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Factors Associated With Length of Hospital Stay in Acute Ischemic Stroke

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Abstract

Ischemic Stroke is one of the leading causes of death and disability in low- and middle-income countries. Given the time-dependent nature of ischemic stroke, understanding patient care pathways across emergency, therapeutic decision-making, hospitalization, and discharge is essential. This study analyzed the care pathway of acute ischemic stroke patients in a Brazilian hospital, aiming to identify factors associated with hospital length of stay. Secondary data from 232 patients were evaluated using a hybrid analytical approach combining machine learning (Gradient Boosting Machine) with interpretable statistical modeling through knowledge distillation. Clinical and demographic variables were considered, such as age, sex, history of stroke, NIHSS score at admission, and TOAST classification. Age and baseline NIHSS were the factors most strongly associated with length of stay, highlighting the relevance of initial neurological severity. Additionally, TOAST classification was associated with length of stay, particularly for the Large-Artery Atherosclerosis and Other Etiologies categories.

Keywords
Ischemic Stroke, Care Pathway, Length of Stay, Machine Learning and Knowledge Distillation

1. Introduction
Between 1990 and 2019, the global number of stroke cases increased by more than 70%, with 86% of stroke-related deaths occurring in low- and middle-income countries (Feigin et al., 2022). In these settings, stroke mortality rates are 3.6 times higher than in high-income countries (GBD 2019 Stroke Collaborators, 2021), reflecting persistent inequalities in access to prevention, diagnosis, and treatment. In Brazil, stroke is recognized as one of the leading

causes of hospital admissions, frequently resulting in some degree of disability in patients, and remains the second leading cause of death among adults (Rosa et al., 2023).

Patient flow, understood as a comprehensive and continuous approach to healthcare delivery (Almeida et al., 2018), and patients' acute hospital length of stay (LOS) play a crucial role in patient recovery, particularly in stroke care, given the time-dependent nature of this condition (Jauch et al., 2010). Efficient management of acute hospital length of stay across the care continuum is essential not only for optimizing clinical outcomes, improving hospital efficiency, and ensuring appropriate resource allocation.

Despite its importance, the ischemic stroke care pathway remains underexplored in the literature (Gagliardi & Gagliardi, 2019). In particular, LOS stratification by validated stroke severity scores, such as the NIHSS, is lacking in the Brazilian literature, underscoring the need for context-specific evidence.

1.1 Objectives
This study aims to identify the factors with the greatest impact on variations in acute hospital length of stay across hospital units and treatment types throughout the patient care cycle. The findings are expected to inform the development of strategies to improve efficiency and patient outcomes in the region.

2. Literature Review
In low and middle-income countries, stroke mortality is increasing at faster rates than in high-income countries, reflecting insufficient levels of and inequalities in access to preventive services (Feigin et al., 2023). In response, stroke care pathways have been implemented in several countries (Jauch et al., 2010). These care flows are organizational to promote evidence-based and guideline-driven care, improve the organization and efficiency of service delivery, and reduce costs (de Luc, 2000).

Hospital length of stay in acute stroke is defined as the number of days from the date of hospital admission to discharge or in-hospital death and is a key indicator of hospital resource utilization, quality of care, (Bustami et al., 2025; Han et al., 2022; Koton et al., 2010) and healthcare expenditure (Holloway et al., 1996; Jørgensen et al., 1997; Mamoli et al., 1999)**.** Despite its relevance, substantial variability persists in LOS, care processes, and clinical outcomes, even among high-performing hospitals (Bélanger et al., 2024; de Souza et al., 2022).

The importance of LOS has increased alongside rising rates of hospital admissions and readmissions (Friebel et al., 2018) Prolonged LOS is associated with higher complication rates, increased healthcare costs, and potential hospital inefficiency (Duke et al., 2025; Marfil-Garza et al., 2018). Although LOS is influenced by patient, clinical, and institutional factors, risk-adjusted models indicate that most variation is driven by patient-level characteristic (Duke et al., 2025). Understanding patient flow across care stages is therefore essential to support more efficient and cost-effective stroke care pathways, particularly in resource-limited settings (Chang et al., 2002; Lindsay et al., 2014).

3. Methods
This study is designed as a cross-sectional analysis at a high-complexity hospital center in Brazil. The study was conducted at a hospital center certified by the World Stroke Organization (WSO), which ensures the adoption of internationally validated clinical protocols and compliance with minimum standards of care quality. The data used are secondary data derived from a database. All procedures complied with ethical principles and were approved by the Research Ethics Committee under the Certificate of Presentation for Ethical Review (CAAE: 53723521.8.0000.5330), as required by national regulations. In addition, the data were anonymized and securely handled in accordance with international clinical research practices, ensuring confidentiality and data protection.

