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Predictive factors for lack of neurological improvement in acute stroke patients without large vessel occlusion treated with low-dose thrombolysis and screened with 3T MRI

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Abstract. – OBJECTIVE: The study evaluated the lack of neurological improvement and the factors influencing it in patients with acute ischemic stroke (AIS) without major arterial occlusion.

PATIENTS AND METHODS: A cross-sectional study was conducted on patients diagnosed with acute ischemic stroke without significant occlusion of major arteries, with imaging evidence from 3-tesla magnetic resonance imaging (MRI) scans at the S.I.S Hospital in Can Tho, Vietnam, from 2019 to 2023. Eligible patients received treatment with low-dose alteplase (a single dose of 0.6 mg/kg).

RESULTS: Among the 268 patients included in the study, a significant improvement in neurological function was observed in 195 patients (72.8%) [modified Rankin Scale (mRS): 0-1 points], while 73 patients (27.2%) demonstrated little or no improvement after 3 months of treatment. There were no recorded fatalities during the study period. Female patients accounted for 35.8% of the total sample. The average age of the participants was 62.9 years. The multivariate regression analysis identified several predictive factors associated with the risk of lack of improvement after 3 months, including advanced age, higher National Institute of Health Stroke Scale (NIHSS) scores, elevated blood glycemia levels (mmol/L), and elevated high-sensitive (hs) troponin I levels (ng/mL) ($p < 0.05$). Glycemia and hs troponin I levels were identified as biomarkers for predicting outcomes after ischemic stroke. No evidence was found linking sex, a history of chronic illness, and a lack of improvement.

CONCLUSIONS: Predicting prognostic factors for lack of neurological improvement will assist neurologists in developing personalized treatment plans for patients, reducing complications, and promoting patient recovery.

Key Words:
Acute ischemic stroke, Lack of neurological improvement, Low-dose alteplase, 3-tesla MRI, S.I.S Hospital, Vietnam.

Introduction

Stroke encompasses both ischemic stroke and hemorrhagic stroke, with approximately 87% of cases being acute ischemic stroke (AIS)[1,2]. Patients with AIS receive thrombolytic therapy through intravenous administration of tissue plasminogen activator and experience significant clinical improvement[1-3]. The use of recombinant tissue plasminogen activator (rTPA) is considered effective and safe within a 3 to 4.5-hour timeframe from the onset of stroke symptoms[3,4]. In the 2016 ENCHANTED trial[5] conducted on Asian AIS patients, comparing treatment outcomes of low-dose (0.6 mg/kg) *vs.* standard-dose (0.9 mg/kg) thrombolytic therapy within a 0 to 4.5-hour window, the low-dose regimen demonstrated comparable efficacy to the standard dose in terms of mortality and disability. However, the rate of symptomatic intracranial hemorrhage complications was higher in the standard-dose group compared to the low-dose group (2.1% *vs.* 1.0%). Therefore, it is recommended to use low-dose rTPA for Asian patients[5]. Many studies[6-8] have shown that the number of cerebral microbleeds (CMBs) is a risk factor for an increased likelihood of hemorrhagic transforma-

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tion after rTPA treatment. The American Stroke Association[9] recommends considering rTPA treatment for AIS patients with more than 10 CMBs, with a Level 2B evidence rating, as it may increase the risk of hemorrhagic transformation.

In Vietnam, there are approximately 200,000 stroke cases reported annually, with direct treatment costs ranging from 20 million to over 250 million Vietnamese dongs (900 – 10,000 USD). Currently, thrombolysis is the primary treatment option for AIS[10]. Several studies[11-13] conducted in Vietnam have implemented low-dose thrombolytic therapy during the early stages (within 4.5 hours) of AIS, demonstrating effective neurological improvement. However, according to statistics from the Vietnamese Ministry of Health[14], in 2022, only 20% of stroke patients recognize their condition and seek early treatment at hospitals. Moreover, up to 80% of stroke patients experience severe disabilities, with approximately 30% unable to achieve recovery. Prognosis is always a concern for neurologists when facing AIS, as it guides appropriate management and provides good counseling for the patient's family. Therefore, it is essential to identify prognostic factors for immediate non-improvement in patients upon hospital admission.

