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Original Article

Cost analysis of endovascular treatment for unruptured intracranial aneurysms at a private hospital in Brazil

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Received: 17 June 2024
Accepted: 05 September 2024
Published: 04 October 2024

DOI
10.25259/SNI_475_2024

Quick Response Code:

ABSTRACT

Background: Intracranial aneurysms have a prevalence of 1–6% and significant rupture risks, leading to high morbidity and mortality. Endovascular therapy demands an understanding of its economic impacts. This study evaluates the costs and complications of unruptured intracranial aneurysm treatment in a private Latin American hospital.

Methods: A retrospective longitudinal observational study was carried out in a private hospital in Brazil from February 2015 to January 2021. Patients undergoing elective endovascular treatment for unruptured intracranial aneurysms (UIAs) were included in the study. Data collected included patient demographics, aneurysm characteristics, treatment modalities, costs, and clinical outcomes. Costs were adjusted to their present value in 2023 US dollars (USD). Descriptive statistics summarized the data.

Results: A total of 77 patients (68 females and nine males) with 111 aneurysms were included. The average total cost per patient was $31,831.08, with materials (65.9%) and hospital daily rates (11.3%) being the primary cost drivers. Device associations included flow diverter (51.9%), stent-assisted coiling (19.2%), and coiling (11.5%). Clinical outcomes were favorable, with an average inpatient stay of 6.5 ± 10.2 days, 6.5% of patients requiring readmission for complications, and no deaths within 90 days. The highest costs were associated with coiling and stent-assisted coiling.

Conclusion: The cost of endovascular treatment for UIAs at a private hospital in Brazil is substantial, primarily driven by materials and hospital daily rates. Despite high costs, clinical outcomes were favorable, with low complication rates. These findings underscore the need for continuous cost-effectiveness evaluation and treatment optimization to balance clinical benefits with financial considerations.

Keywords: Cost analysis, Endovascular procedures, Health expenditures, Hospital costs, Intracranial aneurysm, Treatment complications

INTRODUCTION

Background

Intracranial aneurysms are characterized by dilations in the arterial wall occurring within the subarachnoid space, most frequently at vessel bifurcation points.[28] The prevalence of these aneurysms in the adult population ranges from 1% to 6%, as evidenced by large autopsy

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series,[15,22] with a rupture risk varying between 0% and 50% over 5 years, depending on location and personal history.[31] Subarachnoid hemorrhage resulting from aneurysm rupture is a catastrophic event associated with high morbidity and mortality rates: Approximately 12% of patients die before receiving medical attention,[27] 40% of those hospitalized die within a month, and over one-third of survivors suffer significant neurological deficits.[12,16,20,24,26]

Over recent decades, the treatment of intracranial aneurysms has significantly evolved, with emerging paradigms around various therapeutic options.[4] The primary treatment modalities are surgical clipping and endovascular therapy.[9] Numerous studies and reviews comparing these techniques have been published, with many demonstrating superior clinical and functional outcomes for endovascular embolization.[1,2,7,19] Furthermore, the number of endovascular procedures has increased rapidly,[8,14] underscoring the importance of understanding the economic impacts and related expenses of this therapeutic approach. Consequently, some studies have aimed to elucidate the economic and expenditure aspects of endovascular therapy [1,3,6,9,32], highlighting various influencing factors, including socioeconomic, patient-specific, and hospital-related variables.[3]

Objectives

In light of the above, this study aims to evaluate the costs and clinical complications of endovascular treatment for unruptured intracranial aneurysms (UIAs) in a private hospital in Latin America.

MATERIALS AND METHODS

Study design and patient population

This retrospective longitudinal observational study was conducted at the Department of Interventional Medicine, Neurointervention section, at Hospital Israelita Albert Einstein, São Paulo, Brazil. The study period spanned from February 2015 to January 2021. We included patients who underwent elective endovascular treatment for UIAs during the study period. Patient selection was based on the availability of complete clinical and cost data.

