ORIGINAL ARTICLE
ARTIGO ORIGINAL

Comparative approaches to estimating lifetime post-stroke costs

Abordagens comparativas para estimar os custos pós-AVC

Henrique Diegoli[1], Juliana Safanelli[2], Vivian Nagel[2], Rafaela Bitencourt Liberato[2], Vanessa Guesser[2], Ivonei Bittencourt[2], Paulo Henrique Condeixa França[2], Marcia Makdisse[1], Davi de Santi[3], Gabriel Toffoli da Silva[3], Karynna Pimentel Viana[3], Pedro Magalhães[1]

DOI: 10.21115/JBES.v17.p2-10

Keywords:
stroke, productivity loss, direct costs, indirect costs, time-driven activity-based costing

ABSTRACT

Introduction: Stroke has a significant impact on health and has risen by 62% among individuals under the age of 45, which mainly represents greater productivity losses. **Objectives:** To estimate the lifetime direct and indirect financial burden of stroke in Brazil, comparing the estimates obtained through Time-Driven Activity-Based Costing (TDABC) with the reimbursement data for public (DataSUS) and private (TISS) patients. **Methods:** We developed a Markov model to simulate the lifetime costs associated with stroke. Transition probabilities, the frequency of resource use, and productivity loss were derived from the population-based Joinville Stroke Registry (Joinvasc). The direct costs included medication and healthcare services, while indirect costs covered formal and informal caregiving, nursing home stays, and productivity loss. We assessed healthcare services costs using the TDABC method and compared these with reimbursement values from DataSUS and TISS. The protocol was approved by the Institutional Review Board (53991221.1.0000.5362). **Results:** Applying TDABC, we estimated the total discounted post-stroke costs to be BRL 96,562. In comparison, total discounted costs estimated using reimbursement values from DataSUS and TISS were BRL 71,498 and BRL 125,569, respectively, showing significant variations (BRL 30,404 with TDABC, BRL 4,378 with DataSUS, and BRL 48,748 with TISS). Indirect costs amounted to BRL 63,588, with productivity loss being the most significant contributor (BRL 59,990). **Conclusions:** Prioritizing TDABC for costing and analyzing indirect costs is crucial for understanding the stroke's financial burden in Brazil. The prevalent reliance on healthcare reimbursement data for decision-making might overlook substantial stroke-related costs, potentially limiting access to necessary treatments.

Palavras-chave:
AVC, perda de produtividade, custos diretos, custos indiretos, custeio baseado em atividades por tempo

RESUMO

Introdução: *O AVC tem impacto significativo na saúde e aumentou em 62% entre pessoas com menos de 45 anos, resultando em maiores perdas de produtividade.* **Objetivos:** *Estimar o impacto financeiro direto e indireto do acidente vascular cerebral (AVC) no Brasil, comparando as estimativas obtidas por meio do custeio baseado em atividades por tempo (TDABC) com os dados de reembolso para pacientes públicos (DataSUS) e privados (TISS).* **Métodos:** *Desenvolvemos um modelo de Markov para simular os custos associados ao AVC. Os dados foram baseados na população derivada do Registro de AVC de Joinville (Joinvasc). Os custos diretos incluíram medicamentos e serviços de saúde, enquanto os custos indiretos cobriram cuidados formais e informais, estadias em lares de idosos e perda de produtividade. Avaliamos os custos dos serviços de saúde usando o TDABC, comparando-os com os valores de reembolso do DataSUS e TISS. O protocolo foi aprovado pelo Comitê de Ética em Pesquisa (53991221.1.0000.5362).* **Resultados:** *Aplicando o TDABC, estimamos que os custos totais descontados pós-AVC sejam de BRL 96.562. Em comparação, os custos totais descontados usando valores de reembolso do DataSUS e TISS foram BRL 71.498 e BRL 125.569, respectivamente, mostrando variações significativas. Os custos indiretos totalizaram BRL 63.588, sendo a perda de produtividade o maior contribuinte (BRL 59.990).* **Conclusões:** *Priorizar o TDABC para custeio e analisar os custos indiretos é crucial para entender o impacto financeiro do AVC no Brasil. A dependência predominante dos dados de reembolso de serviços de saúde pode negligenciar custos substanciais relacionados ao AVC, potencialmente limitando o acesso a tratamentos necessários.*

Received on: 26/09/2024. **Approved for publication on:** 12/12/2024.
1. Academia VBHC, São Paulo, São Paulo, Brazil.
2. Joinvasc, Joinville, Santa Catarina, Brazil.
3. AstraZeneca, Cotia, São Paulo, Brazil.
Conflict of interests: The current work was funded by AstraZeneca, which was involved in the review and approval of the manuscript.
Corresponding author: Henrique Diegoli. Academia VBHC, Min Godoi Street 637, ap. 31, Perdizes, São Paulo, SP, Brazil.
CEP: 05015-000. Telephone: +55 (47) 8407-4072. E-mail: hdiegoli@academiavbhc.org

Introduction

Stroke is a leading cause of death and disability globally, with a concerning shift towards affecting younger age groups in recent decades (Katan & Luft, 2018; Owolabi *et al.*, 2022). This trend is particularly prominent in low- and middle-income countries, with rising cardiovascular risk factors among young adults (Katan & Luft, 2018). In recent decades, Brazil has seen stroke incidence rise by 62% under age 45 and 29% under age 55 (Cabral *et al.*, 2016). Younger stroke patients encounter reduced life expectancy and quality-adjusted life years, alongside greater productivity losses and long-term healthcare expenses.