The patient care flow was established based on the literature corresponding to the database used. Possible care pathways were mapped according to the hospital routine of the participating center and validated by vascular neurologists, allowing a detailed description of the main care routes and the specific characteristics of each phase of care. The process scope was defined as the in-hospital care flow, from patient admission to discharge. This delimitation was adopted because it encompasses the most critical phases of ischemic stroke management, during which the main diagnostic and therapeutic interventions occur, and because it corresponds to the period with the highest level of standardization in clinical records and care protocols.

3.1 Data Collection

The data were drawn from an ongoing study by Dittrich et al. (2025), which collected information on care duration in hours by department and total length of hospital stay, as well as patients' clinical and sociodemographic characteristics such as age and sex, the treatment received, and its risk level. The initial target sample comprised all participants included in the database, representing all patients with ischemic stroke admitted to the study center in 2023, totaling 232 individuals. After excluding patients with missing NIHSS data (n = 2) and history of previous stroke (n = 9), 221 observations remained. Only cases with complete treatment information were included, resulting in a final sample of 214 observations.

3.2. Data analysis

Data analysis was performed using descriptive and inferential statistics, supported by Microsoft Excel and RStudio. Initially, descriptive statistics were used to characterize the sample in terms of age, sex, comorbidities, type of treatment, and care times by department. Demographic variables (age and sex) were included because they reflect biological and social determinants widely associated with disease severity and functional recovery (Rexrode et al., 2022). Clinical variables, such as admission NIHSS score (a standardized clinical scale used to assess the severity of neurological deficits in patients, ranging from 0 [no deficit] to 42 [most severe]; Kasner, 2006), etiological subtype according to TOAST classification, and history of previous stroke, were considered due to their role in outcome heterogeneity (Feigin et al., 2022). Variables related to the care process, including treatment type and duration of care in each unit, were included as they directly reflect care efficiency and adherence to therapeutic guidelines (Nogueira et al., 2022).

Statistical tests were applied to compare groups and investigate associations between variables. Given the continuous nature of the outcome analyzed and the presence of multiple clinical and demographic predictors, machine learning models were employed to identify patterns and estimate the relative influence of variables on length of stay, combined with interpretable statistical modeling techniques. This methodological choice was based on the premise that more complex models, such as Gradient-Boosting Machines (XGBoost), can capture subtle interactions and non-obvious patterns in clinical data, whereas linear regression preserves the transparency and interpretability required in healthcare contexts (Rajkomar et al., 2019)

Following this approach, the analysis was conducted in two complementary stages. In the first stage, a boosting model was used to estimate complex patterns in length of stay, with an exploratory purpose to understand how each variable contributed to outcome behavior. The second stage consisted of a knowledge distillation process, in which the knowledge learned by the more complex model was transferred to a simpler linear model in order to translate the identified patterns into directly interpretable coefficients (Liu et al., 2023). For each hospital unit, two student models (RAW and Z-score) were fitted, and the final model was selected based on the highest coefficient of determination (R^2) and the lowest mean absolute error (MAE).

4. Results and Discussion

4.1 Patient Care Flow

The flowchart of the ischemic stroke care cycle (Figure 1) summarizes the logical sequence of care, structured around three key decision points: triage and initial diagnosis, determination of therapeutic eligibility, and referral to the appropriate inpatient unit. Two main treatment pathways were identified: patients with symptom onset beyond 4.5 hours or with contraindications proceed to conservative management, whereas patients with shorter symptom duration may undergo thrombectomy or intravenous thrombolysis (IVT) (Powers et al., 2018). In Brazil, the ischemic stroke care cycle comprises four main stages: emergency care, therapeutic decision-making, referral and in-hospital care, and discharge (Dittrich et al., 2025). In addition, five hospital units were identified through which patients progress: Emergency Department, General Ward, Angiography Suite, Intensive Care Unit (ICU), and Stroke Unit.

