

Trends in Hospitalization and Mortality Among Stroke Patients in a Brazilian Public Hospital: A 16-Year Retrospective Analysis

Tendências de Hospitalização e Mortalidade entre Pacientes com Acidente Vascular Cerebral em um Hospital Público Brasileiro: Uma Análise Retrospectiva de 16 Anos

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ABSTRACT

Objective: To assess trends in hospitalization, in-hospital mortality, and thrombolysis rates among stroke patients treated at a Brazilian public hospital over a 16-year period.

Methods: This retrospective observational study analyzed data from 6,203 patients admitted for stroke at the Hospital Estadual Sumaré, São Paulo, between 2006 and 2022. Stroke subtypes, length of hospital stay, thrombolysis rates, and in-hospital mortality were evaluated. Descriptive statistics characterized temporal trends, while multivariate logistic regression identified mortality predictors.

Results: Ischemic stroke was the most prevalent subtype (73.7%), followed by hemorrhagic stroke (19.0%) and subarachnoid hemorrhage (7.3%). The thrombolysis rate increased from 1.2% in 2006 to about 10% in 2022, coinciding with a decline in ischemic stroke mortality from 27.3% to 17.1%. However, hemorrhagic stroke mortality remained high (39.7%). Advanced age (OR = 1.008; 95% CI: 1.005–1.011) and prolonged hospital stay (OR = 1.015; 95% CI: 1.012–1.018) were independent predictors of in-hospital mortality ($p < 0.001$).

Conclusion: This study highlights a significant increase in thrombolysis use within Brazil's public healthcare system, associated with a progressive decline in ischemic stroke mortality. However, persistently high mortality rates in hemorrhagic stroke cases underscore the need for specialized treatment strategies. These findings provide valuable insights for policymakers to optimize stroke care in Brazil.

Keywords: Hospital Mortality; Stroke; Thrombolysis; Epidemiology; Public Health.

RESUMO

Objetivo: Avaliar as tendências de hospitalização, mortalidade intra-hospitalar e trombólise em pacientes com Acidente Vascular Cerebral (AVC) atendidos em um hospital público brasileiro ao longo de 16 anos.

Métodos: Estudo observacional retrospectivo com análise de dados de 6.203 pacientes internados por AVC no Hospital Estadual Sumaré, São Paulo, entre 2006 e 2022. Foram analisados os subtipos de AVC, tempo de internação, taxa de trombólise e mortalidade intra-hospitalar. Estatística descritiva caracterizou as tendências temporais, enquanto regressão logística multivariada identificou preditores de mortalidade.

Resultados: O AVC isquêmico foi o subtipo predominante (73,7%), seguido pelo AVC hemorrágico (19,0%) e hemorragia subaracnóidea (7,3%). A taxa de trombólise aumentou de 1,2% em 2006 para aproximadamente 10% em 2022, acompanhada de uma redução na mortalidade intra-hospitalar por AVC isquêmico de 27,3% para 17,1%. No entanto, a mortalidade por AVC hemorrágico permaneceu elevada (39,7%). A idade avançada (OR = 1,008; IC95%: 1,005–1,011) e o tempo prolongado de internação (OR = 1,015; IC95%: 1,012–1,018) foram preditores independentes de mortalidade ($p < 0,001$).

Conclusão: O estudo evidencia um aumento significativo no uso da trombólise no Sistema Único de Saúde, associado à redução progressiva da mortalidade por AVC isquêmico. No entanto, a alta mortalidade nos subtipos hemorrágicos reforça a necessidade de estratégias especializadas para esse grupo. Esses achados contribuem para a formulação de políticas públicas voltadas à otimização do atendimento ao AVC no Brasil.

Palavras-chave: Acidente Vascular Cerebral; Mortalidade Hospitalar; Trombólise; Readmissão Hospitalar; Tempo de internação.

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Author Contributions

GC conceptualized the study, conducted data analysis and interpretation, drafted and critically revised the manuscript. ALG was responsible for data collection. CJC analyzed and interpreted the results and revised the manuscript. MWPJ contributed to the study design and critically reviewed the manuscript. All authors approved the final version of the manuscript and are responsible for all its aspects, including ensuring its accuracy and integrity.

