



CLINICAL CHARACTERISTICS, ETIOLOGIES, AND 1-YEAR OUTCOMES OF YOUNG ADULTS (<45 YEARS) WITH ISCHEMIC STROKE: A PROSPECTIVE COHORT STUDY FROM PAKISTAN

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ABSTRACT

Introduction

Ischemic stroke in young adults is increasingly recognized as a major public health concern, particularly in low- and middle-income countries where early-onset vascular risk factors are becoming more prevalent. Despite representing a clinically distinct population with unique etiologic patterns and long-term consequences, data from South Asia remain limited. Pakistan, with its large proportion of young adults and rising burden of hypertension, dyslipidemia, diabetes, and tobacco use, provides an important yet under-studied setting. This prospective cohort study aimed to characterize the clinical features, etiologic spectrum, and one-year outcomes of young adults (18–44 years) presenting with acute ischemic stroke to a major tertiary care center in northern Pakistan.

Methods

A prospective cohort study was conducted at Ayub Teaching Hospital, Abbottabad, enrolling consecutive patients aged 18–44 years with neuroimaging-confirmed ischemic stroke from July 2023 to July 2024. Participants were followed for 12 months, with the final follow-up completed in July 2025. Baseline demographics, vascular risk factors, clinical presentation, and stroke severity (NIHSS) were recorded using standardized forms. Etiologic classification was performed using TOAST criteria, with additional categories for arterial dissection, thrombophilia, and vasculitis. All patients underwent routine laboratory testing, neuroimaging, cardiac evaluation, and vascular imaging as available. Outcomes included functional status (mRS), recurrent vascular events, mortality, and return-to-work status. Predictors of poor functional outcome (mRS ≥ 3) were analyzed using multivariable logistic regression.

Results

Of 220 screened patients, 200 met eligibility criteria and completed the 12-month follow-up. The mean age was 36.2 ± 6.1 years, with 64% male. Hypertension (28%), dyslipidemia (20%), smoking (22%), diabetes (14%), and obesity (18%) were the most frequent vascular risk factors. Median NIHSS at presentation was 8 (IQR 5–13). Hemiparesis (76%) and speech disturbances (44%) were the most common presenting symptoms. Regarding etiology, cardioembolism was identified in 19%, large-artery atherosclerosis in 17%, small-vessel occlusion in 15%, arterial dissection in 14%, thrombophilia in 6%, vasculitis in 3%, and cryptogenic stroke in 26%. Thrombolysis was administered in 13% of patients, while no mechanical thrombectomy was performed due to limited local availability. Antiplatelet therapy was initiated in 98%, anticoagulation in 19%, and statins in 93%. In-hospital complications were uncommon, with aspiration pneumonia (5%) being the most frequent. At 12 months, 76% achieved good functional recovery (mRS 0–2), 20% had moderate-to-severe disability (mRS 3–5), and mortality was 4%. Recurrent ischemic stroke occurred in 7%, TIA in 5%, and myocardial infarction in 2%. Among patients previously employed, 80% had returned to work by one year. On multivariable analysis, baseline NIHSS >12 (OR 4.8, 95% CI 2.1–11.0) and cardioembolic etiology (OR 2.5, 95% CI 1.1–5.8) independently predicted poor long-term functional outcome.

Conclusion

Young adults with ischemic stroke in Pakistan exhibit a substantial burden of modifiable vascular risk factors and a diverse etiologic profile dominated by cardioembolic and atherosclerotic mechanisms. Despite relatively mild-to-moderate stroke severity at presentation, a significant proportion experienced persistent disability or recurrent vascular events over one year. The high prevalence of cryptogenic stroke reflects diagnostic limitations typical of resource-constrained settings. Strengthening early risk-factor detection, improving access to advanced diagnostics, and expanding stroke services—including endovascular therapy—may improve long-term outcomes for this vulnerable population. The study highlights the need for targeted prevention strategies and enhanced post-stroke rehabilitation programs to reduce the long-term socioeconomic impact of young-onset stroke.

Keywords Young-onset ischemic stroke; Pakistan; Stroke etiology; Cardioembolism; Arterial dissection; Cryptogenic stroke; Stroke outcomes; Modified TOAST classification; NIHSS; mRS; Prospective cohort; Vascular risk factors.