Despite stroke's significant health impact in Brazil and the public healthcare system (SUS) entitling all residents with universal healthcare access without out-of-pocket costs, substantial nationwide disparities in access to and quality of stroke care remain (Diegoli *et al.*, 2023b; Ouriques Martins *et al.*, 2019). Acute stroke care and rehabilitation units are covered by SUS, yet their regional accessibility varies and is often limited. Similarly, while some cities offer free nursing home social care, access to these services is frequently restricted.

In the SUS, healthcare funding responsibilities are divided among the federal government, which accounts for high-complexity care, state governments, which cover medium-complexity care, and municipalities, which are accountable for primary care. For hospital admissions, the Ministry of Health establishes a fixed reimbursement fee per procedure (Ministry of Health, 2023). Upon discharge, hospitals bill the federal government for provided procedures. However, reimbursement fees often fall below actual healthcare costs, with the shortfall made up by state or municipal funds. However, federal reimbursement is typically viewed as the actual costs in decision-making, such as in the development of cost-effectiveness models for healthcare policy implementation. The private sector also operates on fee-for-service reimbursement, like the public system, but fees may differ among insurers.

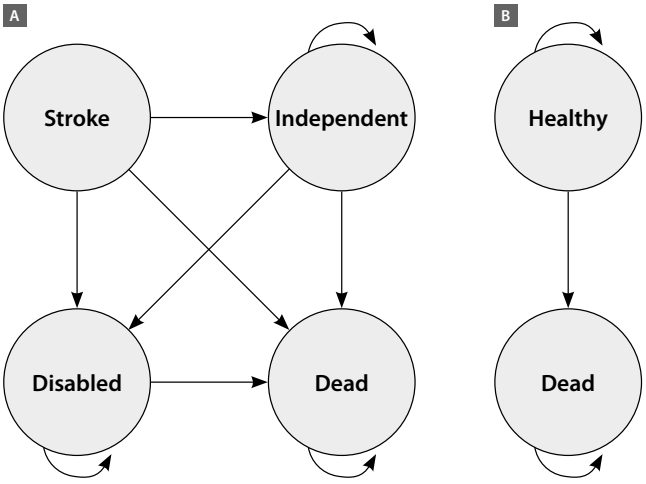
Time-driven activity-based costing (TDABC) determines costs by calculating the time a patient spends with healthcare resources such as physicians, nurses, or equipment and the cost per time unit of each resource. Thus, TDABC offers a more precise insight into the costs associated with stroke care.

This study aims to estimate stroke's direct and indirect lifetime costs in Brazil. Additionally, we seek to compare the total costs calculated with TDABC against reimbursement values and, as an exploratory analysis, contrast public costs derived from TDABC with private healthcare reimbursement figures.

Methods

We estimated the lifetime costs after a stroke using a Markov model, which simulates the progression of an individual's health status over time. This model is specifically useful for chronic diseases, like post-stroke follow-up. The model started with patients who had suffered a stroke and tracked their progress through three health states: independent, disabled, or dead (see Figure 1 for a visual representation). We obtained most inputs for the model from the Joinville Stroke Registry (Joinvasc), which provided data on transition probabilities and costs for each cycle, complementing nationwide mortality and income data. The Institutional Review Board approved the protocol 53991221.1.0000.5362.

The Markov model used Joinvasc data to estimate patients' proportion in different health states after a stroke (dependent, independent, dead) for each 10-year age group between 20 and ≥80 years. Then, unit prices and quality of life were assigned to each health state. The study adopted a societal perspective, using a 40-year time horizon and a 5% discount rate.



A: Persons with a stroke. **B:** Persons in the general population without a stroke.

Figure 1. Markov models are used to estimate long-term costs following a stroke.

The Joinvasc

The Joinville Stroke Registry (Joinvasc) is a prospective population-based stroke registry including all stroke patients living in the city of Joinville since 2009 (Diegoli *et al.*, 2022). We employed its data to assess risks of post-stroke death, recurrence, resource use by dependent or independent post-stroke patients and costs through TDABC.