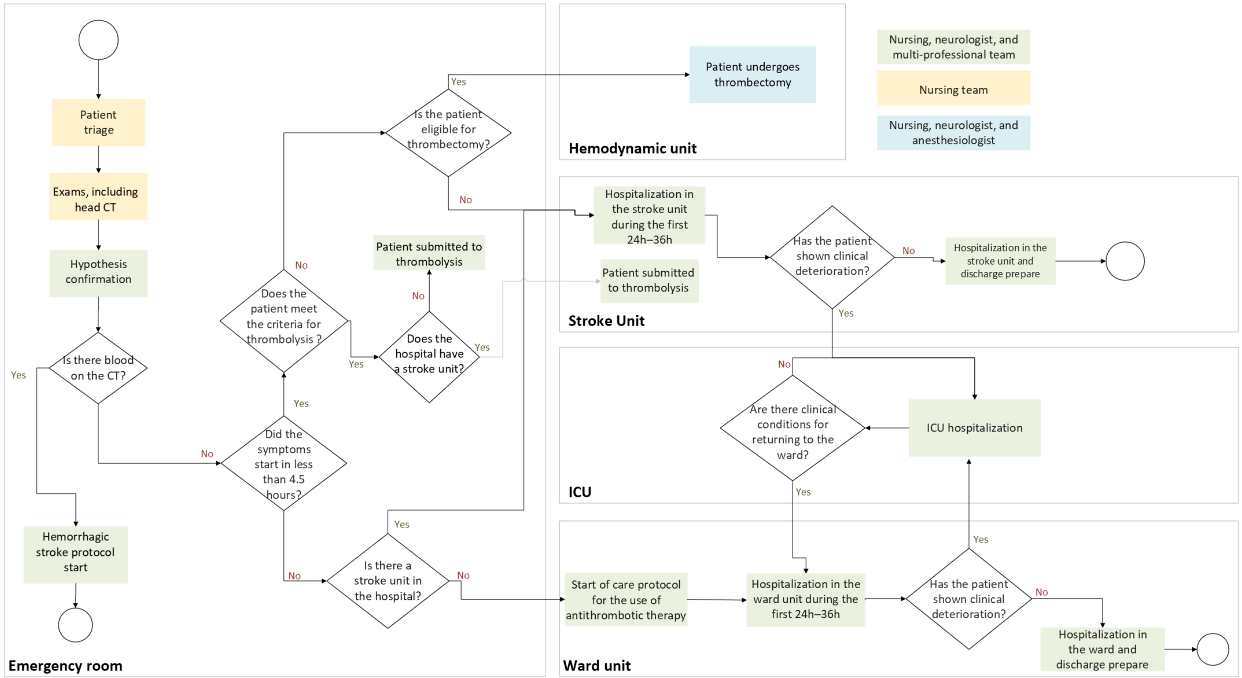

Figure 1. Adapted from Dittrich et al. (2025)

4.2 Baseline Characteristics of the Study Participants

The mean age was 69 years (60–75), and 44.9% of the patients were female. Conservative management was the most frequently used treatment, accounting for 130 cases (60.7%), followed by intravenous thrombolysis in 80 patients (36.9%). Regarding TOAST stroke categories, large-artery atherosclerosis was the most common subtype (39%). At hospital admission, most patients (44%) were classified as moderate risk. The median NIHSS score at admission was 6 (IQR 4–12), and at discharge, the majority of patients (72%) presented with mild neurological deficits (NIHSS 0–7). At discharge, 53.7% of patients achieved favorable functional outcomes (mRS 0–2), and 72% had mild deficits (NIHSS 0–7). At the 3-month follow-up, the median mRS score was 2 (IQR 1–4), and the mortality was 8.5% (n = 19). The clinical characteristics of the study sample are detailed in Table 1.

Table 1. Sample baseline characteristics

Attributes	**N (%)**
Demographics	
Age (years)	69 (60–75)
Sex (female)	96 (44.9%)
Therapies	
Conservative treatment	130 (60.7%)
Intravenous thrombolysis (IVT)	79 (36.9%)
Mechanical thrombectomy (MT)	3 (1.4%)
Intravenous thrombolysis + mechanical thrombectomy	2 (0.9%)
Etiology (TOAST)	
Cardioembolism	67 (31%)
Large-artery atherosclerosis	84 (39%)
Small-vessel occlusion (lacunar)	22 (10%)
Other etiologies	7 (3.1%)
Undetermined origin	34 (16%)
Risk level	
Low	60 (28%)
Moderate	95 (44%)

High	59 (28%)
NIHSS (on admission)	
0–7	118 (55%)
8–15	64 (30%)
16–42	20 (9.3%)
NIHSS (at discharge)	
0–7	154 (72%)
8–15	40 (18.7%)
16–42	20 (9.3%)
mRS * (at discharge)	
0	23 (10.7%)
1	44 (20.6%)
2	48 (22.4%)
3	48 (22.4%)
4	27 (12.6%)
5	23 (10.7%)
6	1 (0.5%)
mRS * (3 months after stroke)	
0	19 (8.9%)
1	44 (20.6%)
2	52 (24.3%)
3	43 (20.1%)
4	30 (14%)
5	8 (3.7%)
6	18 (8.4%)

* mRS: standardized clinical scale used to assess the degree of disability or functional dependence in patients who have experienced a Stroke.