INTRODUCTION

Stroke is a leading cause of morbidity and mortality worldwide, accounting for approximately 6.6 million deaths annually and contributing to 120 to 150 million disability-adjusted life years (DALYs)¹⁻¹⁰. In 2016, the global incidence of stroke ranged between 12 and 14 million new cases, with ischemic stroke comprising 75-87% of cases, while hemorrhagic stroke and subarachnoid hemorrhage accounted for 13-25%^{2,4,5,10-15}. Beyond its high lethality, stroke is the leading cause of acquired disability in adults, significantly affecting quality of life and burdening healthcare systems^{4,7,16,17}.

The global stroke burden has increased in recent years, particularly in low- and middle-income countries, driven by epidemiological transitions, an aging population, and disparities in access to specialized care^{3,5,18}. In Brazil, stroke is the second leading cause of death, with an estimated incidence of 120 to 150 cases per 100,000 inhabitants and a mortality rate ranging from 20.9% to 34.1%, depending on stroke subtype and access to intensive care^{4,6,7,11,15,19}. Major risk factors such as hypertension, smoking, and diabetes mellitus remain highly prevalent, contributing to the disease burden²⁰⁻²⁶.

The economic impact of stroke is considerable, encompassing direct hospitalization costs and indirect costs related to rehabilitation and productivity loss²⁷⁻²⁹. In Brazil, hospital expenses for stroke treatment within the Unified Health System (UHS) increased by 15% between 2010 and 2019, reaching US\$120-140 million annually, with 89% of this amount allocated to hospitalizations^{1,30,31}. In private healthcare settings, mechanical thrombectomy costs range from US\$3,827 to US\$35,092 per patient³². These figures highlight the need to optimize hospital resource allocation to ensure effective stroke management.

Evidence-based therapies, such as intravenous thrombolysis with recombinant tissue plasminogen activator (rt-PA) and mechanical thrombectomy, have significantly improved clinical outcomes. However, the implementation of these interventions in Brazil remains limited, with thrombolysis rates ranging between 1% and 5%, primarily due to delays in medical care and a shortage of specialized stroke centers^{33,34}. The average hospital stay varies between 7 and 15 days, with longer durations observed in hemorrhagic stroke cases, reflecting the complexity of managing these patients^{2,4,11,12,25,26}.

Given this context, this study aims to analyze trends in hospitalization, mortality, and thrombolysis rates among stroke patients at Hospital Estadual Sumaré (HES), a referral center in the Metropolitan Region of Campinas (MRC), São Paulo. Additionally, it seeks to identify mortality predictors and discuss strategies to enhance hospital management and resource allocation within the UHS.

METHODS

This study follows the RECORD (REporting of studies Conducted using Observational Routinely-collected health Data) guidelines to ensure transparency in methodology, data extraction, and analysis. Adhering to these guidelines ensures that data management and statistical methods align with best practices for observational studies using routinely collected health data. This is a retrospective observational study that analyzed secondary data from stroke patients hospitalized at HES between January 2006 and December 2022. The study aimed to assess trends in hospitalization, in-hospital mortality, and thrombolysis rates, as well as to identify predictors of clinical outcomes using appropriate statistical models.

HES is the primary stroke referral center for the MRC, São Paulo, an area with 3.3 million inhabitants, providing direct coverage for 1.2 million people across six municipalities. Campinas, the region's largest urban center, hosts high-complexity hospitals and renowned universities, playing a key role in biomedical research. However, access to specialized stroke care remains inconsistent, with limited referral centers and restricted availability of advanced therapies such as mechanical thrombectomy.

All patients admitted with a primary diagnosis of ischemic stroke, hemorrhagic stroke, or subarachnoid hemorrhage, confirmed by neuroimaging, were included in the study. Exclusion criteria encompassed medical records with more than 50% missing data, unconfirmed stroke diagnosis due to lack of neuroimaging, and duplicate records with identical information across all analyzed variables. Data were extracted exclusively from the HES electronic medical records system, without linkage to external databases. While this approach ensures standardization and data consistency, it may limit the generalizability of findings, as the dataset reflects the reality of a single healthcare institution. HES follows standardized protocols for stroke diagnosis and treatment, ensuring uniformity in clinical documentation. The data extraction process included automated validation procedures to detect inconsistencies, standardization of diagnostic codes, and removal of duplicate records.

The primary outcome analyzed was in-hospital mortality, while secondary outcomes included length of hospital stay and six-month readmission rate. The analyzed variables were age, sex, stroke subtype, hospital length of stay (in days), in-hospital mortality (defined as death during hospitalization related to stroke), and six-month readmission (defined as any hospital admission related to stroke within six months of discharge). Potential sources of bias included missing or misclassified data, which were handled using multiple imputation techniques whenever feasible. Variables with excessive missing data were

excluded, and automated consistency checks were applied to remove duplicate records. Outlier detection methods were used to minimize errors in data entry and classification.

