2023, the majority of deaths from both procedures occurred in procedures defined as urgent, with 204 deaths from endarterectomy and 406 from angioplasty. In electives, the numbers were 145 and 91, respectively. Thus, the number of deaths in the emergency nature of endarterectomy were 41% higher than those in the elective nature, while in angioplasty they were even higher, equivalent to an increase of 346%. From these numbers, it can be seen, finally, that endarterectomy generates fewer deaths in emergencies (0.5 times less) and angioplasty in elective processes (0.63 times fewer deaths).

When evaluating the nature of care in relation to the mortality rate for both procedures in the period 2008-2023, there is, again, a greater tendency for negative outcomes in emergency procedures: 2.3 times greater for endarterectomies and 2 .09 times for angioplasties, thus there is a 9% reduction in the mortality rate in relation to angioplasty. This trend remains when evaluating elective situations, with rates of 0.8 in angioplasty and 1.4 in endarterectomy. Regarding the nature of the average hospitalization for these forms of treatment, the numbers speak in favor of angioplasty, which generally requires fewer days of hospitalization both in emergency procedures (5.6 days to 9.7 days in endarterectomy) and elective (3.6 days to 7 days of endarterectomy). With the data cited, it can also be seen that emergency procedures in general require more days of hospitalization than elective procedures, following the trend of the topics discussed previously. When analyzing the number of hospitalizations based on their nature in this period from 2008 to 2023, it is clear that in endarterectomy, elective procedures have a higher number of hospitalizations (10,378) than emergency procedures (8,865), whereas angioplasty is noted if the pattern is the opposite, with 19,425 emergency admissions and 11,318 elective admissions. Furthermore, the

preponderance of this last procedure in relation to the total number of emergency and elective hospitalizations is noted, with this value being 2.19 and 1.09 times greater than the total number of endarterectomies, respectively. Finally, the nature of the total value invested in the procedures is discussed, in which there is a greater investment in emergency procedures ($5,601,518.78 for endarterectomies and $26,997,924.78 for angioplasties) in both types of treatments. , with elective costs being $4,594,038.71 and $13,436,725.88, in that order. Therefore, it is clear that angioplasty has much higher costs, whether urgent or elective, costing 4.82 and 2.92 times higher, respectively.

4. Discussion

Initially, we can observe that, on average, during the period analyzed, more angioplasty procedures were performed than endarterectomies at the carotid site in Brazil per year, with the values obtained being, respectively, 343.13 and 220.65. This result differs from that found in the CREST clinical trial study ("Carotid Revascularization Endarterectomy versus Stenting Trial"), which showed higher rates of endarterectomies, in a proportion approximately 3 times higher when compared to angioplasty. This can be explained by the fact that, in the same study, it was shown that performing open surgery offers lower risks of neuroembolic complications (stroke) and, subsequently, a greater risk of death for the patient [24-26].

Regarding the number of deaths, it is possible to observe that the results found in this study, in which an average of 8.25 deaths/year/Region were recorded in the angioplasty procedure, while in endarterectomy 7.52 deaths/year/Region, correspond with the results of studies already carried out, since angioplasty is responsible for the largest number of perioperative deaths, although this difference is not significantly high, since during the study a reduction of approximately 10% in the number of associated deaths was noted in endarterectomy. Thus, it can be noted that the results are consistent with the CREST study, which demonstrated a 5% higher occurrence of deaths or other complications in angioplasty compared to the open procedure, but differed from the ICSS ("The International Carotid Stenting Study"), which elucidated a risk 80 Higher % of complications and deaths associated with the endovascular procedure [25, 26].

Regarding the mortality rate, a higher value is also observed in closed surgery (2.99%) when compared to open surgery (2.4%). This can be explained due to the greater protection offered by endarterectomy in preventing the occurrence of adverse postoperative events, such as stroke [26].

The analysis of the mortality rates of the two procedures did not show marked differences between angioplasty and endarterectomy (2.2% and 1.62%, for CEA and CAS, respectively), similar to American studies (CREST). However, this data disagrees with the European ICSS study, which demonstrated a higher mortality and stroke for angioplasty, 8%, than for endarterectomy, 4.2%. Furthermore, based on the latest data cited, a contrary trend can be seen in Brazil regarding treatment with higher mortality, as the intravascular procedure proved to be less deadly, which was not found in both CREST and ICSS. This may be due to the fact that mortality rate data from multiple years are missing, although it does not justify, for example, the endarterectomy results in the Midwest, which even without the years 2004, 2012, 2014, 2020, 2021 , was the region with the highest mortality for this procedure [24, 25].

The fact that the endarterectomies performed require a longer hospital stay and, therefore, demonstrate a longer average length of stay (9.65 days compared to 4.95 of the CAS) is consistent with the type of procedure, as it is more invasive, requiring longer recovery time. This is consistent with the American literature, although it presents a certain inconsistency, since for both procedures the length of stay in Brazil is much longer than in the USA, which has an average of 1.2 and 2.1 days of stay for angioplasty. and endarterectomy, respectively [27].

Regarding the values of professional and hospital services, it is clear that CAS tends to be much more expensive than CEA (39.25% and 337.41% times more expensive for professional and hospital services, respectively), which follows the premise of the more expensive nature of the procedure, coming into consensus with research carried out in other countries, such as the USA. In the North American country, in a study carried out using the "Premier Perspective Database", it was recorded that angioplasty cost 40% and 37% times more than endarterectomy in asymptomatic and symptomatic patients, respectively. These data are similar with regard to the percentage difference in expenses between professional services in Brazil, however, with regard to hospital services, the difference in values was close to 8 times greater than the difference in the USA [28].

Starting with an analysis of the nature of the procedure (emergency or elective), although angioplasties as an emergency procedure have twice the number of deaths and spend almost 5 times the total cost of endarterectomy, they stand out positively, since their Mortality rate (2.09 to CEA's 2.3) and average length of stay (5.6 days to CEA's 9.7) are lower and were performed more than twice as often as endarterectomy. This alone can justify the greater number of CAS deaths and, in part, its greater total value. In elective procedures, angioplasty performs even better, with a lower number of deaths (91 to 145 in the CEA), a lower mortality rate (0.8 to 1.4 in the CEA) and approximately half the average length of stay (3.6 days to 7 days of CEA). Only the total value of elective CAS is lower than that of the other more invasive procedure, being approximately 2.92 times higher ($13,430,469.02 and $4,591,899.48, respectively), which, again, can be explained in part by the greater number of elective angioplasties performed (940 more surgeries).

5. Conclusion

Extracranial carotid atherosclerosis is a serious clinical condition that requires monitoring and intervention as it significantly increases the risk of stroke and transient ischemic attack. Surgical treatment can be through angioplasty or endarterectomy, and in Brazil, from 2003

to 2023, there were approximately 1.5 times more AIH angioplasties performed compared to endarterectomy. The data analyzed still show a lower mortality rate and shorter hospitalization time for angioplasty, however, this procedure also has a higher average cost. In Brazilian territory, the South region led the prevalence of both procedures, while the North region took the last position. The divergent socio-economic reality in different regions of Brazil explains the difference in the number of procedures, data collection and amounts spent. The present study, whose database comes from DataSUS, has limitations, as there is a gap in records prior to 2008 and underreporting in older data. This resulted in inaccurate information, negatively impacting the epidemiological design of the comparative analysis of surgical treatments for extracranial carotid atherosclerotic disease in Brazil during the period studied.

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