The registry is regulated by municipal law, ensuring the inclusion of every stroke patient in the city through a three-step approach (Sudlow & Warlow, 1996). Follow-up data, collected via phone calls up to five years post-stroke onset, includes evaluations of functional status using the Modified Rankin Scale (mRS), mortality, stroke recurrence, and resource use. This study analyzed resource use and TDABC for patients within the public healthcare system, representing about 80% of Joinvasc's patients (Diegoli *et al.*, 2022). Detailed Joinvasc methodologies are documented in published articles (Cabral

et al., 2009; Diegoli *et al.*, 2022; Diegoli *et al.*, 2023a; Katan & Luft, 2018).

We used three patient cohorts from the Joinvasc since the types of information available varied over time:

- Patients admitted to any hospital in Joinville from October 2009 to December 2021 were the basis for calculating the mean age at stroke onset, post-stroke outcomes (independence (mRS 0-2), dependence (mRS 3-5), and mortality 3 months post-stroke), annual mortality risk by mRS, annual stroke recurrence risk, and risk of functional decline after stroke recurrence.
- Patients admitted to a public hospital from March 2018 to November 2021 were the basis for calculating resource use post-stroke, categorized by one-year mRS.
- Patients admitted to a public hospital from September 2016 to November 2019, with healthcare costs assessed using TDABC (Diegoli *et al.*, 2022).

Patients with missing data were not included in the analysis, and those with missing one-year mRS data were excluded from the resource use calculation because it was not possible to determine their group assignment. In addition, patients who died within one year of follow-up were also excluded from this calculation, as the missing data could not be collected after death.

Unit costs

The cost estimates were grouped into direct costs, including healthcare services and medication, and indirect costs, covering formal and informal caregiving, nursing home stays, and productivity loss. Healthcare services encompassed initial hospital admission, admissions for recurrent stroke or other post-stroke reasons, plus primary and specialized care visits, and rehabilitation. Post-discharge medication costs were only outpatient oral anticoagulants and antiplatelets, with medications administered during hospital stays included in hospital costs.

Three distinct approaches were employed to estimate the cost of healthcare services:

1. Public healthcare with TDABC (Diegoli *et al.*, 2022): TDABC calculates the actual healthcare costs by recording the time professionals spend on each care step for hospital admissions, medical visits, and rehabilitation sessions. It is, then, multiplied by the average hourly wages of directly and indirectly involved professionals. Additionally, the expenses with public utility services, administration, and other support services were incorporated.
2. Public healthcare with DataSUS (DataSUS, 2022; Ministry of Health, 2023): This approach uses government reimbursement fees to providers and is the primary method for economic evaluations in public healthcare.
3. Private healthcare with TISS (Agência Nacional de Saúde Suplementar, 2023): This method is based on reimbursement data between health insurance agencies and providers commonly used in economic evaluations in the private sector.

In the DataSUS and TISS approaches, average reimbursement prices for hospital admissions resulted from governmental databases, calculating the average reimbursement for all patients with an ICD-10 diagnosis of I60-I66 in the public and private healthcare systems. For post-hospital services, the unit costs provided in the public sector through the SIGTAP table are fixed fees. The private sector uses TISS to report average reimbursement rates per procedure. Medication costs were obtained from the Brazilian Medicines Market Regulation Chamber (CMED). The costs associated with caregivers and nursing homes were collected directly from patients and their families in the TDABC cohort using the reported average costs.

All unit costs were adjusted for inflation using the implicit deflator of the Gross Domestic Product (GDP) for the period (International Monetary Fund, 2021), and all costs in 2023 were Brazilian Reais (for comparison, purchasing power parity USD 1.00 = BRL 2.66) (International Monetary Fund, 2021).

Indirect costs

To estimate productivity loss, we initially calculated the anticipated income for each individual, assuming a stroke had not occurred, and contrasted this with post-stroke income projections. The average annual income of a working person in Brazil was BRL 32,724 (Brazilian Institute of Geography and Statistics, 2022). The potential lifetime productivity of an individual unaffected by stroke was determined using general population mortality rates multiplied by the employment rate within each age group before stroke, according to Joinvasc data. The difference represents the productivity loss attributable to stroke. Unit costs for formal caregivers and nursing homes resulted from the average prices reported by patients in the Joinvasc.

Statistical analysis

The age distribution at stroke onset was obtained from the Joinvasc, and the RStudio® package "fitdistrplus" was used to identify the best-fitting probability distribution according to the Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC), which was the Weibull distribution. Exponential distributions were applied to model the risks of death and recurrent stroke, facilitating the assumption of constant risks over time.

Costs were calculated for each 10-year age cohort from 20 to 80 and over 80 rather than using the average age of patients. This approach allowed us to account for the variance in post-stroke costs across different age groups. It provided a more accurate estimate of total stroke costs,

highlighting the disproportionately higher financial impact on younger patients.

Sensitivity analysis

The model's sensitivity to parameter changes was assessed through probabilistic sensitivity analysis, employing Monte Carlo simulations with 1,000 iterations. In each iteration, variable values were randomly resampled based on their distributions. This analysis produced 95% credible intervals (95% CI) around the central cost estimates of the model.