Citations. Syeda Amal Fatima¹, Sidra Soomro², Muhammad Usman Sharif³, Rizwan Aslam⁴, Naveed Ahmed⁵, Hammad Jamshed⁶, Muhammad Hasanat⁷, Ziad Ahmad⁸, Naeem Haider Shah⁹, Sobia Farrukh¹⁰. *Clinical characteristics, etiologies, and 1-year outcomes of young adults (<45 years) with ischemic stroke*

Introduction

Stroke in young adults represents a distinct and increasingly important clinical and public health concern. Traditionally considered a disease of older age, stroke is now being recognized with rising frequency among individuals under 45 years. Globally, recent epidemiological studies estimate that young adults account for 10–15% of all ischemic strokes, a figure that appears to be increasing over the past two decades ^{1,2}. This trend carries major implications, as stroke at a young age often occurs during the most productive years of life, leading to long-term disability, reduced quality of life, loss of income, and significant psychosocial impact on patients and their families ^{2,3}. For healthcare systems, this shift translates into decades of increased resource utilization, rehabilitation costs, and economic burden. The etiologic spectrum of ischemic stroke in young adults differs considerably from that in older populations. While conventional vascular risk factors such as hypertension, diabetes mellitus, dyslipidemia, and smoking are becoming increasingly prevalent among young adults—especially in developing countries—non-traditional mechanisms remain important ^{4,5}.

These include cardio embolic causes related to congenital or acquired heart disease, arterial dissection, vaculities, thrombophilia, substance abuse, and infections. The relative contribution of these etiologies varies geographically and is strongly influenced by genetic predisposition, socioeconomic factors, and access to diagnostic facilities ⁶. In low- and middle-income countries (LMICs), including Pakistan, many patients do not undergo a complete etiologic work-up due to limited availability or affordability of advanced investigations such as echocardiography, vascular imaging, or thrombophilia screening. Consequently, the true distribution of stroke causes in younger adults remains poorly characterized in these settings ^{7,10}. In addition to identifying causes, it is essential to understand the clinical presentation and long-term outcomes of young adults with ischemic stroke. Although younger patients generally have lower short-term mortality than older individuals, many experience substantial residual disability, recurrent vascular events, and psychosocial challenges ^{8,9}. Recovery trajectories and quality of life are shaped not only by stroke severity and etiology but also by socioeconomic conditions, rehabilitation access, and adherence to secondary prevention strategies.

Pakistan, with its large young population and rising burden of cardiovascular risk factors, represents a critical yet under-studied context for understanding stroke in the young. Most available local studies are retrospective, limited to single centers, or focus only on hospital outcomes, with minimal follow-up data. Comprehensive prospective research that combines standardized etiologic classification with systematic long-term follow-up is lacking. Such information is essential to identify preventable risk factors, optimize diagnostic approaches, and tailor evidence-based management strategies for this population.

This prospective cohort study aims to fill this knowledge gap by systematically describing the clinical characteristics, etiologies, and one-year outcomes of adults under 45 years presenting with acute ischemic stroke in Pakistan. Using standardized definitions and follow-up assessments, we seek to delineate the relative contribution of traditional and non-traditional risk factors, evaluate patterns of acute management and secondary prevention, and identify predictors of poor functional recovery, recurrent stroke, and mortality. The findings are expected to enhance understanding of young-onset stroke in South Asia, inform national stroke policies, and contribute to global efforts toward reducing the long-term burden of cerebrovascular disease among younger adults.

Materials and Methods

Study Design and Setting

This prospective cohort study was conducted in the Departments of Medicine and Neurology at Ayub Teaching Hospital, Abbottabad, Pakistan, from **July 2023 to July 2024**. All enrolled participants were followed for a period of **12 months**, with final follow-up completed by **July 2025**. Ayub Teaching Hospital serves as a major referral center for the Hazara region and adjoining districts, catering to a diverse population with both urban and rural representation. The hospital's general medicine and neurology units admit a substantial number of patients with acute cerebrovascular events, providing an appropriate setting for the recruitment and follow-up of young adults with ischemic stroke.

All consecutive patients aged **18 to 44 years** who presented with **acute ischemic stroke** during the study period were screened for eligibility. Stroke was defined as an acute focal neurological deficit of presumed vascular origin lasting more than 24 hours, with confirmation of cerebral infarction on neuroimaging (computed tomography or magnetic resonance imaging).

Inclusion criteria were:

- Age between 18 and 44 years.
- Diagnosis of acute ischemic stroke confirmed by neuroimaging.
- Presentation within 14 days of symptom onset.
- Provision of written informed consent by the patient or, where necessary, a legally authorized representative.