Patients and Methods

Participants

The study was conducted at the General Emergency Department of Can Tho Stroke International Service Hospital, Can Tho City, Vietnam, with data collected from 2019 to 2023. The study included all AIS patients who met the following criteria: (1) symptom onset within 4.5 hours, (2) no large vessel occlusion, (3) treated with low-dose intravenous thrombolytic therapy (a single dose of 0.6 mg/kg), (4) had evidence of acute ischemic stroke on 3T MRI and (5) participation in the study is voluntary. Consent to participate in the study was confirmed by directly asking the patients and obtaining their signatures on the consent form. In cases of indirect consent *via* phone, patients confirmed their agreement to participate in the study through email.

The exclusion criteria consist of patients with a National Institute of Health Stroke Scale (NIHSS) score below 5, patients in a deep coma with a Glasgow Coma Scale (GCS) score below 5, patients experiencing cardiac arrest upon admission, patients with over 10 CMBs detected on a 3T MRI scan, patients lacking indications of cerebral hemorrhage on a 3T MRI scan, and patients with a history of cerebral hemorrhage.

Sample Size and Sampling Method

We have chosen a sample consisting of 268 cases that met the aforementioned criteria. Between February 2019 and December 2023, the hospital encountered a total of 4,629 cases of acute stroke. Out of these, 334 cases met the criteria for inclusion in the research sample. Among them, 45 cases exhibited more than 10 CMBs, as observed through 3T MRI scans. Additionally, 12 cases declined to participate in the study, and 9 cases were lost to follow-up (either failing to attend a follow-up visit within 3 months or being unreachable by phone).

Study Content

The study recorded demographic, clinical, mortality, routine laboratory, and hemodynamic variables of patients upon admission. Data on the history of risk factors were obtained from medical records, patients, or their families. The presence of intracranial lesions, new infarction, or hemorrhagic transformation and micro-bleeding was determined using 3T MRI.

We defined the lack of neurological improvement as patients having a modified Rankin Scale (mRS) score ≥ 2 at 3 months from the onset of the disease, which is a commonly used timeframe in studies[15-17] of acute stroke thrombolysis. Factors influencing neurological improvement were analyzed and divided into two groups: improved neurological function and lack of improvement after 3 months of treatment.

Data Collection Method

All patients were continuously monitored and evaluated for vital signs, mRS, NIHSS, and complications at 24 hours, 7 days, prior to discharge, and at the 3-month follow-up. After explaining the purpose and significance of the study, patients/family members provided voluntary consent, and then information was collected based on medical records. During the patient's post-discharge follow-up to assess the survival rate, we contacted them directly *via* phone or conducted a re-examination to gather information.

Statistical Analysis

The data were analyzed using Stata software version 17.0 (Stata 17.0, College Station, TX, USA). Descriptive statistics included mean val-

ues, standard deviations for quantitative variables, and percentages for categorical variables. Analytical statistics included Chi-square tests for categorical variables, *t*-tests and ANOVA for quantitative outcome variables. Logistic regression models (odds ratios) were used for factors associated with a lack of neurological recovery. A p-value < 0.05 was considered statistically significant.

Results

Lack of Neurological Improvement in Patients with Acute Ischemic Stroke Without Major Arterial Occlusion After 3 Months of Treatment

At the time of reception, nearly all acute stroke patients (99.3%) exhibited severe neurological symptoms (mRS score ≥ 2). After receiving thrombolytic therapy, the proportion of patients with severe symptoms gradually decreased to 74.6% at 24 hours and 27.2% at 3 months. The average mRS scores at the corresponding time points were 3.3, 2.4, and 1.1, respectively (Figure 1).

Among the 268 patients, 196 patients (73.1%) showed significant improvement in neurological function, while 72 patients (26.9%) showed little or no improvement after 3 months of treatment; there were no fatalities recorded. Women accounted for 35.8% of the total. The average age was 62.9 years, with a notable age difference between the lack of improvement group (68.1 years) and the improvement group (61.1 years) ($p < 0.001$). The average body mass index (BMI) was 23.1 kg/m^2. Additionally, the mean arterial pressure (MAP) was 112 mmHg, with no significant difference in MAP between the two groups (Table I). Upon admission, specialized indices were recorded to assess neurological deficits. For the Glasgow Coma Scale, the average score was 14.3, with the lack of improvement group achieving a score of 12.7 and the improvement group achieving a score of 14.9. The average NIHSS score was 9.7, with scores of 14.6 and 7.9 for each respective group. The average mRS score was 3.3, with scores of 3.9 and 3.1, respectively. All three evaluation indices showed statistically significant differences between the improvement and lack of improvement groups ($p < 0.001$) (Table I).