Age distribution was modeled using the Weibull distribution, proportions using the beta distribution, and costs and the number of medical visits with the gamma distribution. The age confidence interval was set between 58 and 75 years, aligning with the 25th to 75th percentiles of the Weibull distribution. Cholesky decomposition was used to calculate different age distributions. Costs varied by ±25%, and other parameters varied according to the standard errors of their original data.

Results

Population and parameter estimation

Of the 8,235 patients registered in the Joinvasc by December 2021, 4 (0.1%) have been excluded due to missing data. The remaining dataset informed the model inputs. For resource use calculations, out of 1,221 patients, 161 (13.2%) were excluded for missing data, remaining 1,060 patients. The TDABC unit cost calculations drew on 607 patients, with 18 (3.0%) excluded due to missing data, resulting in a cohort of 589 patients. Supplementary Table 1 details the primary characteristics of these patients. Reimbursement data encompassed 239,794 patients from DataSUS and 19,533 from TISS.

Resource use after stroke, highlighted in Table 1, showed low levels of rehabilitation, home care, or formal care, even among patients who became disabled (MRS 3-5). Additionally, most post-stroke patients stopped working, including those who were functionally independent (MRS 0-2).

TDABC-estimated hospital costs were higher than those from DataSUS but lower than TISS, as Table 2 indicates. Costs for post-stroke medical visits were also higher with TDABC compared to DataSUS or TISS.

Table 1. Resource use frequency

Parameter	Estimates (standard error)	
	MRS 0-2 (n = 758)	MRS 3-5 (n = 302)
Primary care visits	87.1% (1.2%)	92.4% (1.5%)
Secondary care visits	64.2% (1.7%)	68.9% (2.7%)
Average number of medical visits	3.3 (0.1)	4.1 (0.2)
Follow-up rehabilitation with physical therapy	13.9% (1.3%)	37.4% (2.8%)
Follow-up rehabilitation with occupational therapy	1.2% (0.4%)	4.0% (1.1%)
Follow-up rehabilitation with psychologist	1.7% (0.5%)	2.0% (0.8%)
Follow-up rehabilitation with speech therapist	1.6% (0.5%)	4.3% (1.2%)
Average number of rehabilitation sessions	19.7 (0.9)	28.8 (1.6)
Hospital readmissions for stroke recurrence	3.6% (0.7%)	3.3% (1.0%)
Hospital readmissions for other causes	5.4% (0.8%)	6.3% (1.4%)
Homecare services after discharge	8.5% (1.0%)	14.6% (2.0%)
Starting living in a nursing home	0.4% (0.2%)	4.0% (1.1%)
Formal caregiver 6 hours per day	0.1% (0.1%)	1.3% (0.7%)
Formal caregiver 12 hours per day	0.8% (0.3%)	4.6% (1.2%)
Formal caregiver 24 hours per day	0.0% (0.0%)	2.6% (0.9%)
Family members stopped working to become informal caregiver	3.2% (0.6%)	15.6% (2.1%)
Stopped working after stroke*	58.2% (3.2%)	88.7% (4.3%)

*The proportion of patients who stopped working after a stroke was calculated based on those who reported working before the stroke, including 239 patients in the mRS 0-2 group and 53 patients in the mRS 3-5 group. mRS: Modified Rankin Scale.

Model results

The average discounted post-stroke costs using TDABC totaled BRL 96,562 (95% CI: 84,367-110,709), equivalent to USD 36,302 in purchasing power parity (Figure 2 and Figure 3). Direct costs amounted to BRL 32,974 (34.1% of total costs), and indirect costs to BRL 63,588 (65.9% of total costs), as outlined in Table 3. Undiscounted costs reached BRL 134,050, with direct costs at BRL 42,043 and indirect costs at BRL 92,007. Supplementary Table 2 presents the average costs per patient during the first five years after stroke, considering either all patients or only surviving patients.

Total discounted costs varied significantly by age, from BRL 361,244 for ages 20-29 to BRL 30,206 for ages ≥80. The highest direct cost component was the initial hospital admission (BRL 14,255; 14.8% of total costs), followed by readmissions (BRL 7,643; 7.9% of total costs). Productivity loss was the most substantial indirect cost (BRL 52,990; 54.9% of total costs).

Compared to TDABC, discounted costs estimated using DataSUS for healthcare services were lower (BRL 4,378 *vs.* BRL 30,404), especially for initial hospital admission and rehabilitation costs, as shown in Table 4. In contrast, costs estimated

Table 2. Unit costs of post-stroke healthcare services and medication (BRL)

Parameter estimates	Public – TDABC	Public – Reimbursement (DataSUS)	Private – Reimbursement (TISS)
Healthcare service costs			
Hospital admission mRS 0-2	11,179	2,106	24,151
Hospital admission mRS 3-5	15,175	2,106	24,151
Hospital admission with death	17,900	3,899	52,740
Home care services	8,546	209	1,711
Readmission for stroke recurrence	10,625	2,389	26,757
Readmission for other causes	12,276	2,069	23,517
Primary care visits	87	10	101
Specialized care visits	130	10	101
Rehabilitation sessions	100	5	60
Costs with medication (per year)			
Warfarin	162		
Direct oral anticoagulants	2,427		
Acetylsalicylic acid	192		
Clopidogrel (3 months)	119		
Societal costs (per year)			
Formal caregiver - 6 hours	17,498		
Formal caregiver - 12 hours	34,996		
Formal caregiver - 24 hours	77,600		
Nursing home	42,604		
Average income per working person	32,724		

TDABC: time-driven activity-based costing; mRS: modified Rankin Scale.

using TISS were higher (BRL 48,748), with hospital admissions showing the greatest difference.