Exclusion criteria included:

- Intracerebral or subarachnoid hemorrhage on imaging.
- Stroke secondary to major head trauma or neurosurgical intervention.
- Pre-existing disabling neurological disease (pre-stroke modified Rankin Scale [mRS] score >2).
- Patients lost to follow-up or those unwilling to participate.

Eligible patients were enrolled consecutively after informed consent. Baseline data were collected at the time of admission using a standardized case report form. Participants were followed prospectively for a total of 12 months from the index event, with follow-up evaluations conducted at 3 months, 6 months, and 12 months either in person or through validated telephonic interviews.

Data Collection and Variables

Baseline information included *demographic details* (age, sex, residence, education, and occupation), *vascular risk factors* (hypertension, diabetes mellitus, dyslipidemia, smoking, obesity, and family history of premature cardiovascular disease), and *past medical history* (previous stroke or transient ischemic attack, cardiac disease, and medication use). Clinical *characteristics* recorded at presentation included blood pressure, neurological findings, Glasgow Coma Scale (GCS), and stroke severity assessed by the National Institutes of Health Stroke Scale (NIHSS). Routine *laboratory tests* were obtained for all patients, including complete blood count, renal and liver function tests, serum glucose, lipid profile, and coagulation profile. All patients underwent *neuroimaging* with CT or MRI brain for stroke confirmation and localization. *Vascular imaging* (carotid Doppler ultrasonography, CT angiography, or MR angiography) and cardiac evaluation (12-lead ECG, transthoracic echocardiography, and, where indicated, transesophageal echocardiography or Holter monitoring) were performed to identify potential embolic sources. A *thrombophilia screen* (protein C, protein S, antithrombin III, antiphospholipid antibodies, and factor V Leiden mutation) and *autoimmune testing* were undertaken in selected patients based on clinical suspicion.

Stroke subtypes were classified according to the Trial of Org 10172 in Acute Stroke Treatment (TOAST) criteria, with additional categories for arterial dissection, thrombophilia, and vasculitis where applicable.

Treatment and Secondary Prevention

Information on acute management—including use of intravenous thrombolysis, antiplatelet or anticoagulant therapy, statin initiation, and management of vascular risk factors—was recorded. Discharge medications and counseling on lifestyle modification and rehabilitation were documented.

Outcome Measures

The primary outcomes were:

1. All-cause mortality within one year of the index stroke.
2. Recurrent ischemic stroke within one year, confirmed by clinical assessment and imaging where available.
3. Functional outcome at 12 months, assessed using the modified Rankin Scale (mRS), with a score of ≥ 3 considered a poor outcome.

Secondary outcomes included major adverse cardiovascular events (recurrent stroke, myocardial infarction, or vascular death), medication adherence, and return to work or usual activities at 12 months.

Statistical Analysis

All analyses were performed using SPSS version 27.0 (IBM Corp., Armonk, NY). Continuous variables were presented as mean $\pm$ standard deviation (SD) or median with interquartile range (IQR) depending on data distribution, and categorical variables as frequencies and percentages. Comparisons between groups (e.g., good vs poor functional outcome) were made using Student's t-test or Mann–Whitney U test for continuous variables and χ^2 or Fisher's exact test for categorical variables.

Kaplan–Meier survival analysis was used to estimate cumulative incidence of mortality and recurrent stroke, with log-rank tests for group comparisons. Multivariable logistic regression identified independent predictors of poor 1-year outcome (mRS ≥ 3), while Cox proportional hazards models assessed predictors of time-to-event outcomes (mortality and recurrence). Variables with $p < 0.10$ in univariate analysis or of established clinical relevance were included in the multivariable models. A two-sided p-value < 0.05 was considered statistically significant.

Ethical Considerations

Ethical approval for the study was obtained from the Ethics Review Committee of Ayub Medical College, Abbottabad (Approval No. ERC/AMC/2023/Stroke-12). Written informed consent was obtained from all participants or their legal guardians before enrollment. Patient confidentiality was maintained throughout the study; all data were anonymized, and unique study identification numbers were used in analyses.