Descriptive statistics were used to summarize the data, with continuous variables presented as mean, standard deviation, median, and interquartile ranges, while categorical variables were described using absolute and relative frequencies. Comparisons between stroke subgroups were performed using chi-square tests for categorical variables and Mann-Whitney tests for non-parametric continuous variables. To identify independent predictors of in-hospital mortality and readmission, a multivariate logistic regression model was applied, considering age, sex, stroke subtype, and hospital length of stay as independent variables. A significance level of $p < 0.05$ was adopted for all statistical analyses. Data analysis was conducted using Python, with the pandas library for data processing and statistical analysis. Additionally, visual graphs were generated to facilitate the interpretation of results. Data access was restricted to the study researchers, and the data cleaning process included removal of duplicate records, standardization of categorical variables, and validation of critical variables such as age and hospital length of stay.

A descriptive analysis approach was chosen to assess trends in hospitalizations, mortality, and thrombolysis rates over a 16-year period, without imposing assumptions about linear or nonlinear statistical patterns. This method is widely used in epidemiological studies to document changes in healthcare policies and hospital-based interventions over time. To enhance the robustness of the analysis, temporal trend data were presented graphically, and confidence intervals were used to validate statistically significant trends.

This study was approved by the Research Ethics Committee of the Universidade de Campinas (UNICAMP), registered under CAAE: 79472324.7.0000.5404. As this was a retrospective analysis based on secondary data with no direct patient contact, the need for informed consent was waived, in accordance with Brazilian regulations. The dataset used in this study is available in the Research Data Repository of UNICAMP, ensuring transparency and accessibility for future investigations.

RESULTS

A total of 6,203 patients hospitalized with stroke at HES between January 2006 and December 2022 were included in this analysis, ensuring sufficient statistical power for subgroup comparisons and robust estimates of mortality and readmission rates. The mean age was 64.2 years (SD ± 13.4), with a median of 66 years, and 53.1% of patients were male.

Ischemic stroke was the most prevalent subtype

(73.7%), followed by hemorrhagic stroke (19.0%) and subarachnoid hemorrhage (7.3%). The sample size allowed reliable stratified analyses, summarized in Table 1.

Table 1. Clinical Characteristics and Outcomes of Stroke Patients by Subtype

	All	iStroke	hStroke	SAH
Distribution (n %)	6203 100.00	4568 73.64	1180 19.02	455 7.34
Mean age \pm	65.41 \pm 13.76	67.28 \pm 12.95	61.73 \pm 14.31	55.14 \pm 14.24
Sex (Male Female)	54.38 45.62	54.14 45.86	61.78 38.22	37.58 62.42
Hospitalization \pm (Days)	11.89 \pm 18.21	9.81 \pm 16.28	16.22 \pm 20.12	21.58 \pm 25.07
Mortality (%)	25.36	18.91	39.66	52.97

iStroke - Ischemic Stroke; hStroke- Hemorrhagic Stroke; Subarachnoid hemorrhage (SAH)

The mean length of hospital stay varied across stroke subtypes, being longest in subarachnoid hemorrhage cases (21.5 days), followed by hemorrhagic stroke (16.2 days) and ischemic stroke (9.8 days). When comparing hospital stay duration between patients who were discharged and those who died, it was observed that patients who died had significantly longer hospitalizations (14.8 days vs. 9.4 days, $p < 0.0001$).

The evolution of thrombolysis rates and in-hospital stroke mortality is illustrated in Figures 1 and 2. Since 2010, the thrombolysis rate has steadily increased, coinciding with a progressive reduction in in-hospital ischemic stroke mortality. These patterns suggest that the adoption of structured stroke care protocols and improved access to evidence-based treatments played a crucial role in this trend.