Discussion

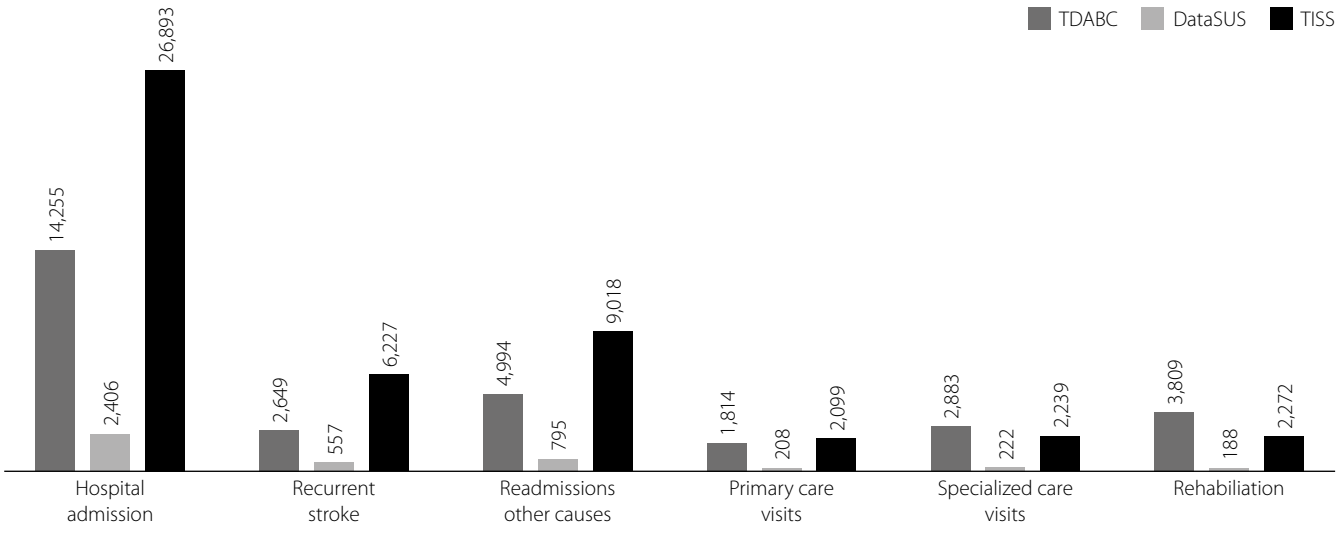
This study provides a detailed estimate of the direct and indirect financial burdens of stroke in Brazil, revealing that healthcare costs calculated using TDABC significantly exceed those based on public healthcare reimbursements, with indirect costs comprising most post-stroke expenses.

Unit costs estimated using TDABC were significantly higher than those listed in the SIGTAP tables or DataSUS. The TDABC-calculated costs for hospital admissions ranged from 4.6 to 7.2 times higher than those reported in DataSUS, while costs for rehabilitation and follow-up visits were 8.7 to 20 times higher than SIGTAP values. These findings underscore that DataSUS and SIGTAP values, which reflect monetary transactions between the federal government and healthcare providers, are inadequate for estimating the direct costs of stroke. This aligns with the understanding that, in Brazil, healthcare is also funded by states and municipalities, meaning federal reimbursements represent only a portion of total healthcare funding.

Notably, the study found low levels of rehabilitation, nursing home, or formal carer services among disabled patients, suggesting potential barriers to access or affordability. Additionally, cessation of work post-stroke, even among those who were functionally independent, highlights the significant contribution of lost productivity to the overall economic burden. The cost variation by patient age, with younger patients incurring the highest expenses, is of particular concern given the increasing incidence of stroke among younger Brazilians (Cabral *et al.*, 2016).