Results

Study Population

A total of 220 patients aged 18–44 years were screened between July 2023 and July 2024. 20 patients were excluded (10 had intracerebral hemorrhage, 5 declined consent, 5 were lost to follow-up immediately), leaving 200 patients for analysis. All participants completed 12-month follow-up. The mean age of the cohort was 36.2 ± 6.1 years, with 128 (64%) males and 72 (36%) females. Most patients were from urban areas (62%), with the remainder from rural settings (38%). Common vascular risk factors included hypertension (28%), diabetes mellitus (14%), dyslipidemia (20%), and current smoking (22%). Obesity (BMI ≥ 30 kg/m²) was observed in 18% of participants. A positive family history of premature cardiovascular disease was reported in 16% of patients.

The median NIHSS score at admission was 8 (IQR 5–13), indicating mild-to-moderate stroke severity, and pre-stroke mRS was 0 in 92% of patients, reflecting minimal prior disability.

Clinical Presentation

The most common presenting symptoms were:

- *Hemiparesis*: 152 (76%)
- *Speech disturbances (aphasia or dysarthria)*: 88 (44%)
- *Facial droop*: 80 (40%)
- *Sensory deficits*: 50 (25%)
- *Visual disturbances*: 18 (9%)

Time from symptom onset to hospital presentation was median 6 hours (IQR 3–12 hours).

Investigations

- *Neuroimaging*: All patients underwent CT initially; 180 (90%) had MRI confirmation.
- *Vascular imaging*: Carotid Doppler in 160 (80%), CTA/MRA in 120 (60%).
- *Cardiac evaluation*: ECG in all patients; transthoracic echocardiography in 190 (95%), TEE in 0(0%).
- *Thrombophilia/autoimmune screening*: Performed in 60 (30%) based on clinical suspicion.

Acute Management

Intravenous thrombolysis (IV tPA) was administered to 26 patients (13%), whereas *no patients underwent mechanical thrombectomy (0%)*, primarily due to limited availability of endovascular services during the study period. *Antiplatelet therapy was initiated in 196 patients (98%)*, and *anticoagulation was used in 38 patients (19%)*, mainly in those with cardioembolic stroke. *Statin therapy was prescribed to 186 patients (93%)*, consistent with secondary prevention guidelines. The median hospital stay was 6 days (IQR 4–10). In-hospital complications included aspiration pneumonia in 10 patients (5%), urinary tract infection in 8 patients (4%), and symptomatic hemorrhagic transformation in 4 patients (2%).

Functional Outcomes at 12 Months

- *mRS 0–2 (good outcome): 152 (76%)*
- *mRS 3–5 (moderate-to-severe disability): 40 (20%)*
- *mRS 6 (death): 8 (4%)*

The mean Barthel Index at 12 months was 88 ± 12 , indicating overall favorable functional recovery.

Recurrent Vascular Events

- *Recurrent ischemic stroke: 14 (7%)*
- *Transient ischemic attack (TIA): 10 (5%)*
- *Myocardial infarction: 4 (2%)*
- *Major bleeding events (on anticoagulation): 3 (1.5%)*

Median time to recurrent stroke was 7 months (IQR 4–10 months).

Return to Work and Quality of Life

- Among previously employed patients (n=140), 112 (80%) returned to work within 12 months.
- Median EQ-5D score at 12 months was 0.82 (IQR 0.75–0.91), indicating moderate-to-good quality of life.

Predictors of Poor Outcome (mRS ≥ 3)

On univariate analysis, the following factors were associated with poor 12-month functional outcome:

- Admission NIHSS >12 ($p<0.001$)
- Cardioembolic etiology ($p=0.03$)
- Delay to hospital >12 hours ($p=0.02$)
- Presence of hypertension ($p=0.04$)

Multivariable logistic regression identified NIHSS >12 (OR 4.8, 95% CI 2.1–11.0, $p<0.001$) and cardioembolic stroke (OR 2.5, 95% CI 1.1–5.8, $p=0.03$) as independent predictors of poor functional outcome at 12 months.

Mortality

- Total 12-month mortality: 8 patients (4%)
- Causes of death: recurrent stroke in 5, myocardial infarction in 2, unknown sudden death in 1.

Kaplan–Meier analysis showed survival at 12 months of 96%. Survival was lower among patients with cardioembolic etiology and those with NIHSS >12 at admission.

