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IMPACT OF ATHEROGENIC INDEX OF PLASMA ON STROKE RISK IN DIABETIC AND NON-DIABETIC PATIENTS: A PROSPECTIVE STUDY

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Keywords:

AIP, Stroke, Diabetes, Ischemic Stroke, Hemorrhagic stroke

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ABSTRACT: Background: Diabetes mellitus is a significant stroke risk factor that can affect the distribution of stroke subtypes, clinical presentation, and prognosis. The purpose of this study was to compare the features of stroke in patients with and without diabetes and to assess the function of the atherogenic index of plasma (AIP) in conjunction with traditional risk factors. **Methods:** From November 2024 to April 2025, a prospective observational study was conducted at Narayana Medical College and Hospital in Nellore. A total of 200 consecutive stroke patients were recruited and categorized according to their diabetes status. Demographics, medical history, presenting symptoms, laboratory tests (fasting lipids for AIP, blood glucose, HbA1c) and were categorized according to Modified Rankin Scale scores. A comparison between types of stroke (Chi-square), distribution of risk factors in Diabetic and Non-Diabetic Patients were seen. AIP was compared along the stroke subtypes using One-way ANOVA. **Conclusion:** Stroke rates and poor functional outcomes rise with age, especially in elderly populations. Ischemic stroke is the most prevalent subtype. Although diabetes, AIP, and stroke subtypes did not exhibit significant relationships, poor glycemic control, greater BMI, and vascular hazards all contribute to poorer recovery, emphasizing the need of early risk management.

INTRODUCTION: Stroke is a major cause of morbidity and mortality worldwide. Dyslipidemia and Diabetes Mellitus are important modifiable risk factor, but their impact on different stroke subtypes remains unclear. The Atherogenic index of plasma (AIP), calculated as log 10 [TG/HDL-C], reflects atherogenic dyslipidemia and may be a useful marker for stroke risk assessment.

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Diabetes is associated with insulin resistance and adverse lipid profile, which increase the risk of ischemic stroke through atherosclerotic mechanisms. In non-diabetic individuals, lipid patterns and stroke risk may differ, raising questions about whether the predictive value of AIP varies by diabetic status [1].

Stroke: Stroke is a serious medical emergency that occurs when blood supply to the brain is suddenly reduced, due to lack of oxygen and nutrients, brain cells begin to die within minutes often called a "Brain attack", a stroke can lead to long term disability, problems with thinking and movement, or even death if the treatment is delayed.

Recognizing early signs which needs immediate medical help is crucial to protect brain function and improve recovery [2]. The resulting brain damage can affect the functions controlled by the involved brain area, such as movement, speech, memory or vision. Strokes are broadly classified into three main types:

1. Ischemic stroke – occurs when a blood vessel that supplies blood to the brain is hindered. It is commonly caused by Atherosclerosis, blood clots in heart that may travel to brain and block blood flow.

2. Hemorrhagic stroke – occurs when there is a rupture of weakened blood vessel. Uncontrolled blood pressure is the common cause of this type of stroke.

3. Transient ischemic attack is a temporary stroke caused by a clot. It can be considered as a "warning for stroke" [5].

Epidemiology of Stroke: Stroke is a second leading cause of death of world wide, affecting about 13.7 million people and causing nearly 5.5 million deaths each year. Around 87% of strokes are ischemic, with raising prevalence due to improved survival and better medical care stroke incidence has increased in low- and middle-income countries but decline significantly in high income regions [3].

The risk of stroke increases with age, cases among younger adults (20-54 years) have been risen in recent decades. Stroke patterns also differ by sex, with women experiencing higher severity and fatality rates, while men are more commonly affected by lifestyle related risk factors [4].

Diabetes Mellitus: Diabetes mellitus is a long-term disorder where the body is unable to properly regulate blood sugars levels due to problems with insulin production, insulin action or both. High glucose levels for a prolonged time can quietly damage the organs especially eyes, kidneys, nerves, heart and blood vessels. Diabetes includes some categories- Type 1 Diabetes Mellitus, Type2 Diabetes Mellitus and Gestational Diabetes. Type 2 DM is more common when compared to Type 1 DM. Gestational diabetes develops during the pregnancy and usually resolves after delivery [6].