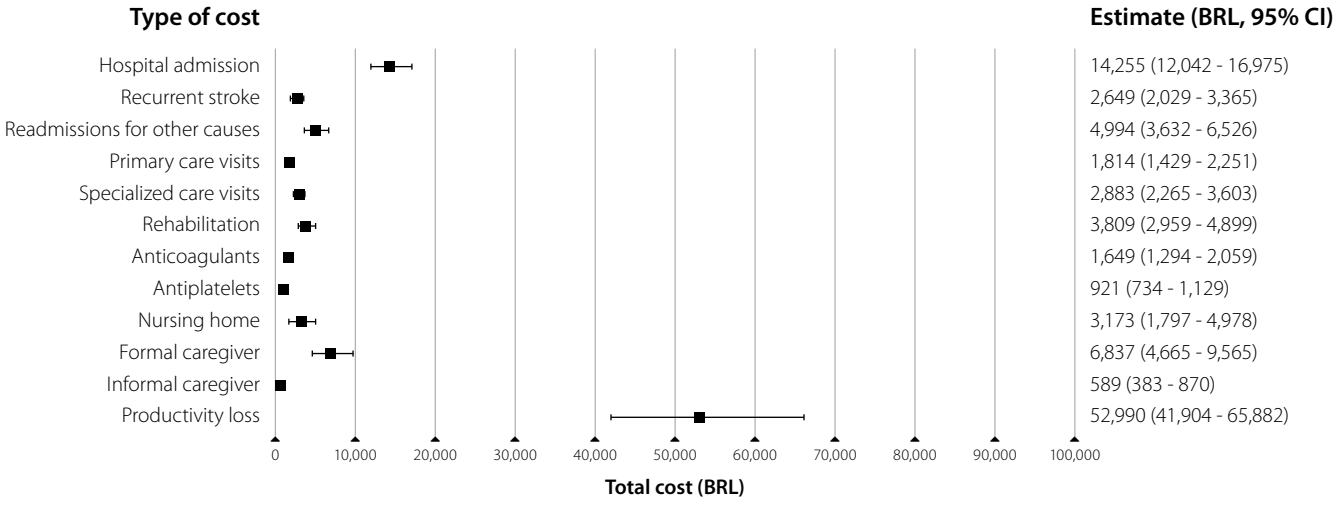
Aligning with previous TDABC research, our findings surpass SUS reimbursement rates, incorporating a broader patient cohort and distinctively quantifying both direct and indirect lifelong financial impacts (Etges *et al.*, 2022a; Etges *et al.*, 2022b).

Comparatively, global studies on stroke financial burden differ in methodologies, total cost estimates, and the impact of indirect costs. A recent systematic review analyzed 46 studies; 39% took a societal perspective, and 31% employed



TDABC: time-driven activity-based costing.

Figure 2. Healthcare services cost with unit costs originating from the DataSUS (public sector), TDABC (public sector), and TISS (private sector) (BRL).



Squares indicate the central estimates, and bars represent a 95% credible interval resulting from the Monte-Carlo simulation with 1,000 iterations.

Figure 3. Cost estimates following a stroke using TDABC, including indirect costs (BRL).

a bottom-up methodology (Strilciuc *et al.*, 2021). Only six articles (8%) have detailed lifetime per-patient costs (in Australia and Sweden), with estimates from USD 48,600 to USD 232,100 (2020 USD). Although our findings might seem lower in comparison, the impact of stroke in the Brazilian developing economy could be more severe, given Brazil's lower Gross Domestic Product *per capita*.

Our research contributes to understanding the economic impact of stroke, providing insights into the actual direct cost of stroke, the relative contribution of direct and indirect costs, and how these costs have been distributed across various age groups. Sensitivity analysis confirmed the model's robustness against parameter variations, maintaining the overall interpretation of the findings regardless of parameter changes.

Limitations include reliance on registry data from a specific area and excluding partial productivity losses, potentially underestimating productivity-related costs. Also, applying the TDABC in the public sector may not fully translate to private healthcare cost interpretations.

Conclusion

Our results extend beyond Brazilian health policy and economic evaluations and have global relevance. They highlight the importance of implementing TDABC costing and a comprehensive assessment of indirect costs, thereby

addressing the issue of healthcare reimbursement, which traditionally underestimates stroke-related expenses. Furthermore, our study illustrates the economic impact of stroke in Brazil. It highlights the need to reduce the incidence of stroke, especially in younger populations, and to improve access to treatment. Such measures would not only reduce the burden on patients and their families, but also the indirect costs associated with lost productivity.

Table 3. Lifetime results of the TDABC model (40-year time horizon), stratified by patient age (years) at stroke onset, discount rate applied (BRL)