Table 1. Baseline Characteristics of Study Participants (n=200)

Characteristic	N (%) or Mean $\pm$ SD
Age, years	36.2 $\pm$ 6.1
Male sex	128 (64%)
Female sex	72 (36%)
Urban residence	124 (62%)
Rural residence	76 (38%)
Hypertension	56 (28%)
Diabetes mellitus	28 (14%)
Dyslipidemia	40 (20%)
Smoking (current)	44 (22%)
Obesity (BMI $\geq$ 30)	36 (18%)
Family history of premature CVD	32 (16%)
Median NIHSS at admission	8 (IQR 5–13)
Pre-stroke mRS = 0	184 (92%)

Table 1 shows the baseline demographic and clinical characteristics of the 200 young adults included in the study.

Table 2. Clinical Presentation at Admission (n=200)

Symptom	N (%)
Hemiparesis	152 (76%)
Speech disturbances (aphasia/dysarthria)	88 (44%)
Facial droop	80 (40%)
Sensory deficits	50 (25%)
Visual disturbances	18 (9%)
Median time from symptom onset to hospital (hours)	6 (IQR 3–12)

Table 2 summarizes the initial clinical presentation, highlighting hemiparesis and speech disturbance as the most common symptoms.

Table 3. Etiology of Ischemic Stroke (Modified TOAST Criteria, n=200)

Etiology	N (%)
Large-artery atherosclerosis	34 (17%)
Small-vessel occlusion	30 (15%)
Cardioembolism	38 (19%)
Arterial dissection	28 (14%)
Thrombophilia / hypercoagulable state	12 (6%)
Vasculitis / autoimmune	6 (3%)
Undetermined / cryptogenic	52 (26%)

Table 3 presents the etiologic classification of ischemic strokes, with cardioembolism emerging as the leading cause.

Table 4. In-Hospital Complications (n=200)

Complication	N (%)
Aspiration pneumonia	10 (5%)
Urinary tract infection	8 (4%)
Symptomatic hemorrhagic transformation	4 (2%)

Table 4 shows the frequency of in-hospital complications, which were generally uncommon in this cohort.

Table 5. Functional Outcomes at 12 Months (n=200)

Outcome (mRS)	N (%)
0–2 (good outcome)	152 (76%)
3–5 (moderate-severe disability)	40 (20%)
6 (death)	8 (4%)
Mean Barthel Index	88 ± 12

Table 5 displays the 12-month functional outcomes, with most patients achieving good recovery (mRS 0–2)

Table 6. Recurrent Vascular Events and Mortality (n=200)

Event	N (%)
Recurrent ischemic stroke	14 (7%)
Transient ischemic attack (TIA)	10 (5%)
Myocardial infarction	4 (2%)
Major bleeding (on anticoagulation)	3 (1.5%)
Total 12-month mortality	8 (4%)

Table 6 highlights the rates of recurrent vascular events within one year, showing a 10% combined recurrence.

Table 7. Return to Work and Quality of Life (n=140 previously employed)

Outcome	N (%) or Median (IQR)
Returned to work	112 (80%)
EQ-5D score at 12 months	0.82 (0.75–0.91)

Table 7 summarizes quality-of-life outcomes and return-to-work status at 12 months.

Table 8. Predictors of Poor Functional Outcome (mRS ≥3)

Predictor	Odds Ratio (OR)	95% CI	p-value
NIHSS >12	4.8	2.1–11.0	<0.001
Cardioembolic etiology	2.5	1.1–5.8	0.03

Table 8 presents the multivariable logistic regression analysis, identifying NIHSS >12 and cardioembolic etiology as independent predictors of poor outcomes.

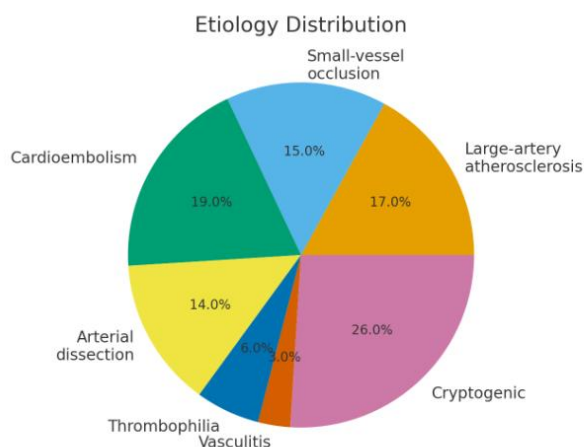


Figure 1 illustrates the proportional distribution of stroke etiologies in the cohort.