Epidemiology of Diabetes Mellitus: Globally DM affects approximately one in eleven adults, with type 2 diabetes mellitus accounting for the majority of cases. Type 1 DM typically present in childhood, with incidence increasing from birth and showing two peaks one in early childhood and another during adolescence. Nearly 45% of cases occurs before 10yrs of age, the prevalence among individuals under 20yrs in around 2.3 per 100. The incidence of type 1 diabetes is raising worldwide. Annual increases of 2 to 5% have been reported in Europe, Australia, and the middle east [7].

Etiology: The pancreas contains small clusters of cells which are called as islets of Langerhans, where insulin producing beta cells and glucagon releasing alpha cells work together to keep blood sugar levels within range. In Type 1 diabetes, the body's immune system mistakenly attacks and destroys the beta cells, leaves the body with no insulin. Type 2 diabetes linked to reduced sensitivity to insulin which occurs due to obesity and aging. Gestational diabetes occurs during pregnancy, due to hormonal changes [8].

Atherogenic Index of Plasma: Lipoprotein particle size is indicated by the Atherogenic Index of Plasma (AIP), which is computed as log 10 [TG/HDL-C] and provides a more precise representation of atherogenic dyslipidaemia. AIP has proven to be a better predictor of CVD risk than specific lipid indicators.

The Atherogenic Index of Plasma (AIP), which is computed as log 10 [TG/HDL-C], indicates inflammation and poor lipoprotein metabolism. Because of its correlation with the size, density, and peroxidation rate of lipoprotein particles, it is a more sensitive indicator of atherosclerosis than individual lipid profiles. The units of measurement for HDL cholesterol (HDL-C) and triglycerides (TG) are moles per Liter (mmol/L) [9].

Effect of AIP on Stroke:

Atherogenesis and Plague Formation: By encouraging atherogenesis through elevated TG and low HDL-C levels which result in small, dense LDL particles, elevated AIP is associated with an increased risk of stroke. In cerebral arteries, these particles lead to plaque formation and endothelial degradation, which can burst and result in ischemic stroke. Insulin resistance and hyperglycaemia exacerbate dyslipidaemia in diabetes, hastening atherosclerosis. High AIP is an indicative of underlying metabolic abnormalities that cause comparable, but milder, vascular damage even in non-diabetics. This primarily contributes to ischemic stroke types such as small vessel blockage and major artery atherosclerosis. Metabolic abnormalities in diabetes aggravate cerebral ischemia [10] by raising AIP through increased TG, decreased HDL-C, and visceral fat [11]. AIP effects in non-diabetics are caused by heredity or lifestyle. Stroke, AIP, and diabetes have a complicated and intertwined interaction that includes vascular health, glucose control, and lipid metabolism. A higher risk of ischemic stroke, particularly as a result of major artery atherosclerosis, is directly linked to elevated AIP, which is defined by high triglycerides and low HDL-C [12].

Mechanisms:

Atherosclerosis: AIP is indicative of a lipid profile that encourages the development and rupture of plaque, which results in obstruction of the cerebral arteries.

Insulin Resistance: AIP worsens vascular inflammation and endothelial dysfunction by acting as a surrogate marker.

Inflammation: Systemic inflammation, which destabilizes plaques and increases the risk of stroke, is associated with high AIP.

Diabetes and Stroke Risk: People with diabetes have a 2–4 times increased chance of having a stroke than people without the disease. Mechanisms include oxidative stress, inflammation, vascular damage, dyslipidaemia, and microvascular and macrovascular effects. AIP, diabetes, and stroke have a synergistic association because diabetes exacerbates AIP's effects on vascular health. Insulin resistance is reflected in intact proinsulin, which deteriorates lipid metabolism and encourages the development of tiny, dense LDL. The association between AIP and stroke is modest in those with normal blood sugar levels. However, by exacerbating dyslipidaemia and poor glucose metabolism, elevated AIP dramatically increases the risk of stroke in people with pre-diabetes and diabetes.

Cumulative Effects: Diabetics who are exposed to high AIP over an extended period of time are much more likely to have strokes. Compared to one-time measures, cumulative AIP is a better indicator of ischemic stroke, particularly in patients with longer-term diabetes and inadequate glucose control. AIP is a quick and affordable method of detecting high-risk people, particularly those with diabetes and pre-diabetes. Stroke prevention is aided by routine AIP and glucose monitoring. Exercise, diet, and weight control help lower AIP, improve glucose control, and lessen the risk of stroke [13].