Clinical data and outcomes analysis

General information, including sex, age, and presence of comorbidities (hypertension, smoking, and alcohol use) or related major events (trauma or subarachnoid hemorrhage), was collected. Detailed clinical data encompassed primary, secondary, tertiary, quaternary, and quinary diagnoses when present. Specific information on the aneurysms, such as the number of aneurysms, their locations, and sizes (maximum diameter and neck width), was also recorded. The aneurysm size was categorized as small (<10 mm), large (10–25 mm), and giant (>25 mm), and 4 mm was the discriminative value for small and wide necks.

Clinical outcomes were assessed based on complications, readmissions and their causes, length of hospital stay, and the need for reinterventions. This data was used to evaluate the efficacy and safety of the endovascular treatment.

Cost data and analysis

For the cost analysis, data were extracted for up to 90 days post-hospitalization. This included costs incurred during diagnostic medicine, emergency unit visits, and inpatient care. All expenses were converted to US dollars (USD) using the average exchange rate for the year 2023. In addition, all costs were adjusted to their present value in 2023, accounting for inflation and other economic factors such as changes in healthcare pricing, technological advancements, and variations in medical service fees to ensure accurate and current financial representation.

We performed a comprehensive analysis of the costs associated with planned procedures, reinterventions, readmissions, and other complications. This analysis provided insights into the financial burden of endovascular treatment, offering a detailed evaluation of the economic impacts related to elective endovascular management of UIAs.

Statistical analysis

Descriptive statistics were employed to summarize patient demographics, clinical characteristics, and cost data. Continuous variables were presented as means with standard deviations (SDs) to provide a measure of central tendency and dispersion. In addition, medians and interquartile ranges (IQR) were reported to capture the central tendency and variability in a non-parametric manner. Categorical variables were summarized as frequencies with corresponding percentages. Comparative analyses were conducted to identify significant differences in costs and clinical outcomes.

Ethical considerations

The study was conducted in accordance with the ethical standards of the Institutional Research Committee, and the Institutional Review Board approved the study protocol (ethical committee approval number CAAE 46199521.2.0000.0071).

RESULTS

Patient demographics and clinical characteristics

A total of 77 patients undergoing elective endovascular treatment for UIAs were included in the study. The cohort

comprised 68 females (88.3%) and 9 males (11.7%); the prevalence ratio (PR) for women compared with men was 7.56, with a mean age of 54.9 ± 13.8 years. Comorbidities information was not available in a great portion of the participants: 10.4% for hypertension, subarachnoid hemorrhage, and history of trauma, 97.4% for smoking, and 98.7% for alcohol use. Of the patients with available data, 43.5% (30 of 69 patients) had hypertension, 14.5% (10 of 69) subarachnoid hemorrhage, and no patient had a history of trauma (zero of 69). For the comorbidities with more expressive missed information, 100% (2 of 2 patients) had a history of smoking, and 50% (1 of 2 patients) had alcohol use.

Aneurysm characteristics

The study recorded a total of 111 aneurysms among the 77 patients, with 25 patients having multiple aneurysms: 20 patients had two aneurysms, three had three aneurysms, and two had five aneurysms. Missing aneurysm information occurred in one aneurysm on location, two on size, and in 27 on aneurysm neck size. About the available information, the majority of aneurysms (95%; n = 105) were located in the anterior circulation, specifically the internal carotid artery (58%; n = 64), anterior communicating artery (16%; n = 18), and medial cerebral artery (14%; n = 16). Posterior circulation aneurysms accounted for 5.4% (n = 6), primarily in the vertebral artery (3.6%; n = 4) and basilar artery (1.8%; n = 2). Regarding size, the majority of aneurysms were small, accounting for 90.8% of the available data (99 of 109 aneurysms), with none classified as giant (mean maximum diameter 5.5 ± 3 mm). Concerning the aneurysm neck, the majority were also small, representing 79.8% of the available data (67 of 84 aneurysms). Magnetic resonance angiography was the predominant initial radiological examination utilized for studying aneurysms, accounting for 52.3% (n = 58), while computed tomography angiography was utilized for the remaining cases (47.7%; n = 53).