The location of primary brain damage is mainly in the anterior circulation (84.7%), with a lower rate in the posterior circulation (15.3%). There was no significant difference in the distribution of traumatic brain injury between the two groups. In addition, preexisting medical conditions were analyzed, including a history of minor stroke or transient ischemic attack (TIA), diabetes, coronary artery disease, and dyslipidemia. There was no significant difference in the incidence of these conditions between the two groups ($p > 0.05$). All irreversible cases were associated with hypertension. Blood biochemical indices upon admission, including blood glucose, creatinine, estimated glomerular filtration rate (eGFR), and hs troponin I, were also tested with average concentrations of 149.9 mmol/L, 84.9 µm/L, 84.8 mL/min/1.73 m^2 and 20.1 ng/mL, respectively. The blood glucose levels between the two groups were found to have a statistically significant difference ($p = 0.02$) (Table I). The door-to-needle time (DTN) is the number of minutes calculated from the patient's admission to the time of intervention with intravenous thrombolysis (Diamond standard is 45 minutes - World Stroke Organization Angels Awards - USA). In this study, the average DTN was 46.5 minutes, with 47.3 minutes for the lack of improvement group and 46.2 minutes for the improvement group. The onset-to-treatment time remains the most important factor in the prognosis of stroke patients treated with intravenous thrombolysis. The average time from symptom onset to treatment was 180 minutes, with 185.8 minutes for the non-improvement group and 178.8 minutes for the improvement group. Both DTN and onset of treatment time did not show statistically significant differences between the two groups (Table I).

After receiving intravenous thrombolysis, patients were evaluated for the presence of cerebrovascular complications through CT brain imaging after 24 hours. In the non-improvement group, there were 5/73 cases with hemorrhage transformation (6.9%) and 3/73 cases with new infarction (4.1%). In contrast, the improvement group had fewer complications, with 3/195 cases experiencing hemorrhage transformation (1.5%) and 1/195 cases with new infarction (0.5%). This difference was statistically significant ($p < 0.05$) (Table I). The NIHSS score after 7 days of treatment in the lack of improvement group was 7.6, which was higher than the average score of 2.4 in the improvement group ($p < 0.001$). Patients who did not show neurological improvement had longer ICU stays and hospitalizations (31.7 hours and 7.6 days) compared to the improvement group (26.9 hours and 7.2 days) (Table I).

Table I. Comparison of clinical characteristics and univariate analysis based on lack of neurological improvement at 3 months. The comparison of demographic and clinical factors between patients with and without neurological improvement at 3 months revealed the associated factors were age, Glasgow Coma Scale (at admission), NIHSS (at admission and day 7), mRS (at admission, day 7 and 3 months), blood glucose level at admission, presence of hemorrhagic transformation, and new infarction ($p < 0.05$).