4.3 Acute Hospital Length of Stay by Treatment Modality and Care Unit

First, a variable importance analysis was performed using the gradient boosting methodology, with treatments analyzed separately and subsequently compared. For conservative management, 130 patients were analyzed, whereas 79 patients were included in the intravenous thrombolysis (IVT) group. Despite differences in sample size, consistent clinical patterns were observed across hospital units, with age and admission NIHSS score emerging as the most relevant predictors in both therapeutic contexts.

Table 2 summarizes the main determinants and the explanatory performance (R^2) of the gradient boosting models for each hospital unit. The observed R^2 values are consistent with those reported in clinical studies, in which multiple uncontrollable factors influence the outcome of interest (Hamilton et al., 2015). Therefore, even moderate R^2 values can be considered satisfactory, as they reflect the intrinsic heterogeneity of real-world clinical care (Gupta et al., 2024).

Table 2. Gradient Boosting (GBM)

	Conservative treatment		**Intravenous thrombolysis (IVT)**	
Hospital unit	**Key variables**	**R^2**	**Key variables**	**R^2**
Emergency Room	Age, NIHSS, and prior stroke	0.481	Age, NIHSS, and prior stroke	0.587
Ward	Age, NIHSS, and TOAST – large-artery atherosclerosis	0.540	Age and TOAST – other etiologies	0.994
Angiography Suite	Age, sex, and TOAST – cardioembolism	0.582	Age, NIHSS, and sex	0.871

Intensive Care Unit (ICU)	Age, NIHSS, and prior stroke	0.637	Age, NIHSS, and sex	0.893
Stroke Unit	Age, NIHSS, and sex	0.555	Age, NIHSS, and TOAST – small-vessel occlusion	0.619

The comparison of treatments reveals distinct unit-specific patterns, despite being supported by the same core clinical variables. In the Emergency Department and ICU, the combination of age, NIHSS score, and prior stroke remained the dominant predictor across conservative treatment, suggesting that these units directly reflect the impact of initial stroke severity on length of stay. In the General Ward, the TOAST classification gained greater prominence, indicating that length of stay may vary according to stroke etiology, particularly for the "other etiologies" and "atherosclerosis" categories. In the Angiography unit, the influence of age and sex remained stable across treatments, with TOAST standing out for conservative management and NIHSS for IVT. In the Stroke Unit, the IVT model showed a slight improvement in model fit ($R^2 = 0.618$) and reinforced the role of the etiological subtype TOAST–Occlusion as a relevant factor in rehabilitation length of stay.

Despite these sectoral differences, analysis of variable gain and frequency measures indicates that age and NIHSS remain global determinants of hospital length of stay. The improved explanatory power allows clearer identification of relationships between clinical profile and length of stay, consolidating age and initial stroke severity (NIHSS) as the most universal and influential predictive factors. Based on these findings, knowledge distillation was applied to translate gradient-boosting models into interpretable linear regression models.

The application of knowledge distillation to the conservative treatment group demonstrated consistency between the clinical patterns captured by the original model and those reproduced by the distilled linear regression (Table 3). The R^2 values ranged from 0.113 to 0.914, reflecting the intrinsic heterogeneity across hospital units. High performance was observed in the Emergency Department ($R^2 = 0.914$) and the Stroke Unit ($R^2 = 0.849$), whereas the General Ward ($R^2 = 0.113$), Angiography ($R^2 = 0.152$), and ICU ($R^2 = 0.156$) showed more modest values due to the high proportion of zero length-of-stay observations. Across these three units, more than 85% of records had a length of stay (LOS) of 0, which limits variability in outcomes and reduces the explanatory power of linear models.

In the unit-specific analysis, the Emergency Department showed age ($\beta = 0.714$; $p < 0.001$) and NIHSS score ($\beta = 1.261$; $p < 0.001$) as positive and significant predictors, while female sex had a negative and significant effect ($\beta = -9.46$; $p = 0.0017$); prior stroke and indeterminate TOAST were not significant. In the Stroke Unit, NIHSS ($\beta = 8.68$; $p < 0.001$) and age ($\beta = 1.64$; $p < 0.001$) maintained strong positive effects, whereas the remaining variables did not reach statistical significance. In the ICU, only NIHSS was significant ($\beta = 0.49$; $p = 0.035$), suggesting that greater initial severity is associated with longer length of stay when ICU care is required. In the General Ward, female sex was the only significant coefficient ($\beta = 1.63$; $p = 0.028$), a finding that should be interpreted with caution given the very high proportion of zero values; in the Angiography unit, no coefficients were significant, consistent with its minimal utilization. Overall, the findings reinforce that age and neurological severity (NIHSS) are consistent determinants of LOS, whereas the effects of binary variables vary across units and become unstable in the presence of many zero observations.