Rationale for using AIP to Compare Stroke Patients with and Without Diabetes: The relevance of metabolic dysregulation in stroke risk is highlighted by comparing the AIP of stroke patients with diabetes to those without the disease. Diabetes, which is characterized by insulin resistance, frequently raises AIP because of low HDL-C and excessive triglycerides. Other risk factors, including as smoking or high blood pressure, may be present in non-diabetics. In contrast to other pathways in non-diabetics, this comparison elucidates how diabetes-specific lipid abnormalities increase the risk of stroke [14].

AIP is a sensitive indicator of atherogenic risk, which is a significant cause of ischemic stroke. AIP is a better indicator of stroke in diabetics because insulin resistance and hyperglycemia exacerbate vascular inflammation and plaque development. AIP has a smaller involvement in non-diabetic strokes, which can result from other causes such cardio embolism or small vessel disease. By comparing the two groups, it is possible to determine whether AIP's prognostic value is generalizable or unique to diabetes. Because of decreased vascular healing and increased recurrence, which may be related to elevated AIP, stroke outcomes are frequently worse for diabetics. AIP may help with risk stratification as a low-cost measure, particularly in diabetes.

METHODOLOGY: The goal of the current prospective observational study is to evaluate the relationship between the incidence of stroke in individuals with and without diabetes and the Atherogenic Index of Plasma (AIP).

The study was conducted in the neurology outpatient and inpatient departments of Narayana Medical College and Hospital, Chinthareddypalem, Nellore, Andhra Pradesh, over a six-month period, from November 2024 to April 2025. During the trial period, 200 patients who met the inclusion and exclusion criteria were enrolled. All eligible patients who met the inclusion criteria were recruited; no formal sample size calculation was carried out. For analysis, patients with stroke were clinically investigated, divided into groups based on whether they had diabetes or not. Data regarding ongoing pharmacological treatment were not included in the analysis.

Inclusion Criteria:

- Adults over 35 who have been diagnosed with an Ischemic, Haemorrhagic stroke and Transient Ischemic Attack (TIA) based on WHO criteria.
- Patients with type 1 or type 2 diabetes were diagnosed using the American Diabetes Association's criteria (HbA1c ≥6.5%).
- Individuals without a history of diabetes who have normal glucose levels (HbA1c <6.5%).
- Triglycerides and HDL-C from the fasting lipid profile are available to calculate the Atherogenic Index of Plasma (AIP = log 10 [TG/HDL-C]).
- Patients were recruited consecutively from Inpatient department (IPD).

Exclusion Criteria:

- Inadequate or missing information about the Glycemic state or lipid profile.
- Hepatic or renal failure, acute infections, autoimmune illnesses, critical sickness, or abrupt myocardial infarction are examples of severe comorbid conditions.
- Neurological disorders other than stroke, such as stroke mimics or subarachnoid haemorrhage.

RESULTS& DISCUSSION:

Assessing Demographic Factors on Stroke Type: Age is a significant contributing factor, as seen by the age-wise distribution of stroke, which indicates a higher frequency in older age groups, especially 61–80 years.

In most age groups, women are more affected when compared to men. Across all age groups, Ischemic stroke was the most prevalent subtype, followed by haemorrhagic stroke and Transient ischemic attack (TIA). The increased frequency of stroke in advancing age may be attributed to cumulative vascular risk factors such as hypertension, diabetes, and atherosclerosis. These results emphasize the need of managing risk factors early on, particularly in middle-aged and older populations.