Endovascular treatment

The endovascular materials recorded in this study included coils, stents, and flow diverters. Among the 77 patients treated (i.e., including 25 patients with multiple aneurysms), different associations of devices were observed. The most common device associations were isolated use of a flow diverter (45.4%; n = 35), followed by coiling (15.6%; n = 12), stent-assisted coiling (15.6%; n = 12), coils associated with flow diverter (7.8%; n = 6), isolated use of stent (7.8%; n = 6), stent associated with a flow diverter (6.5%; n = 5), and a single case of stent-assisted coiling associated with pipeline flow diverter (1.3%; n = 1). All these procedures utilized 48 stents, 123 coils, and 26 pipeline flow diverters.

A subgroup analysis of patients with single aneurysms (n = 52) was conducted, and the distribution of patients across different treatment groups, presented in descending order of prevalence, was as follows: flow diverter in 27 patients, stent-assisted coiling in 10 patients, isolated coils in six patients, flow diverter with coils in four patients, flow diverter associated with usual stent in three patients, and isolated usual stent in two patients.

Cost analysis

We analyzed the overall cost per patient, including a detailed breakdown of expenses for each individual. In addition, we performed subgroup analyses for patients with single aneurysms to assess the costs by treatment approach.

The average total cost per patient was USD 31,831.08 ± $28,367.08. This amount includes additional expenses incurred due to readmissions or emergency department visits within 90 days post-procedure. Among these visits, 35 (45%) were for minor issues not requiring reintervention or invasive procedures, with a median cost of $193.54 (IQR = $121.18 - $365.25). Five visits (6.5%) were for complications related to aneurysm treatment necessitating clinical hospitalization, with a median cost of $4,571.62 (IQR = $3,441.04 - $12,914.71). Four visits (5.2%) were for the treatment of another aneurysm, with a median cost of $24,512.02 (IQR = $20,757.24 - $28,073.42). One patient (1.3%) required rehospitalization for re-treatment of the aneurysm, with a cost of $32,295.59.

A breakdown of costs revealed that materials (65.9%) and hospital daily rates (11.3%) accounted for the majority of the expenses, followed by hospital fees for non-routine equipment and examinations (6.1%), medications (5.8%), nursing care (4.8%), laboratory and radiological exams (3.9%), and non-medical staff fees (1.1%). Physician fees were not included in the cost analysis due to their variability and dependence on direct agreements with patients.

Among the different associations of devices observed in the 77 patients treated, including those with multiple aneurysms, the average cost of materials was $20,975.63 ± $8,978.09. In descending order of value, the average total treatment cost was $41,838.96 ± $43,883.79 for the isolated use of coils, $41,491.16 for a single case of stent-assisted coiling associated with a flow diverter, $40,318.93 ± $55,329.01 for stent-assisted coiling, $33,193.44 ± $14,144.86 for stent associated with flow diverter, $28,770.80 ± $10,194.86 for the isolated use of stent, $26,482.33 ± $5,051.10 for the pipeline flow diverter, and $26,355.60 ± $11,871.90 for coils associated with flow diverter.

A subgroup analysis of patients with single aneurysms (n = 52) was conducted to assess costs by treatment approach. The average total cost for the endovascular treatment per patient in this subgroup was $32,333.04 ± $32,274.04. The average total costs and SDs for each treatment modality in

patients with single aneurysms, presented in descending order of value, were as follows: $52,917.07 ± $51,674.67 for isolated coils, $42,907.29 ± $60,825.34 for stent-assisted coiling, $32,227.09 ± $1,864.32 for isolated stent use, $26,446.7 ± $6,490.73 for stent associated with flow diverter, $25,913.35 ± $4,789.89 for flow diverter, and $22,822.04 ± $13,543.70 for flow diverter with coils.

A breakdown of costs revealed that materials (65.7%) and hospital daily rates (11.4%) accounted for the majority of the expenses, followed by hospital fees for non-routine equipment and examinations (6.1%), medications (5.8%), nursing care (4.8%), laboratory and radiological exams (3.9%), and non-medical staff fees (1.1%). Physician fees were not included in the cost analysis due to their variability and dependence on direct agreements with patients.