Variable	Total	Lack of improvement (n = 73)	Improvement (n = 195)	*p*-value*
Age, mean (SD), years	62.9 (12.2)	68.1 (11.2)	61.1 (12.1)	**< 0.001**
Age group, n (column %)				
Patients aged < 60	102 (38.1)	15 (20.6)	87 (44.6)	**< 0.001**
Patients aged ≥ 60	166 (61.9)	58 (79.4)	108 (55.4)	
Sex, n (%)				
Female	96 (35.8)	32 (44.4)	64 (32.6)	0.09
Male	172 (64.2)	40 (55.6)	132 (67.4)	
BMI, mean (SD)	23.1 (3.3)	22.5 (3.1)	23.3 (3.4)	0.07
MAP, mean (SD)	112.0 (16.7)	112.0 (17.3)	112.0 (16.4)	0.99
Glasgow, mean (SD) (at hospital admission)	14.3 (1.5)	12.7 (1.9)	14.9 (0.5)	**< 0.001**
NIHSS score, mean (SD) (at hospital admission)	9.7 (4.4)	14.6 (4.0)	7.9 (2.9)	**< 0.001**
NIHSS score, mean (SD) (after 7 days)	3.8 (3.4)	7.5 (3.3)	2.4 (2.1)	**< 0.001**
mRS score, mean (SD) (at hospital admission)	3.3 (0.7)	3.9 (0.5)	3.1 (0.6)	**< 0.001**
mRS score, mean (SD) (after 24 hours)	2.4 (1.3)	3.9 (0.6)	1.9 (0.6)	**< 0.001**
mRS score, mean (SD) (after 3 months)	1.1 (0.9)	2.4 (0.6)	0.6 (0.5)	**< 0.001**
Regions of the brain damaged n (%)				
Anterior circulation	227 (84.7)	58 (79.4)	169 (86.7)	0.14
Posterior circulation	41 (15.3)	15 (20.6)	26 (13.3)	
Anamnesis, n (column %)				
History of minor stroke or TIA	17 (6.4)	3 (4.2)	14 (7.2)	0.37
Hypertension	253 (94.4)	72 (98.6)	181 (92.8)	0.07
Diabetes	31 (11.6)	13 (17.8)	18 (9.2)	0.05
Coronary artery disease	80 (29.9)	26 (35.6)	54 (27.7)	0.21
Dyslipidemia	45 (16.9)	13 (17.8)	32 (16.5)	0.80
Blood biochemical, mean (SD) (at hospital admission)				
Glycemia, mmol/L	149.9 (87.8)	170.3 (112.7)	142.8 (75.2)	**0.02**
Creatinin, µm/L	84.9 (20.1)	84.9 (17.9)	84.9 (20.9)	0.99
eGFR, mL/min/1.73 m^2	84.8 (131.5)	74.0 (17.6)	88.8 (153.7)	0.19
High-sensitive troponin I, ng/mL	20.1 (188.4)	63.3 (358.2)	6.8 (16.9)	0.18
Door-to-nedle time, mean (SD), min	46.5 (9.7)	47.3 (10.9)	46.2 (9.2)	0.41
The onset-to-treatment time, mean (SD), min	180 (56.5)	185.8 (49.8)	178.8 (58.8)	0.37
Computed tomographic findings, n (column %)				
Hemorrhagic transformation,	7 (2.6)	5 (6.9)	2 (1.0)	**0.008**
New infarction	4 (1.5)	3 (4.1)	1 (0.5)	**0.03**
Length of ICU stay, mean (SD), hour	28.2 (12.3)	31.7 (16.8)	26.9 (9.9)	**0.02**

NIHSS, National Institutes of Health Stroke Scale; BMI, body mass index; MAP, mean arterial pressure; TIA, transient ischemic attack; eGFR, Estimated glomerular filtration rate; ICU, intensive care unit; SD, standard deviation; n, frequency; %, percentage. **t*-test for comparing 2 means (with equal and unequal variance); Chi-square test to compare the difference between expected and observed frequencies.

Factors Influencing the Lack of Neurological Improvement After 3 Months of Treatment

The predictors of the outcome after 3 months of treatment are presented in Table II. In the univariate model, age, NIHSS score at admission, NIHSS score after 24 hours of treatment, and the complication of hemorrhagic transformation were found to be associated with poor improvement, with respective odds ratios of 1.05 (95% CI: 1.009-1.036; $p < 0.001$), 1.8 (95% CI: 1.5-2.0; $p < 0.001$), 7.1 (95% CI: 1.3-37.4; $p = 0.021$), and 1.8 (95% CI: 1.5-2.0; $p < 0.001$). In