Table 3. Knowledge distillation – conservative treatment

Hospital unit	**R²**	**Model equation (LOS, in hours)**
Emergency Room	0.914	LOS = 0,714×Age + 1,261×NIHSS − 9,460×SexF + 0,837×PriorStroke −2,697×TOAST_Cardioembolism + 0,087×TOAST_Undetermined_cause
Ward	0.113	LOS = − 0,0148×Age − 0,0010×NIHSS + 1,629×SexF − 0,330×PriorStrok. + 1,478×TOAST_Atherosclerosis + 1,361×TOAST_Cardioembolism + 1,915×TOAST_Undetermined_cause

Angiography Suite	0.152	LOS = 0,001442×Age − 0,00326×NIHSS − 0,0110×SexF − 0,0683×PriorStroke + 0,02455×TOAST_Atherosclerosis + 0,04444×TOAST_Cardioembolism + 0,01937×TOAST_Occlusion
Intensive Care Unit (ICU)	0.156	LOS = − 0,00129×Age + 0,490×NIHSS + 5,158×SexF − 0,690×PriorStroke + 0,437×TOAST_Atherosclerosis − 3,904×TOAST_Cardioembolism
Stroke Unit	0.849	LOS = 1,641×Age + 8,678×NIHSS + −4,647×SexF + 9,971×PriorStroke + 5,520×TOAST_Atherosclerosis −12,495×TOAST_Cardioembolism + 39,063×TOAST_Undetermined_cause

For patients undergoing intravenous thrombolysis (IVT), the original (RAW) length-of-stay scale was retained, as it proved adequate for capturing the care-flow patterns characteristic of this group and for providing direct clinical interpretability of the coefficients obtained in the distillation process. However, in units with short or no stay for IVT patients, such as the Ward, Angiography, and ICU, both the Z-score and the original scale showed limited performance, directly reflecting the low utilization of these units by thrombolyzed patients (Table 4).

Across nearly all units, age and admission NIHSS score remained among the most relevant variables, reaffirming their role as key determinants of hospital length of stay. In the Emergency Room ($R^2 = 0.898$), the model highlighted age and NIHSS as primary predictors, with positive and significant coefficients (age: $\beta = 0.687$, $p < 0.001$; NIHSS: $\beta = 1.198$, $p = 0.003$), indicating that initial clinical severity is a major determinant of acute care duration. Each additional point on the NIHSS admission score was associated with an increase of approximately 1.2 hours in length of stay, whereas each additional year of age was associated with an additional 0.7 hours in emergency department time, reinforcing that older patients and those with greater neurological severity require longer acute care.

In the Ward ($R^2 = 0.348$), the model identified TOAST "Other Causes" as the main predictor; however, interpretation is limited because only one patient had a stay in this unit. This finding suggests an atypical case rather than a consistent clinical pattern, indicating that the General Ward does not represent a regular care pathway for patients receiving IVT in the studied population. In the Angiography unit ($R^2 = 0.070$), all coefficients were statistically non-significant, which is consistent with the fact that only two patients among the 79 analyzed used this service. Such low utilization renders clinical inference inconclusive and reflects the selectivity of referral to angiographic procedures following IVT.

In the ICU ($R^2 = 0.088$), the model identified female sex as the most influential variable, but the confidence intervals were wide, reflecting the instability inherent in the small sample of 13 patients who actually required ICU care. In the Stroke Unit ($R^2 = 0.926$), the model consolidated NIHSS, age, and prior stroke as the main determinants, with robust and highly significant coefficients (NIHSS: $\beta = 11.673$, $p < 0.001$; age: $\beta = 1.155$, $p < 0.001$). These results clearly reflect the influence of neurological severity, age, and pre-existing comorbidities on rehabilitation length of stay, with NIHSS emerging as the most impactful factor in determining duration of hospitalization in the specialized unit.

Table 4. Knowledge distillation – IVT treatment

Hospital unit	**R²**	**Model equation (LOS, in hours)**
Emergency Room	0.898	LOS = 0,687×Age + 1,198×NIHSS + 2,923×SexF + 2,177×PriorStroke −3,062×TOAST_Atherosclerosis + 3,661×TOAST_Undetermined_cause
Ward	0.348	LOS = 0,000046×Age + 0,003461×NIHSS − 0,048×SexF − 0,077×PriorStroke + 1,128×TOAST_Other_cause −0,0048×TOAST_Atherosclerosis