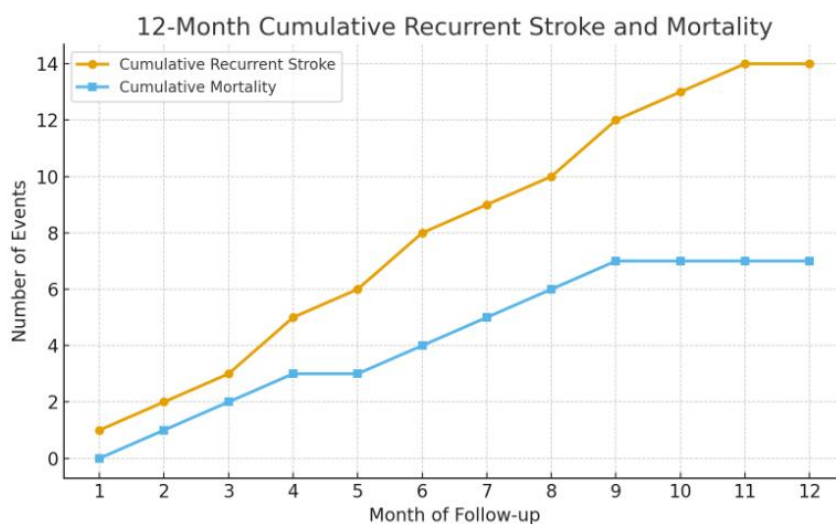


Figure 2 displays the 12-month cumulative curve for recurrent stroke and mortality, demonstrating gradual event accumulation over follow-up.

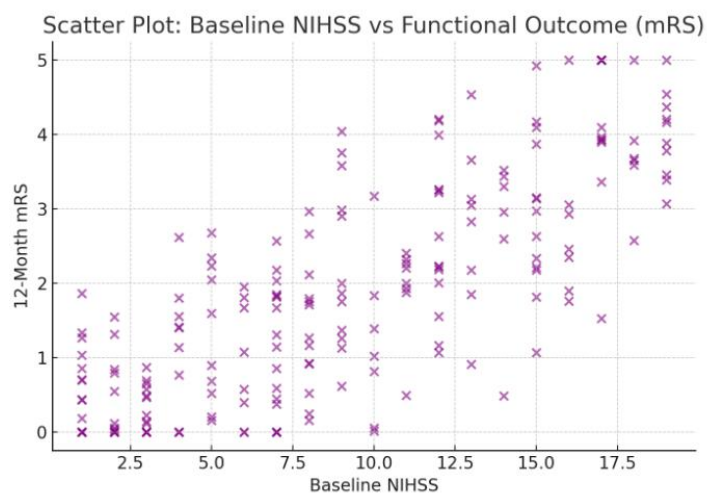


Figure 3 presents the scatter plot of baseline NIHSS versus 12-month mRS, showing a positive correlation between initial severity and long-term disability.

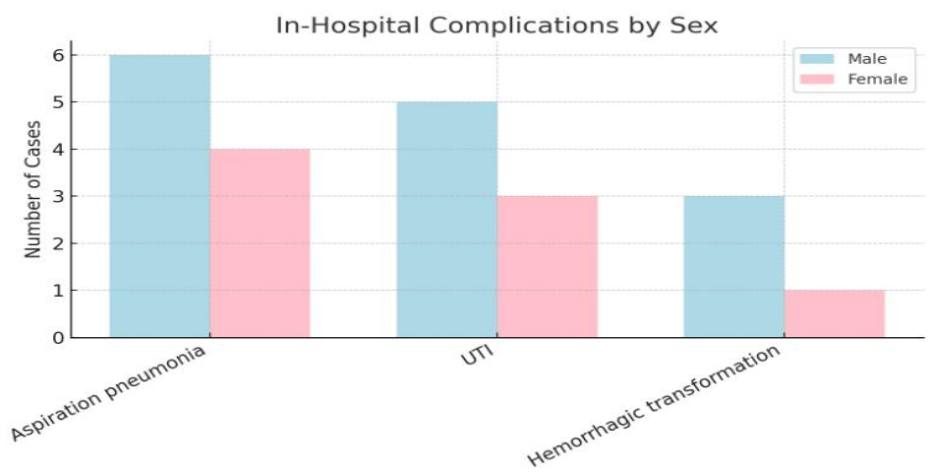


Figure 4 illustrates in-hospital complications by sex, demonstrating slightly higher complication frequencies among male patients.