TABLE 1: AGE GROUP, GENDER AND TYPE OF STROKE

Age Group	Gender		Type of Stroke		
	M	F	Haemorrhagic	Ischemic	TIA
41-50	21	25	4	25	17
51-60	7	25	9	13	12
61-70	19	27	10	22	14
70-80	24	38	8	35	19
>80	8	6	2	5	5
Total =	79 (39.5%)	121 (60.5%)	33 (16.5 %)	100 (50%)	67 (33.5%)

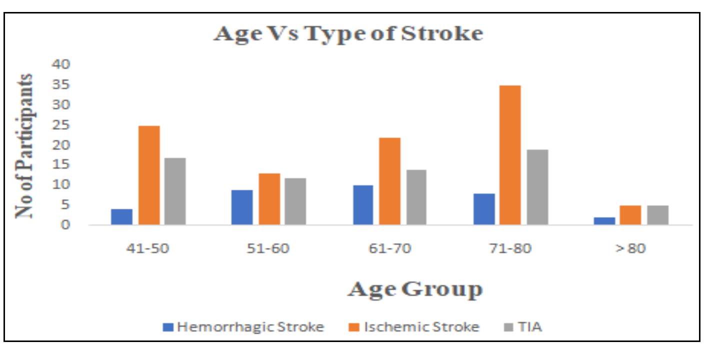

FIG. 1: COMPARISON OF TYPES OF STROKE AMONG DIFFERENT AGE GROUPS

TABLE 2: AGE DISTRIBUTION ALONG WITH mRS SCORES

Age Group	Good Outcome (%)	Poor Outcome (%)	Total (%)
41–50	20 (43.5%)	26 (56.5%)	46 (23.0%)
51–60	12 (37.5%)	20 (62.5%)	32 (16.0%)
61–70	15 (32.6%)	31 (67.4%)	46 (23.0%)
71–80	28 (45.2%)	34 (54.8%)	62 (31.0%)
>80	5 (35.7%)	9 (64.3%)	14 (7.0%)
Total	80 (40.0%)	120 (60.0%)	200 (100%)

Chi-square Test, p = 0.7 (not statistically significant), mRS: Modified Rankin Scale; Good outcome: 0–2; Poor outcome: 3–6

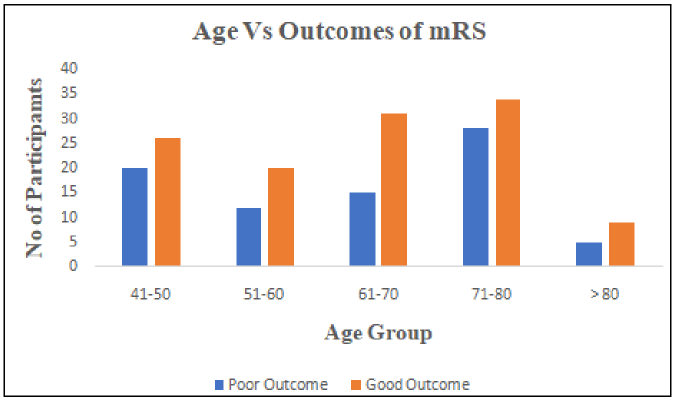

FIG. 2: COMPARISON OF AGE GROUP AMONG THE OUTCOMES OF mRS (MODIFIED RANKIN SCALE)

The distribution of functional outcomes by age reveals a greater percentage of poor outcomes in the majority of groups. Patients between the ages of 61 and 70 had the largest percentage of poor outcomes (67.4%), followed by those beyond the age of 80 (64.3%) and those between the ages of 51 and 60 (62.5%), indicating that the severity increased with age.

Despite having the greatest sample size, the 71–80 age group showed a comparatively larger percentage of excellent outcomes (45.2%) than other older groups. Overall, 60% of patients had poor outcome, suggesting that age may be a significant factor in functional recovery after stroke, necessitating the use of focused treatment techniques in older groups.

Table 2 shows the age-wise distribution of functional outcome among study participants. However, there was no statistically significant association between age group and mRS outcome.

TABLE 3: COMPARISON OF ATHEROGENIC INDEX OF PLASMA (AIP) AMONG STROKE SUBTYPE

Type of Stroke	AIP (Mean ± SD)	Number of Participants (%)
Haemorrhagic Stroke	0.60 ± 0.16	33 (16.5%)
Ischemic Stroke	0.59 ± 0.15	100 (50%)
TIA	0.63 ± 0.17	67 (33.5%)

One-way ANOVA: p = 0.64 (not statistically significant).

There was very slight difference in the mean Atherogenic Index of Plasma (AIP) values between the TIA, ischemic stroke, and haemorrhagic stroke groups. TIA had a slightly higher mean AIP, but the differences were negligible and probably not statistically significant, suggesting that AIP's ability to distinguish between different stroke subtypes in this population was limited. However, one-way ANOVA revealed no statistically significant difference between the groups ($p > 0.05$).