Results	Age groups, in years (% of stroke patients)							Weighted average costs
	20-29 (0.7%)	30-39 (2.1%)	40-49 (8.3%)	50-59 (18.8%)	60-69 (28.7%)	70-79 (25.1%)	≥80 (16.3%)	
First hospital admission for stroke	14,255	14,255	14,255	14,255	14,255	14,255	14,255	14,255
Hospital admissions for recurrent stroke	4,619	4,441	3,994	3,436	2,772	1,931	1,457	2,649
Recurrent hospital admissions for other causes	8,764	8,416	7,552	6,481	5,222	3,632	2,744	4,994
Primary care visits	3,196	3,067	2,748	2,355	1,896	1,317	996	1,814
Specialized care visits	5,062	4,861	4,361	3,741	3,014	2,096	1,584	2,883
Rehabilitation	7,120	6,764	5,926	4,967	3,954	2,696	2,067	3,809
Anticoagulants	2,871	2,761	2,485	2,139	1,726	1,203	908	1,649
Antiplatelets	1,592	1,531	1,380	1,190	963	676	513	921
Nursing home	6,261	5,895	5,062	4,156	3,271	2,189	1,701	3,173
Formal caregiver	13,648	12,828	10,968	8,964	7,038	4,691	3,656	6,837
Informal caregiver	1,025	986	888	764	617	430	324	589
Productivity loss	292,830	253,617	176,707	98,053	31,728	4,695	0	52,990
Total costs (direct)	47,480	46,096	42,701	38,564	33,801	27,806	24,524	32,974
Total costs (indirect)	313,764	273,326	193,625	111,937	42,654	12,005	5,682	63,588
Total costs	361,244	319,422	236,326	150,501	76,455	39,811	30,206	96,562

TDABC: time-driven activity-based costing.

Table 4. Estimates of healthcare service costs and total costs with different methods (BRL)

Parameter estimates	Public – TDABC		Public – Reimbursement (DataSUS)		Private – Reimbursement (TISS)	
Discount rate applied	No	Yes	No	Yes	No	Yes
Hospital admission	14,255	14,255	2,406	2,406	26,893	26,893
Recurrent stroke	3,952	2,649	832	832	9,295	9,295
Readmissions for other causes	7,439	4,994	1,185	1,185	13,439	13,439
Primary care visits	2,699	1,814	310	310	3,124	3,124
Specialized care visits	4,294	2,883	331	331	3,334	3,334
Rehabilitation	5,575	3,809	275	275	3,326	3,326
Total costs with healthcare services	42,043	32,974	9,168	7,910	63,239	61,980
Total costs	134,050	96,562	101,175	71,498	155,246	125,569

TDABC: time-driven activity-based costing.

REFERENCES

Agência Nacional de Saúde Suplementar (ANS). Dados Disponíveis D-TISS. 2023. Available from: https://www.gov.br/ans/pt-br/acesso-a-informacao/perfil-do-setor/dados-e-indicadores-do-setor

Brazilian Institute of Geography and Statistics (IBGE). Continuous National Household Sample Survey. 2022. Available from: https://www.ibge.gov.br/estatisticas/sociais/trabalho/9173-pesquisa-nacional-por-amostra-de-domicilios-continua-trimestral.html?edicao=35504

Cabral NL, Cougo-Pinto PT, Magalhaes PS, Longo AL, Moro CH, Amaral CH, et al. Trends of Stroke Incidence from 1995 to 2013 in Joinville, Brazil. Neuroepidemiology. 2016;46(4):273-81. https://doi.org/10.1159/000445060

Cabral NL, Gonçalves AR, Longo AL, Moro CH, Costa G, Amaral CH, et al. Trends in stroke incidence, mortality and case fatality rates in Joinville, Brazil: 1995-2006. J Neurol Neurosurg Psychiatry. 2009;80(7):749-54. https://doi.org/10.1136/jnnp.2008.164475

DataSUS. TabWin: Transferência de Arquivos. 2022. Available from: https://datasus.saude.gov.br/transferencia-de-arquivos/

Diegoli H, Magalhães P, Makdisse M, Cabral Moro CH, França P, Longo A. Joinvasc: Organizing the Full Cycle of Stroke Care with Universal Coverage. NEJM Catalyst. 2022;4(1). https://doi.org/10.1056/CAT.22.0283

Diegoli H, Magalhães PSC, Makdisse MRP, Moro CHC, França PHC, Lange MC, et al. Real-World Populational-Based Quality of Life and Functional Status After Stroke. Value Health Reg Issues. 2023a;36:76-82. https://doi.org/10.1016/j.vhri.2023.02.005

Diegoli H, Makdisse M, Magalhães P, Gray M. The atlas of variation in healthcare Brazil: remarkable findings from a middle-income country. Res Health Serv Reg. 2023b;2(1):2. https://doi.org/10.1007/s43999-022-00017-z

Etges APBS, Anschau F, Pires LBR. Revisão de remuneração do SUS para linha de cuidado do AVC isquêmico por meio de microcusteio. J Bras Econ Saúde. 2022a;14(2).