Clinical outcomes

The average length of inpatient stay was 6.5 ± 10.2 days. Five patients (6.5%) required readmission for clinical management (without the need for invasive procedures) due to causes directly or indirectly related to the endovascular treatment. The five different causes were ischemic stroke, arteriovenous fistula at the femoral access puncture site, aspiration pneumonia, dyspnea due to an adverse reaction to ticagrelor, and severe back and limb pain attributed to prolonged immobilization following the endovascular procedure. One patient (1.3%) required re-treatment within 90 days. No patients died within 90 days of the procedure.

DISCUSSION

This study provides a detailed cost analysis of endovascular treatment for UIAs at a private hospital in Brazil, presenting valuable insights into the economic and clinical aspects of this therapeutic approach. The average total cost per patient was $31,831.08, with the majority of expenses driven by the cost of materials and hospital daily rates.

A noteworthy finding in our study is the significant gender disparity, with 88.3% of patients being female (PR for women compared with men was 7.56). This discrepancy raises several questions about the underlying reasons. Biological factors such as hormonal, genetic, and anatomical differences are well-documented in the literature and might contribute to this imbalance.[13] However, overdiagnosis in women due to more proactive health-seeking behaviors and screening practices could also play a role. While the literature indicates that approximately 68.75% of intracranial aneurysms occur in women in populations with a mean age exceeding 50 years (PR of 2.2 in study populations with a mean age of more than 50 years),[21] our study's higher percentage suggests that additional factors, such as potentially higher diagnosis rates among women in private healthcare settings, may influence this statistic. There may also be a greater inclination or desire for treatment among women, further influencing these findings. Further research is needed to elucidate the precise causes of this gender disparity.

The aneurysms treated at our institution were predominantly small, with a mean maximum diameter of 5.5 mm. This reflects the hospital's profile of treating UIAs at an earlier stage, likely due to proactive screening and advanced diagnostic capabilities. Small aneurysms are generally associated with a lower risk of rupture, influencing the decision to opt for endovascular treatment over surgical options.

Our study observed a variety of device combinations used in the treatment of UIAs. The most common approaches included flow diverter, stent-assisted coiling, and coiling. This choice of devices reflects the complex decision-making process in treating cerebral aneurysms, where factors such as aneurysm size, location, and neck width must be carefully considered. The use of multiple devices, in some cases, highlights the tailored approach required for effective aneurysm management.

Regarding the budget for these treatments, the high cost of endovascular devices, including coils, stents, and flow diverters, significantly impacts the overall treatment expenses. Materials alone accounted for 65.9% of the total costs, underscoring the financial burden associated with these procedures. Our findings are consistent with other studies reporting high costs for endovascular treatments. For example, a study conducted in Mexico reported an average intervention cost of $21,687.22 for endovascular treatment of UIAs, influenced by factors such as aneurysm size, neck size, and localization in the cavernous segment of the internal carotid artery.[11] In the United States, hospitalization costs for endovascular coiling were found to be higher than Medicare reimbursements, with median costs in 2008 being $25,734 for uncomplicated cases and $40,502 for cases with major morbidity.[5] A comparative study in South Korea indicated that the total hospital costs for endovascular coiling were significantly higher than for surgical clipping, with mean costs of ₩11,700,000 compared to ₩8,280,000, respectively, strongly correlated with aneurysm diameter.[17] In addition, in a study focusing on giant intracranial aneurysms, the total direct treatment costs for endovascular treatment were significantly higher than for surgical treatment, primarily due to the high cost of implants used in endovascular procedures.[10] Therefore, addressing the economic implications of endovascular treatments remains crucial for healthcare planning and resource allocation in managing intracranial aneurysms.

According to the existing literature, among endovascular treatments for UIAs, coiling typically represents the most expensive option due to the high cost of devices used

in the procedure. Twitchell *et al*.[30] reported that both coiling and flow diversion were the costliest approaches, with supplies, including the cost of coils and flow diverter devices, constituting the largest portion of expenses at 43.2% and 57.5% of the total, respectively. Our findings indicate somewhat different trends; while the most expensive approach was coil embolization, the use of flow diverters ranked among the two least costly endovascular treatments – only slightly more expensive than the combination of flow diverters with coils. According to our results, stent-assisted coiling emerged as the second most expensive endovascular treatment, following coil-only treatment. This challenges the prevailing paradigm that flow diverter treatments are among the most expensive. However, these trends may be influenced by other factors such as aneurysm location, aneurysm size and neck width, and even patient age – factors previously noted by other authors as contributing to higher treatment costs.[11,17] These observations suggest that the use of flow diverters may, in fact, be associated with lower costs compared to older endovascular treatments such as coiling and stent-assisted coiling.