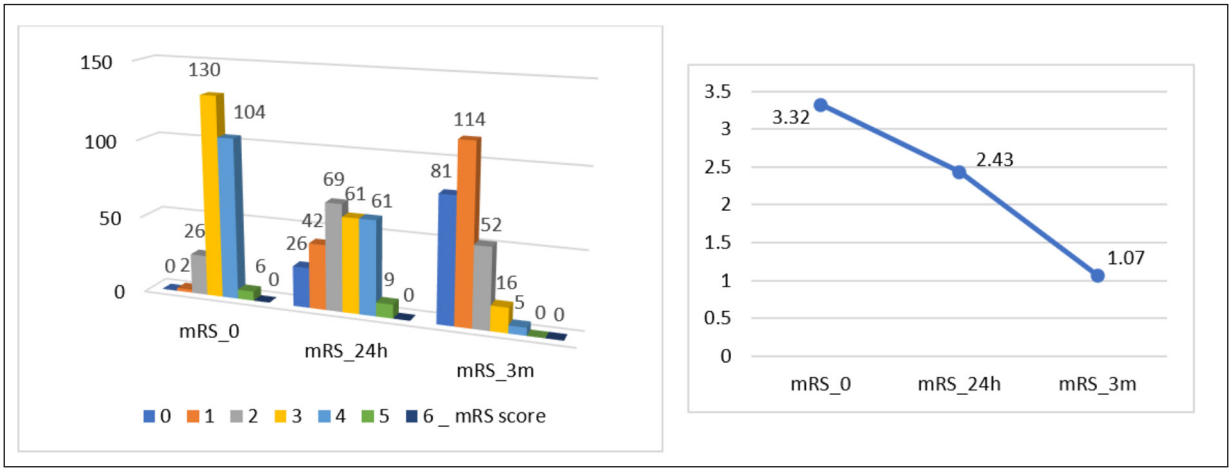

Figure 1. The distribution of mRS scores and mean mRS score at the three treatment time points. **A**, the distribution of mRS score at the three treatment time points. **B**, The mean mRS score at the three treatment time points.
No patient had an mRS score of 6. The number of patients with decreasing mRS scores decreased over the 3 treatment time points. At the 3-month timepoint, no patients had scores of 5 or 6. Additionally, the mean mRS score of patients decreased over the 3 treatment time points, equivalently 3.32, 2.43 and 1.07. mRS_0, mRS_24 h, mRS_3 m: mRS scores of patients at the time of admission, 24 hours, and 3 months after treatment.

the multivariate model, age was found to be an independent predictor of a 7.7% increase in the likelihood of poor outcomes for each one-year increase (OR = 1.077; 95% CI: 1.032-1.123; p = 0.001). An increase of 1 point in NIHSS score at admission predicted a 68% increase in the likelihood of non-improvement (OR = 1.68; 95% CI: 1.40-2.04; $p < 0.001$). The lack of improvement after 24 hours was identified as an independent predictor of poor outcome at 3 months, with each increase in NIHSS score leading to a 92% higher likelihood of non-improvement in neurological function (OR = 1.92; 95% CI: 1.49-2.47; $p < 0.001$). This model had a variance inflation factor (VIF) of 1.36, indicating no issue of multicollinearity (Table II).

Table III presents the values of blood biochemical tests at the time of patient admission. In the univariate model, the concentrations of glycemia and hs troponin I in the blood were found to be associated with delayed neurological function recovery, with respective odds ratios of 1.003 (95% CI: 1.001-1.006; p = 0.031) and 1.020 (95% CI: 1.006-1.032; p = 0.003). Creatinine and estimated glomerular filtration rate (eGFR) did not show a significant association ($p > 0.05$). In the multivariate logistic regression model, the VIF was 1.10, indicating no issue of multicollinearity in the model. After adjusting for age and sex, two blood biochemical indices were identified as independent predictors of the outcome. A 1-unit increase in glycemia (mmol/L) was associated with a 0.3% increase in the likelihood of no improvement in neurological function recovery (aOR = 1.003; 95% CI: 1.001-1.006; p = 0.030). A 1 ng/mL increase in hs troponin I in the blood predicted a 2.4% increase in the likelihood of no improvement in neurological function (aOR = 1.024; 95% CI: 1.009-1.039; p = 0.002). In this model, it was observed that for each one-year increase in age, there was a 4.3% higher likelihood of lack of improvement (aOR = 1.043; 95% CI: 1.015-1.072; p = 0.002) (Table III).

Discussion

In this study, patients with ischemic stroke ranging from mild to severe experienced gradual improvement after a 3-month follow-up, as assessed using the mRS functional and neurological scale. The neurological improvement was more pronounced in AIS patients without severe vessel occlusion, corresponding to mRS scores greater than 2, compared to mild patients. After intravenous infusion of alteplase to dissolve blood clots and restore acute blood flow, we found that age, the severity of the injury, and two blood chemical indices, glycemia and hs troponin I, were predictive factors for neurological improvement. Based on the available medical records, stroke patients

Table II. Logistic regression model of factors associated with lack of neurological improvement at 3 months. Seven factors were included in the multivariate model, and 3 independent factors associated with lack of neurological improvement were identified: age, NIHSS score at admission, and NIHSS score at 7 days ($p < 0.05$).