Angiography Suite	0.073	LOS = 0,000178×Age − 0,001176×NIHSS + 0,0185×SexF + −0,0323×PriorStroke + 0,0277×TOAST_Atherosclerosis + 0,0444×TOAST_Cardioembolism + 0,0194×TOAST_Occlusion
Intensive Care Unit (ICU)	0.01	LOS = −0,001325×Age + 0,244×NIHSS + 23,834×SexF −0,690×PriorStroke + 0,437×TOAST_Atherosclerosis + 12,447×TOAST_Cardioembolism − 1,233×TOAST_Other_cause
Stroke Unit	0.926	LOS = 1,155×Age + 11,673×NIHSS − 10,959×SexF + 32,114×PriorStroke + 7,295×TOAST_Occlusion + 0,780×TOAST_Cardioembolism

5. Conclusion

This study aimed to map the stroke care cycle and identify the variables with the greatest influence on length of stay during the treatment of ischemic stroke in a Brazilian hospital. Based on the care cycle mapping, three key decision points were identified: triage and initial diagnosis; determination of therapeutic eligibility; and referral to the appropriate inpatient unit. In addition, five hospital units were identified through which patients progress: Emergency Department, General Ward, Angiography Suite, Intensive Care Unit (ICU), and Stroke Unit.

Variable analysis, conducted using a hybrid approach combining Gradient Boosting Machines and Knowledge Distillation, enabled a comprehensive assessment of the ischemic stroke care cycle at a Brazilian hospital center by mapping care pathways, identifying variations, and evaluating factors influencing length of hospital stay across different units and treatment contexts.

The results showed that age and admission NIHSS score are the main determinants of length of stay, reflecting the impact of initial neurological severity and care complexity. The TOAST etiological classification also proved relevant, particularly the Occlusion and Other Etiologies categories, which were associated with longer hospitalization periods. The distilled models preserved the clinical coherence of the patterns identified by the GBM, demonstrating that combining algorithmic accuracy with statistical interpretability can enhance hospital management and support value-based clinical decision-making. The study further highlights the importance of process mapping and the integration of BPM, Lean Healthcare, and TDABC methodologies to redesign care flows and promote continuous improvement in ischemic stroke care in Brazil.

Consistency was observed between the patterns identified by the GBM models and those reproduced by the distilled linear regressions for both conservative treatment and intravenous thrombolysis (IVT). Age, admission NIHSS score, and prior stroke history consistently emerged as factors associated with increased length of stay, corroborating previous findings in the literature that recognize them as robust indicators of disease severity and higher care demand (Addisu & Mega, 2025). The inclusion of the TOAST classification allowed differentiation among etiological subtypes, showing that occlusive and undetermined causes may lead to longer and more complex clinical trajectories.

Variations in R^2 across hospital units reflect the multifactorial nature of the care process, which is characteristic of real-world hospital data where biological, institutional, and contextual factors influence outcomes in an uncontrolled manner. Therefore, the focus of this study was not to maximize statistical fit, but rather to understand and rank the most influential variables, thereby strengthening clinical interpretability.

The main limitations of this study lie in sample heterogeneity and the presence of cases with zero length of stay, which reduce explainable variability and the precision of linear coefficients, as well as the potential influence of unmeasured confounding factors, such as socioeconomic status and comorbidities. For future research, the expansion of the database, the inclusion of multiple hospital centers, and the exploration of nonlinear distillation techniques are recommended, as these approaches may enhance patient-level analyses and capture more subtle interactions between clinical and operational variables.

Thus, this study contributes to the advancement of interpretability methodologies in health data science by demonstrating that the integration of machine learning and explainable models can generate clinically relevant insights, support hospital management, and inform policies aimed at continuous improvement in ischemic stroke care.

References

Addisu, Z. D., and Mega, T. A., Predictors of Hospital Stay After Acute Ischemic Stroke in Hospitalized Patients: Retrospective-Cohort Study, *Cardiology Research and Practice*, vol. 2025, no. 1, p. 7598035, 2025. https://doi.org/10.1155/crp/7598035

Almeida, P. F. de, Medina, M. G., Fausto, M. C. R., Giovanella, L., Bousquat, A., and Mendonça, M. H. M. de., Coordenação do cuidado e Atenção Primária à Saúde no Sistema Único de Saúde, *Saúde em Debate*, vol. 42, pp. 244–260, 2018. https://doi.org/10.1590/0103-11042018S116

Bélanger, A., Beaudet, L., Lapointe, T., and Houle, J., Clinical and organisational quality indicators for the optimal management of acute ischaemic stroke in the era of thrombectomy: A scoping review and expert consensus study, *BMJ Open*, vol. 14, no. 2, p. e073173, 2024. https://doi.org/10.1136/bmjopen-2023-073173