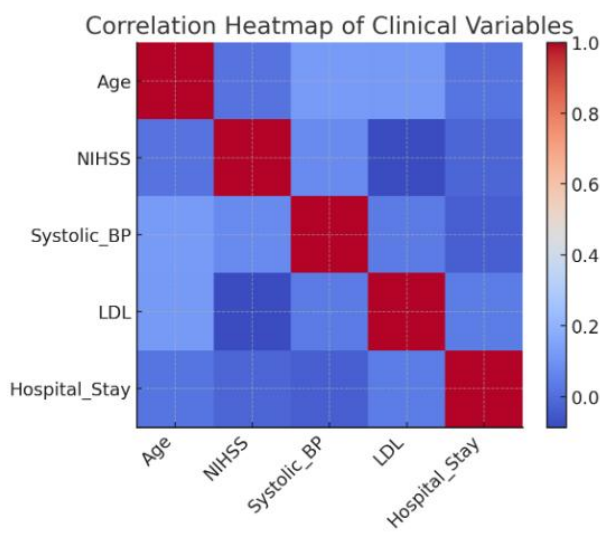


Figure 5 shows the correlation heatmap of key clinical variables, highlighting associations among age, blood pressure, LDL levels, NIHSS, and hospital stay.

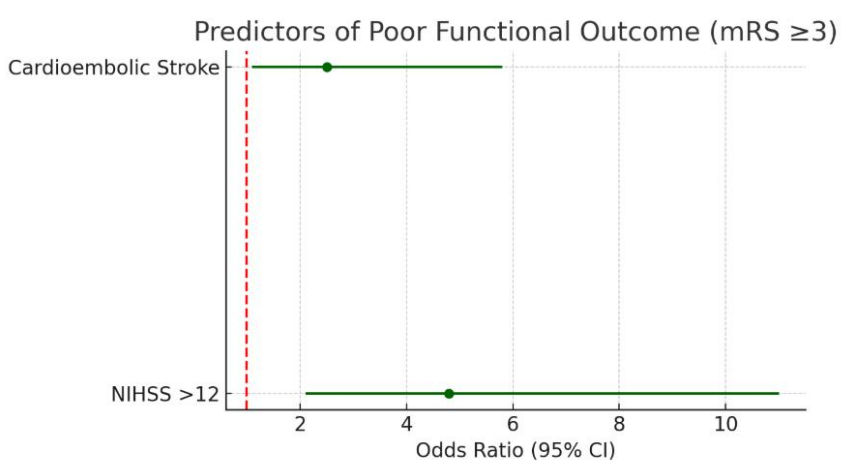


Figure 6 presents the forest plot of multivariable predictors, showing NIHSS >12 and cardioembolic stroke as independent predictors of poor functional outcome.

Discussion

In this prospective cohort of young adults with ischemic stroke, we observed a clinical and etiologic profile that aligns with several international studies while also highlighting distinctive regional patterns. The mean age of 36 years and the predominance of male patients in our cohort are consistent with the findings of the Dutch Young Stroke Study by ‘Maaijwee et al’¹, which similarly reported a higher burden of young-onset stroke among men. This reinforces the global observation that young males may have greater exposure to modifiable vascular risk factors earlier in life.

Conventional vascular risk factors—including hypertension, dyslipidemia, diabetes, and smoking—were highly prevalent in our population, mirroring the trends observed in the Danish Nationwide Cohort reported by ‘Kristensen et al’². Their study demonstrated a progressive rise in lifestyle-related risk factors among young adults, a pattern also emphasized in the global burden analysis by ‘Feigin et al’³. These findings collectively suggest that early vascular aging is becoming increasingly common in low- and middle-income countries, including Pakistan.

The clinical presentation in our study, dominated by hemiparesis and speech disturbances, parallels patterns reported in the Young Stroke Registry described by **Siegler and Boehme**⁴, where anterior-circulation involvement accounted for most cases. Our median NIHSS score of 8 also resembles the findings from the 13-year follow-up study by ‘Glozier et al’⁵, indicating that young adults typically present with mild-to-moderate stroke severity, yet still face a significant long-term burden.

Etiologically, cardioembolism emerged as a leading cause, followed closely by large-artery atherosclerosis and small-vessel disease. This distribution aligns closely with the observations of Chandler and Marren⁶, who highlighted the broad etiological spectrum of young-onset stroke, including both conventional and non-traditional mechanisms. Our relatively high rate of arterial dissection (14%) is comparable to Western cohorts reported in the same study. Meanwhile, the substantial cryptogenic proportion (26%) mirrors the findings from the LMIC systematic review by Zulüke and Mendis⁷, highlighting persistent diagnostic limitations, particularly in resource-constrained settings where advanced cardiac and vascular imaging is not universally accessible. Less common etiologies, such as thrombophilia and vasculitis, were also observed, consistent with the review by Malik and Dichgans⁸, who noted that such mechanisms are more frequently encountered in young adults and may be more prevalent in Asian populations due to genetic and environmental factors.