Variable	Unadjusted model			Adjusted model		
	OR	95% CI	*p*-value	aOR	95% CI	*p*-value
Age, years	1.05	1.02-1.08	**< 0.001**	1.077	1.032-1.123	**0.001**
Men	0.63	0.36-1.09	0.09	0.67	0.25-1.02	0.424
NIHSS score (at hospital admission)	1.8	1.5-2.0	**< 0.001**	1.68	1.40-2.04	**< 0.001**
History of minor stroke or TIA	0.56	0.16-2.0	0.372	0.35	0.05-2.60	0.307
Coronary artery disease	1.44	0.81-2.56	0.208	0.64	0.21-1.93	0.427
Hemorrhagic transformation	7.1	1.3-37.4	**0.021**	1.97	0.10-39.36	0.658
NIHSS score (after 7 days)	2.3	1.8-2.8	**< 0.001**	1.92	1.49-2.47	**< 0.001**

NIHSS, National Institutes of Health Stroke Scale; BMI, body mass index; MAP, mean arterial pressure; CI, confidence interval; OR, odd ratio; aOR, adjusted odd ratio.

received appropriate diagnosis and treatment management. The average onset-to-treatment time was 180 minutes, and the average door-to-needle time was 46.5 minutes. All patients underwent brain scans using 3T MRI, and medications were prescribed according to risk factors.

The average age of the study population in this research was 63, which is younger compared to other similar studies, such as Chen et al[18]'s study in Taiwan in 2016, with an average age of 70, and 12 years younger than the Ibericus study[19] in Spain in 2009 with a reported average age of 75. The study found that age is an unmodifiable factor and an independent predictor of neurological and functional outcomes, similar to other reports[20-22]. This suggests a trend of rejuvenation in the age of stroke. The male population in our sample was predominant (64.2%), but there was no sex difference in the rate of neurological improvement after stroke. This finding differs from the study by Kim et al[23], where females had poorer neurological functional recovery compared to males.

The mRS scale is commonly used to assess disability in stroke patients. The mRS score at admission was 3.3, decreasing by 0.9 points between admission and 24 hours (2.4 points) and decreasing by 2.2 points after 3 months (1.1 points). The non-recovery rates at these three time points were 99.3%, 74.6%, and 27.2%. There was a statistically significant difference in the scores between the good and poor outcome groups at these three time points. This study showed an mRS score of 0-2 after 3 months of 92.2% (247/268), higher than the study by Rangaraju et al[24], whose mRS score of 0-2 was 60.3% and the research by Nguyen and Pham[25] with 47.5%. This difference may be due to differences in the study population's biological characteristics, level of medical

Table III. Logistic regression model of blood biochemical indices at admission and lack of neurological improvement at 3 months. Four blood biochemical indices were included in the age and sex-adjusted multivariate model and three independent factors associated with lack of neurological improvement were identified: age, blood glucose, and high-sensitive troponin I ($p < 0.05$).

Variable	Unadjusted model			Adjusted model		
	OR	95% CI	*p*-value	aOR	95% CI	*p*-value
Age, years	1.05	1.02-1.08	**< 0.001**	1.043	1.015-1.072	**0.002**
Men	0.63	0.36-1.09	0.09	1.48	0.60-3.60	0.394
Glycemia, mmol/L	1.003	1.001-1.006	**0.031**	1.003	1.001-1.006	**0.030**
Creatinin, µm/L	1.0	0.987-1.013	0.99	0.972	0.939-1.006	0.102
eGFR, mL/min/1.73 m^2	0.988	0.973-1.003	0.13	0.967	0.934-1.002	0.063
High-sensitive troponin I, ng/mL	1.020	1.006-1.032	**0.003**	1.024	1.009-1.039	**0.002**

CI, Confidence interval; eGFR, estimated glomerular filtration rate; OR, odd ratio; aOR, adjusted odd ratio.

technology, as well as the assessing ability of neurologists. Clinical scales were also evaluated to estimate the lack of improvement, and there was a clear difference in the non-improvement group when the Glasgow Coma Scale score was lower compared to the improvement group, which is consistent with previous studies[26-28]. Additionally, the NIHSS scale, which measures the degree of neurological impairment, showed that as the score increased, the likelihood of neurological recovery decreased. This study clearly showed that the average admission score for patients with poor outcomes was 16.6, while the good outcome group had a score of 7.9. On reevaluation after 7 days, the scores were 7.5 and 2.4, respectively. These results are similar to Ovbiagele and Saver's findings[29], which demonstrated a strong correlation between mRS scores at day 7/10 and day 90 with improvement.