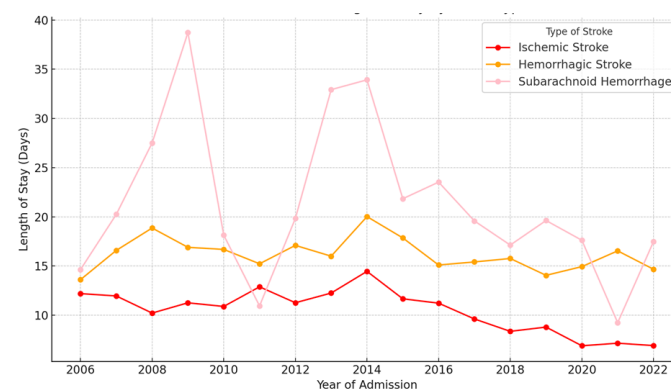


Figure 1. Days of hospitalization x type of stroke

The overall in-hospital mortality rate was 23.8%, with significant variations between stroke subtypes. Patients with subarachnoid hemorrhage had the highest mortality rate (53.0%), followed by hemorrhagic stroke (39.7%). In contrast, ischemic stroke had the lowest mortality rate (18.9%). The temporal evolution of stroke mortality (Figure 2) shows a progressive decline in ischemic stroke mortality, while hemorrhagic stroke and subarachnoid hemorrhage exhibited greater interannual variability without a clear decreasing trend.

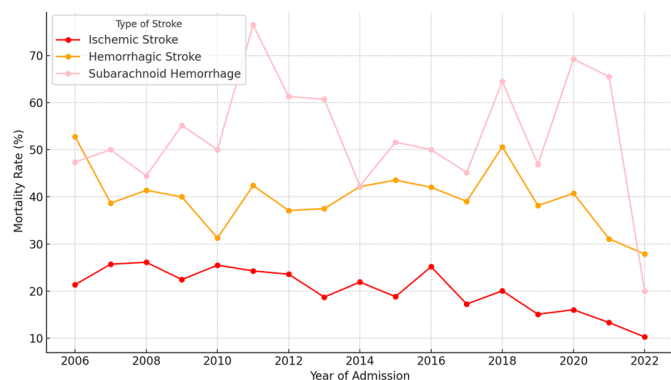


Figure 2. Evolution of Stroke Mortality Over Time

In-hospital mortality also varied by age and sex. Patients aged ≥ 80 years had the highest mortality rate (29.8%), followed by those under 40 years old (26.3%), while the lowest mortality rate was observed among patients aged 40 to 60 years (22.7%). There was no statistically significant difference in mortality between sexes ($p = 0.081$).

Readmission analysis revealed that 1.3% of patients were readmitted within six months after discharge, with a mean time of 62.3 days between hospitalizations. The leading causes of readmission were a new ischemic stroke episode (56.2%), followed by infectious complications (24.1%) and non-stroke cardiovascular events (12.7%).

Statistical analysis confirmed significant differences among stroke subtypes regarding in-hospital mortality ($p < 0.0001$) and hospital length of stay ($p < 0.0001$). Multivariate logistic regression identified age and length of hospital stay as the primary independent predictors of in-hospital mortality. Each additional year of age increased the risk of death (OR = 1.008; 95% CI: 1.005–1.011), as did the need for prolonged hospitalization (OR = 1.015; 95% CI: 1.012–1.018), suggesting that both initial clinical severity and extended hospital support were associated with worse outcomes.

Trend analysis revealed a 190% increase in stroke hospitalizations from 2006 to 2022 (Figure 3).

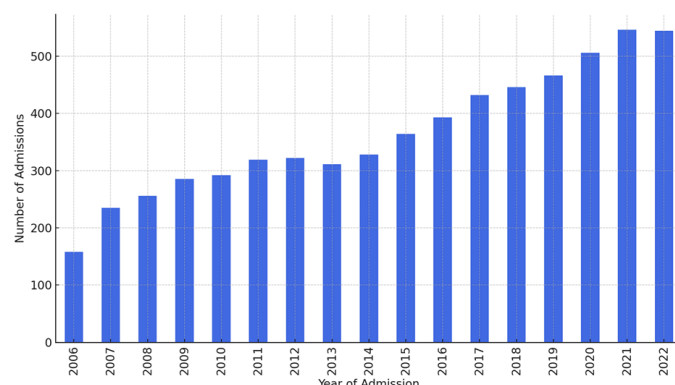


Figure 3. Number of Stroke Hospitalizations Over Time

Despite this increase, in-hospital ischemic stroke mortality progressively declined, whereas hemorrhagic stroke and subarachnoid hemorrhage mortality rates fluctuated yearly without a clear downward trend. The

average hospital length of stay also showed a decreasing trend over time for ischemic and hemorrhagic stroke, while remaining high and unstable for subarachnoid hemorrhage cases.