TABLE 4: TYPES OF STROKE IN DIABETIC AND NON-DIABETIC PARTICIPANTS

Type of Stroke	No of Participants	
	Diabetic	Non-Diabetic
Haemorrhagic Stroke	21 (10.5%)	12 (6%)
Ischemic Stroke	50 (25%)	50 (25%)
Transient Ischemic Attack (TIA)	29 (14.5%)	38 (19%)

Chi-square Test, p = 0.16 (not statistically significant).

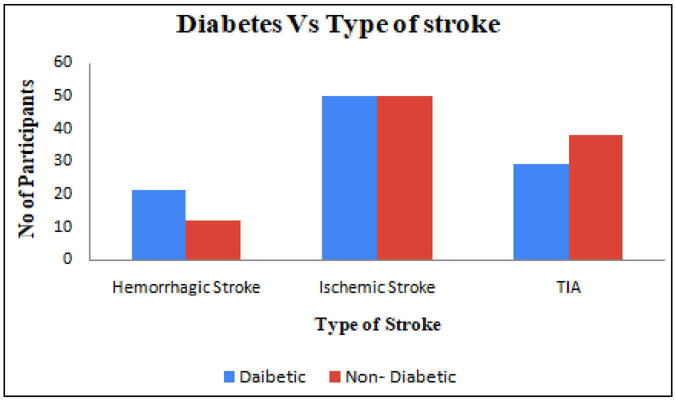

FIG. 3: TYPE OF STROKE AMONG DIABETIC AND NON-DIABETIC PARTICIPANTS

There was no statistically significant difference in the distribution of stroke subtypes between people with diabetes and those without (p = 0.16). The most prevalent category in both groups was ischemic stroke, but those without diabetes seemed to have a slightly greater incidence of transient ischemic attacks (TIAs). Diabetics had a slightly increased incidence of haemorrhagic stroke. These differences, however, were not statistically significant, indicating that the distribution of stroke subtypes in this cohort may not be significantly influenced by diabetes status alone.

TABLE 5: DISTRIBUTION OF RISK FACTORS IN DIABETIC AND NON-DIABETIC PARTICIPANTS

Risk Factor	Diabetic Participants (%)	Non-Diabetic Participants (%)
Hypertension (HTN)	53 (53%)	47 (47%)
Coronary Heart Disease (CHD)	44 (44%)	42 (42%)
Atrial Fibrillation	50 (50%)	57 (57%)
Peripheral Vascular Disease	55 (55%)	51 (51%)
Carotid Plaque	0 (0%)	0 (0%)

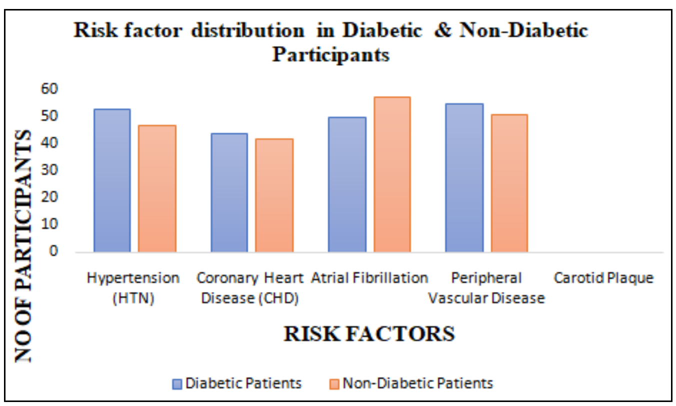

FIG. 4: DISTRIBUTION OF CARDIOVASCULAR RISK FACTORS IN STROKE PATIENTS

The distribution of important cardiovascular risk variables in stroke patients with and without diabetes was assessed in this study. 53% of patients with diabetes and 47% of individuals without diabetes had hypertension, suggesting a marginally greater frequency among diabetics. Additionally, diabetics had a higher prevalence of coronary heart disease (44%) than non-diabetics (42%). Patients with diabetes had a larger percentage of peripheral vascular disease (55%) compared to those without the condition (51%), indicating a higher risk of vascular problems among diabetics. Atrial fibrillation, however, was comparatively more common in non-diabetic patients (57%) than in diabetics (50%). Neither group showed signs of carotid plaque. Overall, the results indicate that a number of vascular risk factors that contribute to stroke are more common in people with diabetes.