Chronic comorbidities were also investigated in this study. Here, patients with hypertension, diabetes, and coronary artery disease had a higher prevalence compared to the group with poor improvement, although the evidence of this difference was not strong enough. Our analysis did not find any association between a history of coronary artery disease and a lack of neurological recovery. However, in theory, and based on other studies[30,31], acute stroke is considered a cardiovascular disease, and the consequences of occlusions in large blood vessels other than those in the cerebrovascular territory, such as the aortic arch, brachiocephalic artery, subclavian artery, or thrombi formed in the heart, may also be relevant. Three similar studies by Naito et al[32], Kang et al[33] and McFarlane et al[34] demonstrated that these factors were independent predictors of outcomes after 3 months.

Since the study excluded cases of large vessel occlusion, the rate of hemorrhagic transformation and new infarction complications was not high, with rates of 2.6% (7/268) and 1.5% (4/268), respectively. However, this study did find that hemorrhagic transformation complications were associated with recovery ability (OR = 7.1; 95% CI: 1.3-37.4; p = 0.021). Hemorrhagic complications are rare but dangerous adverse events following alteplase treatment. In a study by Tian et al[35] in Chinese tertiary hospitals in 2022, the rate of hemorrhagic transformation was 41.2%, with 5.4% experiencing symptomatic intracranial hemorrhage (sICH) and 13.4% having a parenchymal hemorrhage. In another study by Kranendonk et al[36], out of 539 patients, 173 (32%) developed intracranial hemorrhage, and 30 patients had sICH (6%).

An increase in each unit of blood glucose level (mmol/L) is an independent factor with predictive value for poor outcomes. This has also been demonstrated in several studies[37-39] showing significant associations between adverse outcomes after ischemic stroke and biological markers of lipid/metabolism [elevated glucose, low cholesterol, high-density lipoprotein cholesterol (HDL-C), and low-density lipoprotein cholesterol (LDL-C)]. Additionally, higher troponin levels may serve as an important prognostic biomarker for poor improvement in patients with AIS. Elevated troponin levels have also been implicated in numerous studies as a prognostic indicator for mortality associated with cardiovascular diseases, as demonstrated by Alhazzani et al[40] in 2021.

Patients with longer hospital stays have a higher rate of poor improvement. Specifically, in this study, the group with poor improvement had a mean duration of active treatment of 32 hours, while the group with good improvement had a mean duration of 27 hours. These patients had more severe conditions, comorbidities, and delayed hospital admission. The time of initial treatment has also been noted by author Akhtar et al[41] to be associated with reduced risk of complications, disability, and in-hospital mortality for patients staying in the emergency department for less than 8 hours. Personalized treatment management plans and prediction of prognostic factors for poor outcomes are necessary to improve the neurological function of stroke patients. Recommendations include nutritional interventions and muscle strength rehabilitation[42,43] to enhance the quality of life for stroke survivors.

Conclusions

The analysis of predictive factors for lack of neurological improvement indicates that in patients with higher NIHSS scores (at admission and after 7 days), the presence of hemorrhagic transformation, elevated serum glucose levels, and high hs troponin I are associated with poor outcomes, particularly in older adults. In our study, the sample size was not large enough, and we did not have a comparison with cases that did not receive rTPA treatment. Long-term studies are needed to compare different treatment interventions, as well as the impact of dietary regimens and physical activity on the recovery and rehabilitation of patients after acute ischemic stroke.

Conflict of Interest
All authors declare no conflicts of interest for this paper.

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Ethics Approval
The study design was ethically approved by the Science and Technology Council of Can Tho International Stroke Service Hospital, Vietnam (approval No. 7420/QD-SIS, on March 1, 2023).

Informed Consent
Study participants were informed about the research objectives and provided their consent. All participants had the right to withdraw from the study at any time. The anonymity and privacy of the participants were maintained throughout the data collection and reporting process.

Availability of Data and Materials
The data sets during and /or analyzed during the current study are available from the corresponding author upon reasonable request.

AI Disclosure
The authors declare that no artificial intelligence (AI) was used to generate the content of this article.

Authors' Contributions
All authors have made equally significant contributions to this research study. Q.S. Huynh and T.H.T. Nguyen were responsible for designing the study. T.U. To, M.T. Nguyen, and H.V. Nguyen conducted data investigation and ensured accurate and strict exclusions based on the study criteria. The analysis was performed by M.T. Le and M.D. Le, with interpretation by T.T.H. Nguyen; Q.S. Huynh wrote the paper; M.H. Le contributed to the critical evaluation and revision of the manuscript; The final version was shaped by Q.S. Huynh and T.T.H. Nguyen, and all authors approved the final version of the article.

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