Bustami, M., Idaiani, S., Putri, N. D., Satyagraha, A. W., Panjaitan, N. S. D., Ritonga, A. M., Putri, A. N. M., Asyahida, S. R., Nurkhalizah, M. S., Nitisara, D. A., Rilianto, B., Susanto, N. H., Felistia, Y., and Santoso, A., Determinants of hospital length of stay in ischemic stroke patients: A retrospective cohort study at Indonesian national stroke center, *PLOS ONE*, vol. 20, no. 11, p. e0334355, 2025. https://doi.org/10.1371/journal.pone.0334355

Chang, K.-C., Tseng, M.-C., Weng, H.-H., Lin, Y.-H., and Liou, C.-W., Prediction of Length of Stay of First-Ever Ischemic Stroke, *Stroke*, 2002. https://www.ahajournals.org/doi/10.1161/01.STR.0000034396.68980.39

Coffey, R. J., Richards, J. S., Remmert, C. S., LeRoy, S. S., Schoville, R. R., and Baldwin, P. J., An introduction to critical paths, *Quality Management in Health Care*, vol. 14, no. 1, pp. 46–55, 2005. https://doi.org/10.1097/00019514-200501000-00006

de Luc, K., Are different models of care pathways being developed?, *International Journal of Health Care Quality Assurance*, vol. 13, no. 2, pp. 80–87, 2000. https://doi.org/10.1108/09526860010319532

de Souza, A. C., Sebastian, I. A., Zaidi, W. A. W., Nasreldein, A., Bazadona, D., Amaya, P., Elkady, A., Gebrewold, M. A., Vorasayan, P., Yeghiazaryan, N., Michel, P., Khatri, P., Pandian, J. D., Martins, S. C. O., Hacke, W., and Lioutas, V.-A., Regional and national differences in stroke thrombolysis use and disparities in pricing, treatment availability, and coverage, *International Journal of Stroke*, vol. 17, no. 9, pp. 990–996, 2022. https://doi.org/10.1177/17474930221082446

Duke, G. J., Hirth, S., Santamaria, J. D., Li, Z., Read, C., Hamilton, A., Lapiz, E., Le, T., Fernando, T., and Merlo, R., Promising solution for standardised length of hospital stay based on time-to-event models and contemporary Australian administrative data, *BMJ Open*, vol. 15, no. 12, p. e108020, 2025. https://doi.org/10.1136/bmjopen-2025-108020

Feigin, V. L., Brainin, M., Norrving, B., Martins, S., Sacco, R. L., Hacke, W., Fisher, M., Pandian, J., and Lindsay, P., World Stroke Organization (WSO): Global Stroke Fact Sheet 2022, *International Journal of Stroke*, vol. 17, no. 1, pp. 18–29, 2022. https://doi.org/10.1177/17474930211065917

Feigin, V. L., Owolabi, M. O., Feigin, V. L., Abd-Allah, F., Akinyemi, R. O., Bhattacharjee, N. V., Brainin, M., Cao, J., Caso, V., Dalton, B., Davis, A., Dempsey, R., Duprey, J., Feng, W., Ford, G. A., Gall, S., Gandhi, D., Good, D. C., Hachinski, V., and Zagożdżon, P., Pragmatic solutions to reduce the global burden of stroke: A World Stroke Organization–Lancet Neurology Commission, *The Lancet Neurology*, vol. 22, no. 12, pp. 1160–1206, 2023. https://doi.org/10.1016/S1474-4422(23)00277-6

Friebel, R., Hauck, K., Aylin, P., and Steventon, A., National trends in emergency readmission rates: A longitudinal analysis of administrative data for England between 2006 and 2016, *BMJ Open*, vol. 8, no. 3, p. e020325, 2018. https://doi.org/10.1136/bmjopen-2017-020325

Gagliardi, V. D. B., and Gagliardi, R. J., Current and future conditions of stroke care in Brazil, *Arquivos de Neuro-Psiquiatria*, vol. 77, pp. 68–69, 2019. https://doi.org/10.1590/0004-282X20180160

GBD 2019 Stroke Collaborators, Global, regional, and national burden of stroke and its risk factors, 1990-2019: A systematic analysis for the Global Burden of Disease Study 2019, *The Lancet Neurology*, vol. 20, no. 10, pp. 795–820, 2021. https://doi.org/10.1016/S1474-4422(21)00252-0

Gupta, A., Stead, T. S., and Ganti, L., Determining a Meaningful R-squared Value in Clinical Medicine, *Academic Medicine & Surgery*, 2024. https://doi.org/10.62186/001c.125154

Hamilton, D. F., Ghert, M., and Simpson, A. H. R. W., Interpreting regression models in clinical outcome studies, *Bone & Joint Research*, vol. 4, no. 9, pp. 152–153, 2015. https://doi.org/10.1302/2046-3758.49.2000571

Han, T. S., Murray, P., Robin, J., Wilkinson, P., Fluck, D., and Fry, C. H., Evaluation of the association of length of stay in hospital and outcomes, *International Journal for Quality in Health Care*, vol. 34, no. 2, p. mzab160, 2022. https://doi.org/10.1093/intqhc/mzab160

Holloway, R. G., Witter, D. M., Lawton, K. B., Lipscomb, J., and Samsa, G., Inpatient costs of specific cerebrovascular events at five academic medical centers, *Neurology*, vol. 46, no. 3, pp. 854–860, 1996.