Etges APBDS, Marcolino MAZ, Ogliari LA, de Souza AC, Zanotto BS, Ruschel R, et al. Moving the Brazilian ischaemic stroke pathway to a value-based care: introduction of a risk-adjusted cost estimate model for stroke treatment. Health Policy Plan. 2022b;37(9):1098-106. https://doi.org/10.1093/heapol/czac058

International Monetary Fund. World Economic Outlook Database. 2021. Available from: https://www.imf.org/en/Publications/WEO/weo-database/2021/October

Katan M, Luft A. Global Burden of Stroke. Semin Neurol. 2018;38(2):208-11. https://doi.org/10.1055/s-0038-1649503

Ministry of Health. Management System of the Table of Procedures, Medications, Orthoses, Prostheses and Materials of the Unified Health System (SIGTAP) - Unified Table. 2023. Available from: http://sigtap.datasus.gov.br/tabela-unificada/app/sec/inicio.jsp?first=15

Ouriques Martins SC, Sacks C, Hacke W, Brainin M, de Assis Figueiredo F, Marques Pontes-Neto O, et al. Priorities to reduce the burden of stroke in Latin American countries. Lancet Neurol. 2019;18(7):674-83. https://doi.org/10.1016/S1474-4422(19)30068-7

Owolabi MO, Thrift AG, Mahal A, Ishida M, Martins S, Johnson WD, et al. Primary stroke prevention worldwide: translating evidence into action. Lancet Public Health. 2022;7(1):e74-e85. https://doi.org/10.1016/S2468-2667(21)00230-9

Strilciuc S, Grad DA, Radu C, Chira D, Stan A, Ungureanu M, et al. The economic burden of stroke: a systematic review of cost of illness studies. J Med Life. 2021;14(5):606-19. https://doi.org/10.25122/jml-2021-0361

Sudlow CL, Warlow CP. Comparing Stroke Incidence Worldwide. Stroke. 1996;27(3):550-8. https://doi.org/10.1161/01.STR.27.3.550

SUPPLEMENTARY MATERIAL

Supplementary Table 1. Characteristics of the population used to calculate the parameters

Population characteristics	Complete Registry (N = 8,231)	Resource use frequency (N = 1,060)	TDABC (N = 589)
Baseline characteristics			
Female	3.840 (46.6%)	479 (45.2%)	261 (43.0%)
Age (mean, SD)	66.1 (13.3)	65.0 (13.4)	70.2 (14.7)
Pre-stroke mRS (median, IQR)	Not available	0 (0-1)	Not available
NIHSS upon admission (median, IQR)	4 (2-11)	3 (2-6)	6 (3-14)
Stroke type			
Ischemic stroke	7.223 (87.7%)	966 (91.1%)	509 (83.9%)
Hemorrhagic stroke	609 (7.4%)	65 (6.1%)	69 (11.3%)
Subarachnoid hemorrhage	281 (3.4%)	29 (2.7%)	29 (4.7%)
Undefined	122 (1.5%)	0 (0%)	0 (0%)

SD: standard deviation; IQR: interquartile range; NIHSS: National Institute of Health Stroke Scale; TDABC: time-driven activity-based costing.

Supplementary Table 2. Average cost per patient during the first five years after stroke (undiscounted)

	Year 1		Year 2		Year 3		Year 4		Year 5	
Type of cost (BRL)	Average costs	Costs per patient alive	Average costs	Costs per patient alive	Average costs	Costs per patient alive	Average costs	Costs per patient alive	Average costs	Costs per patient alive
Hospital admissions for recurrent stroke	312,21	320,35	291,86	307,78	273,69	297,16	257,40	288,25	242,71	280,87
Hospital readmissions for other causes	591,90	607,32	552,69	582,84	517,78	562,16	486,53	544,83	458,41	530,48
Primary care visits	215,76	221,38	201,33	212,31	188,49	204,65	177,02	198,23	166,71	192,92
Specialized care visits	341,85	350,76	319,18	336,59	298,99	324,62	280,92	314,58	264,67	306,27
Rehabilitation	477,14	489,58	440,66	464,70	408,79	443,83	380,78	426,42	356,02	411,99
Anticoagulants	194,06	199,12	181,47	191,37	170,23	184,82	160,13	179,32	151,03	174,77
Antiplatelets	122,61	125,80	99,57	105,00	93,40	101,40	87,86	98,39	82,86	95,89
Nursing home	416,88	427,75	381,51	402,32	351,00	381,09	324,52	363,41	301,37	348,75
Formal caregiver	907,58	931,23	828,98	874,21	761,35	826,62	702,77	786,99	651,70	754,16
Informal caregiver	69,32	71,13	64,82	68,36	60,81	66,02	57,20	64,06	53,95	62,43
Productivity loss	6246,08	4772,78	6242,54	4742,71	6231,44	4723,39	6212,56	4714,90	6185,65	4717,36
Total direct costs	2255,53	2314,31	2086,75	2200,59	1951,37	2118,64	1830,64	2050,03	1722,41	1993,19
Total indirect costs	7639,87	6202,89	7517,86	6087,60	7404,60	5997,11	7297,05	5929,36	7192,68	5882,70
Total costs	9895,40	8517,20	9604,62	8288,19	9355,97	8115,76	9127,69	7979,39	8915,09	7875,89

The cost per surviving patient represents the total healthcare utilization cost divided by the number of surviving patients. Productivity losses due to death were excluded from this calculation. The average cost per surviving patient decreases gradually over time, as patients with more severe disabilities are more likely to die.