The complication rates for endovascular treatments of UIAs vary depending on the specific procedure and patient characteristics. According to the American Heart Association/American Stroke Association guidelines,[29] a systematic review of literature from 1990 to 2002 by Lanterna *et al*.[18] reported that procedural complications decreased from 8.6% to 4.5% in studies after 1995, with a case fatality rate of 0.6% and a permanent morbidity rate of 7%. Another study, the Analysis of Treatment by Endovascular Approach of Non-ruptured Aneurysms (ATENA),[25] found treatment-related adverse events in 15.4% of cases, including thromboembolic events in 5.4% and aneurysm rupture during the procedure in 2.6%. A meta-analysis by Naggara *et al*.[23] also highlighted that the procedural unfavorable outcome rate was 4.8%, with a mortality rate of 1.8% and unfavorable outcomes (including death) occurring in 4.7% of patients. The study also noted that the use of liquid embolic agents and flow diversion was associated with higher risks of complications, with unfavorable outcomes occurring in 11.5% of patients treated with flow diversion.

Our study reported a lower complication rate compared to the ATENA study, which found treatment-related adverse events in 15.4% of cases. The ATENA study, conducted across 27 neurointerventional centers in Canada and France between June 2005 and October 2006, reflects outcomes from a heterogeneous patient population treated over a decade ago. The variation in practices and perioperative care protocols among multiple centers could contribute to higher complication rates. In contrast, our study's single-center design at a high-volume, specialized neurointerventional center ensures more consistent care, rigorous perioperative and postoperative management, and close ambulatory follow-up. These factors likely contributed to the improved outcomes observed in our study.

In conclusion, the cost of endovascular treatment for UIAs at a private hospital in Brazil is substantial, with materials and hospital daily rates being the primary cost drivers. The choice of device used markedly influences the total cost, particularly with coiling and stent-assisted coiling being the most expensive options. Clinical outcomes in our cohort were favorable, with a lower complication rate compared to multicenter studies, possibly due to the specialized nature of our single-center study and rigorous perioperative care. These findings highlight the need for ongoing evaluation of cost-effectiveness in endovascular treatments and underscore the importance of optimizing treatment protocols to manage UIAs effectively while mitigating financial burdens. Future studies should aim further to elucidate the cost-benefit dynamics of different endovascular approaches and explore potential avenues for reducing treatment costs without compromising clinical outcomes.

Limitations and generalizability

A significant limitation of this study is the short follow-up period for patients. While a 3-month follow-up is crucial for assessing the initial efficacy of endovascular treatment and identifying the need for additional interventions, longer-term follow-up is also essential to monitor the stability of the treatment and detect late recanalizations or aneurysm growth, which can occur even after initial complete occlusion.

CONCLUSION

This study provides a comprehensive cost analysis of endovascular treatment for UIAs at a private hospital in Brazil. The average total cost per patient was $31,831.08, with materials (65.9%) and hospital daily rates (11.3%) being the primary cost drivers. Coiling and stent-assisted coiling emerged as the most expensive treatment options, whereas the use of flow diverters was among the least costly. Despite these substantial costs, clinical outcomes were favorable, with a low complication rate. These findings emphasize the need for continuous cost-effectiveness evaluation and treatment optimization.

Ethical approval

The research/study was approved by the Institutional Review Board at Hospital Israelita Albert Einstein, number 46199521.2.0000.0071, dated June 21, 20221.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

Use of artificial intelligence (AI)-assisted technology for manuscript preparation

The authors confirm that there was no use of artificial intelligence (AI)-assisted technology for assisting in the writing or editing of the manuscript and no images were manipulated using AI.

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How to cite this article: Tatit RT, Malheiro DT, Abud TG, Baccin CE. Cost analysis of endovascular treatment for unruptured intracranial aneurysms at a private hospital in Brazil. Surg Neurol Int. 2024;15:366. doi: 10.25259/SNI_475_2024

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