Jauch, E. C., Cucchiara, B., Adeoye, O., Meurer, W., Brice, J., Chan, Y., Gentile, N., and Hazinski, M. F., Part 11: Adult Stroke, *Circulation*, vol. 122, no. 18_suppl_3, pp. S818–S828, 2010. https://doi.org/10.1161/CIRCULATIONAHA.110.971044

Jørgensen, H. S., Nakayama, H., Raaschou, H. O., and Olsen, T. S., Acute Stroke Care and Rehabilitation: An Analysis of the Direct Cost and Its Clinical and Social Determinants, *Stroke*, vol. 28, no. 6, pp. 1138–1141, 1997. https://doi.org/10.1161/01.STR.28.6.1138

Kasner, S. E., Clinical interpretation and use of stroke scales, *The Lancet Neurology*, vol. 5, no. 7, pp. 603–612, 2006. https://doi.org/10.1016/S1474-4422(06)70495-1

Koton, S., Bornstein, N. M., Tsabari, R., and Tanne, D., Derivation and validation of the Prolonged Length of Stay score in acute stroke patients, *Neurology*, vol. 74, no. 19, pp. 1511–1516, 2010. https://doi.org/10.1212/WNL.0b013e3181dd4dc5

Lindsay, P., Furie, K. L., Davis, S. M., Donnan, G. A., and Norrving, B., World Stroke Organization Global Stroke Services Guidelines and Action Plan, 2014. https://doi.org/10.1111/ijs.12371

Liu, M., Guo, C., and Guo, S., An explainable knowledge distillation method with XGBoost for ICU mortality prediction, *Computers in Biology and Medicine*, vol. 152, p. 106466, 2023. https://doi.org/10.1016/j.compbiomed.2022.106466

Mamoli, A., Censori, B., Casto, L., Sileo, C., Cesana, B., and Camerlingo, M., An analysis of the costs of ischemic stroke in an Italian stroke unit, *Neurology*, vol. 53, no. 1, pp. 112–116, 1999. https://doi.org/10.1212/wnl.53.1.112

Marfil-Garza, B. A., Belaunzarán-Zamudio, P. F., Gulias-Herrero, A., Zuñiga, A. C., Caro-Vega, Y., Kershenobich-Stalnikowitz, D., and Sifuentes-Osornio, J., Risk factors associated with prolonged hospital length-of-stay: 18-year retrospective study of hospitalizations in a tertiary healthcare center in Mexico, *PLOS ONE*, vol. 13, no. 11, p. e0207203, 2018. https://doi.org/10.1371/journal.pone.0207203

Nogueira, R. G., Haussen, D. C., Liebeskind, D. S., Jovin, T. G., Gupta, R., Saver, J. L., Jadhav, A. P., Budzik, R. F., Baxter, B., Krajina, A., Bonafe, A., Malek, A., Narata, A. P., Mohammaden, M. H., Zhang, Y., Morgan, P., Ji, M., Bartolini, B., English, J., and Veznedaroglu, E., Clinical effectiveness of endovascular stroke treatment in the early and extended time windows, *International Journal of Stroke*, vol. 17, no. 4, pp. 389–399, 2022. https://doi.org/10.1177/17474930211005740

Rajkomar, A., Dean, J., and Kohane, I., Machine Learning in Medicine, *New England Journal of Medicine*, vol. 380, no. 14, pp. 1347–1358, 2019. https://doi.org/10.1056/NEJMra1814259

Rexrode, K. M., Madsen, T. E., Yu, A. Y. X., Carcel, C., Lichtman, J. H., and Miller, E. C., The Impact of Sex and Gender on Stroke, *Circulation Research*, vol. 130, no. 4, pp. 512–528, 2022. https://doi.org/10.1161/CIRCRESAHA.121.319915

Rosa, C. T., Zonta, M. B., Lange, M. C., and Zétola, V. de H. F., Quality of life: Predictors and outcomes after stroke in a Brazilian public hospital, *Arquivos de Neuro-Psiquiatria*, vol. 81, pp. 002–008, 2023. https://doi.org/10.1055/s-0042-1758364

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