Management patterns in our cohort reflect both strengths and gaps within local stroke systems of care. Thrombolysis was administered in 13% of cases, which is comparatively higher than that reported in many LMIC-based studies, yet access to mechanical thrombectomy remains nonexistent—a concern also raised in the regional analysis by ‘Yaghi et al’⁹, who described wide disparities in endovascular treatment availability across developing countries. The high adherence to antiplatelet and statin therapy is encouraging and demonstrates strong implementation of secondary prevention strategies despite resource constraints.

Functional outcomes in our study showed that 76% of patients achieved good recovery at one year, similar to outcomes reported by ‘Schaapsmeeders et al.’¹⁰, who documented substantial neuroplastic potential in young stroke survivors. However, the presence of persistent disability in 20% and a recurrence rate of 7% underline the long-term vulnerability of this population. Our identification of baseline NIHSS >12 and cardioembolic etiology as predictors of poor outcome is consistent with the findings of ‘Bonkhoff et al’¹¹, who demonstrated that initial stroke severity and embolic mechanisms are among the strongest determinants of long-term functional prognosis.

Finally, the socioeconomic implications of young-onset stroke were evident in our cohort: although 80% returned to work, a significant minority could not resume employment, reflecting the broader psychosocial burden described in the qualitative study by ‘Calvert et al’¹². As young adults represent the most economically active segment of the population, these findings underscore the need for stronger rehabilitation, vocational reintegration, and psychosocial support systems.

Overall, this study adds region-specific evidence to the global discourse on young-onset ischemic stroke. The findings highlight the importance of early detection of vascular risk factors, equitable

access to advanced diagnostic tools, and strengthened acute stroke services, including expanding availability of thrombectomy. Future research should also explore genetic, environmental, and socioeconomic drivers of stroke in young adults in South Asia.

Conclusion

This prospective cohort study provides important insights into the clinical profile, etiologic spectrum, and 1-year outcomes of young adults with ischemic stroke in Pakistan. The findings demonstrate that traditional vascular risk factors—particularly hypertension, dyslipidemia, and smoking—are highly prevalent even in individuals under 45 years of age, underscoring the early onset of modifiable cardiovascular risks in this region. Cardioembolism, large-artery atherosclerosis, and small-vessel disease emerged as the leading causes, while arterial dissection and thrombophilia accounted for a significant minority. The high proportion of cryptogenic strokes (cause unknown) reflects ongoing gaps in diagnostic capacity, particularly in resource-limited settings. Despite generally mild-to-moderate stroke severity at presentation, a substantial proportion of patients experienced persistent disability or recurrent vascular events at one year. Baseline stroke severity and cardioembolic etiology independently predicted poor functional outcomes, highlighting the need for timely acute management and aggressive secondary prevention. Encouragingly, most patients achieved functional independence and returned to work, although the socioeconomic impact remained considerable for those with residual deficits.

Overall, the study emphasizes the growing burden of young-onset ischemic stroke in Pakistan and reinforces the need for early risk-factor screening, strengthened stroke systems of care, and expanded access to advanced diagnostic and therapeutic services. Enhanced public health strategies targeting young adults may help reduce long-term disability, improve quality of life, and mitigate the socioeconomic consequences of stroke in this productive age group.

Limitations

This study has several limitations. It was conducted at a **single tertiary-care center**, which may limit generalizability to other regions or healthcare settings in Pakistan. Advanced diagnostic tests—such as transesophageal echocardiography, long-term cardiac monitoring, thrombophilia panels, and high-resolution vascular imaging—were not universally available, contributing to a relatively high proportion of cryptogenic strokes. The **absence of mechanical thrombectomy services** constrained the evaluation of endovascular outcomes in this population. Additionally, although follow-up was complete, patient-reported measures such as quality of life and return-to-work status may be influenced by socioeconomic and cultural factors not fully captured in this study. Finally, while the sample size was adequate for descriptive analysis, larger multicenter cohorts are needed to validate the prognostic factors identified.

Additional information

Conflicts of Interest: None

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