Between 2006 and 2022, the thrombolysis rate at HES increased from nearly zero to about 10% (Figure 4).

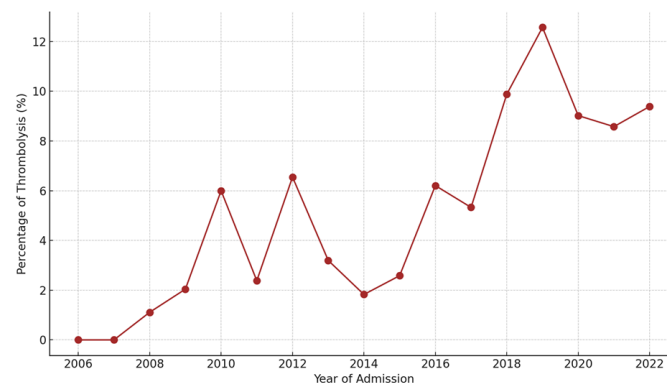


Figure 4. Evolution of the Percentage of Thrombolysis in Patients with Ischemic Stroke

This rise was accompanied by a steady decline in ischemic stroke mortality, suggesting a positive impact on patient outcomes. The expansion of this therapy may be linked to improved hospital protocols and increased access to neuroimaging.

These findings indicate that, despite the expansion of stroke care over the study period, challenges remain, particularly regarding high mortality in hemorrhagic stroke cases, reducing readmission rates, and optimizing risk factor management.

DISCUSSION

This study provides a comprehensive 16-year analysis of hospitalizations and in-hospital outcomes among stroke patients in a Brazilian public hospital. The primary contribution of this research is to demonstrate, for the first time, the significant expansion of thrombolysis rates within the UHS, which was associated with a progressive reduction in ischemic stroke mortality. These findings reinforce the impact of expanding access to evidence-based treatments and enable a more detailed evaluation of advancements in hospital stroke management over time. Furthermore, despite the improvement in ischemic stroke outcomes, mortality rates for hemorrhagic stroke and subarachnoid hemorrhage remain high, suggesting persistent challenges in managing these subtypes.

The findings of this study reinforce the role of HES as a reference center for stroke care, highlighting the predominance of ischemic stroke and the high mortality associated with hemorrhagic stroke and subarachnoid hemorrhage^{2,4,6,11,15,22,23}. The expansion of thrombolysis use in recent years and the progressive decline in ischemic stroke mortality suggest improvements in the quality of care provided. However, the persistently high mortality rates in

hemorrhagic subtypes underscore the need for greater investment in specialized resources³³⁻³⁶.

Despite the robustness of the analyzed data, some limitations must be acknowledged. The lack of information on initial stroke severity may hinder the precise assessment of treatment effectiveness, as patients presenting with more severe conditions tend to have worse clinical outcomes^{8,12,13}. Additionally, the absence of detailed records on pre-hospital care pathways limits the evaluation of the impact of admission delays and potential barriers to timely treatment. Moreover, the retrospective nature of this study introduces a risk of information bias, particularly in older records where data collection standardization may have been less rigorous.

When compared to existing literature, the distribution of stroke subtypes at HES is consistent with findings from other Brazilian regions, with ischemic stroke accounting for approximately 74% of cases, while hemorrhagic subtypes exhibit higher lethality rates^{1-4,8-12,15}. However, the stroke mortality by sex observed in this study did not reflect patterns reported in the literature, indicating a discrepancy in relation to these findings²³⁻²⁶. A hospital-based study conducted in Natal reported similar distributions and mortality rates, while in Fortaleza, the implementation of specialized stroke units contributed to improved clinical outcomes^{12,15}. These regional variations highlight the need to develop strategies tailored to the specific realities of different healthcare systems.

One of the most significant findings of this study was the expansion of thrombolysis use at HES starting in 2008. Although thrombolysis rates in this study remain lower than those observed in high-income countries, the increased adoption of this therapy coincided with a reduction in ischemic stroke mortality^{27,30,33-35}. These results align with international studies demonstrating that thrombolysis, when administered within the therapeutic window, significantly reduces disability and mortality^{2,4,22,33}. However, persistent challenges remain, particularly concerning unequal access to mechanical thrombectomy, which still has limited availability in Brazil^{11,30,34}.

International studies show that the increased use of thrombolysis is strongly associated with reduced ischemic stroke mortality, particularly in countries with structured stroke care protocols. In Brazil, national data on this evolution remain scarce, and this study helps fill that gap by documenting the progressive increase in thrombolysis use over 16 years within the UHS. The findings suggest that improvements in hospital infrastructure, better-trained healthcare teams, and expanded access to neuroimaging may have been key factors driving this evolution. However, the management of hemorrhagic stroke remains a significant challenge, highlighting the need for further refinement of treatment strategies for this subtype.

The clinical and healthcare management implications of these findings emphasize the necessity of continuous improvements in stroke care pathways. The observed reduction in ischemic stroke mortality appears to

be associated with the implementation of structured protocols, enhanced professional training, and better access to neuroimaging^{6,11,22,34}. On the other hand, although the readmission rate observed in this study was relatively low, new protocols at HES have been investigating post-hospitalization follow-up through phone calls. The goal of this initiative is to assess patients' functional status and identify cases of rehospitalization in other healthcare facilities.

The findings of this study also point to several future research opportunities. Prospective studies could more thoroughly evaluate the impact of specific management strategies, such as mechanical thrombectomy, while also investigating operational challenges faced at HES. Additionally, incorporating data on initial stroke severity and door-to-needle time would allow for a more precise assessment of healthcare quality and its correlation with clinical outcomes.

In conclusion, this study demonstrates that over a 16-year period, there was a substantial increase in thrombolysis rates within the UHS, coinciding with a progressive reduction in ischemic stroke mortality. This finding reinforces the importance of expanding access to evidence-based therapies and highlights the evolution of stroke management within the Brazilian public healthcare system. However, the high mortality rates in hemorrhagic stroke cases indicate the need for new strategies to improve care for these patients. These results could contribute to public policies aimed at optimizing stroke care and implementing structured protocols to improve clinical outcomes. The findings of this study emphasize the necessity of expanding access to thrombolysis within the SUS, demonstrating that the progressive increase in this therapy may be associated with reduced ischemic stroke mortality. However, the persistent high mortality rates in hemorrhagic stroke cases suggest that the implementation of new treatment strategies should be considered. These findings may guide public health officials in formulating policies to enhance stroke care pathways and expand the use of evidence-based therapies.

CONCLUSION

This study provides a comprehensive 16-year analysis of hospitalization, thrombolysis, and in-hospital mortality trends among stroke patients in a Brazilian public hospital. The findings reveal a significant increase in thrombolysis rates within the UHS, rising from nearly zero in 2006 to about 10% in 2022, marking a major improvement in ischemic stroke hospital management. This expansion in thrombolysis use was associated with a progressive decline in ischemic stroke in-hospital mortality, reinforcing the positive impact of structured care protocols, enhanced medical team training, and expanded access to neuroimaging.

Despite these improvements, hemorrhagic stroke and subarachnoid hemorrhage mortality remained high, showing no clear downward trend over time. These results suggest that the progress observed in ischemic stroke treatment has not been matched in hemorrhagic stroke subtypes, highlighting the need for specific strategies to improve the management of these patients, including greater access to advanced therapies, specialized Intensive Care Unit beds, and targeted care protocols.

Outcome analysis also demonstrated that older age and prolonged hospital stay were independent predictors of in-hospital mortality, emphasizing the influence of initial clinical severity and extended hospital support on adverse outcomes. Additionally, the six-month hospital readmission rate was low (1.3%), suggesting that post-discharge care quality may be contributing to fewer recurrent hospitalizations, although this aspect warrants further investigation in future studies.

These findings have important policy implications, reinforcing the need to expand thrombolysis access nationwide and to develop new approaches to reduce hemorrhagic stroke mortality. Strategies such as the expansion of mechanical thrombectomy, improvement of emergency care networks, and implementation of specialized hemorrhagic stroke care units should be considered to ensure that the advancements in ischemic stroke treatment are extended to all stroke subtypes.

Future research should explore risk stratification models to optimize hospital resource allocation and evaluate targeted interventions to reduce hemorrhagic stroke mortality. Furthermore, including data on initial stroke severity and door-to-needle time could provide a more comprehensive understanding of healthcare quality and its impact on clinical outcomes.

In summary, this study underscores that the progress in thrombolysis and the reduction in ischemic stroke mortality reflect improvements in hospital stroke care within the SUS. However, it also highlights persistent challenges in hemorrhagic stroke management and disparities in access to advanced therapies. These findings may inform public policies aimed at strengthening the stroke care continuum in Brazil, focusing on expanding specialized treatment and ensuring continuous quality improvement in stroke care delivery.

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