TABLE 6: DISTRIBUTION OF HBA1C AMONG STROKE PATIENTS

HbA1c Level	No of Participants	Stroke Risk
Normal – (<5.7 %)	18	Base line Risk

Prediabetes (5.7 – 6.4%)	36	Slightly increased Risk
Diabetes (> 6.5%)	146	Significantly increased Risk

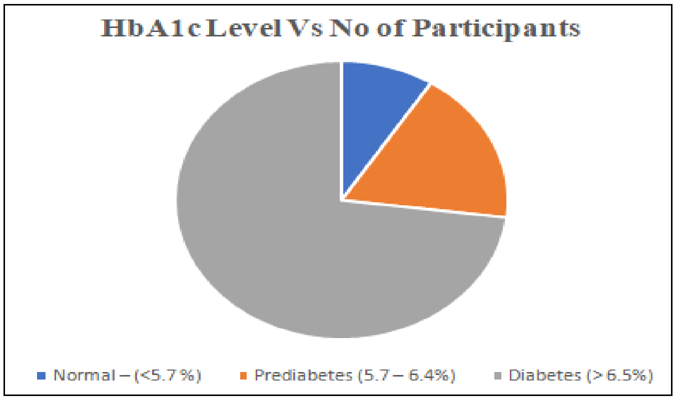

FIG. 5: PARTICIPANTS DISTRIBUTION ACCORDING TO HBA1C LEVEL

The distribution reveals that the majority of stroke patients had poor glycemic control, with HbA1c falling into the diabetic range. A lower percentage had normal or prediabetic readings. These results, which indicate a correlation between increased HbA1c and stroke severity.

TABLE 7: RELATIONSHIP BETWEEN BMI CATEGORIES AND CLINICAL OUTCOMES (mRS SCORE) AMONG STROKE PATIENTS

BMI Range (kg/m²)	No. of Participants (%)	mRS 0–2 (Good Outcome)	mRS 3–6 (Poor Outcome)
< 18.5	3 (1.5%)	3	0
18.5 – 24.9	77 (38.5%)	41	36
25 – 29.9	47 (23.5%)	20	27
30 – 34.9	73 (36.5%)	29	44
≥ 35	0	—	—

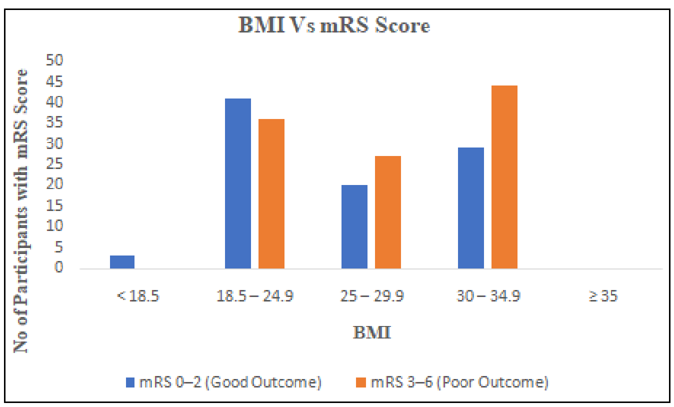

FIG. 6: DISTRIBUTION OF BMI ACROSS mRS SCORE

The study found that those with normal BMI (18.5-24.9 kg/m²) had better functional outcomes, with a higher proportion obtaining mRS 0-2. Overweight and obese patients (BMI ≥25 kg/m²) had lower outcomes, particularly in the 30-34.9 kg/m² group. This shows that a higher BMI may be associated with poorstroke recovery. However, a moderate number of overweight people had positive results, indicating that other clinical characteristics had a major role.

CONCLUSION: The current study demonstrates that increasing age is a significant factor determining both the occurrence and consequences of stroke, with the highest burden reported in older populations. Ischemic stroke was the most prevalent subtype among all age groups. Although old age patients had a higher percentage of poor functional outcomes, the relationship between age and mRS outcome was not statistically significant. The Atherogenic Index of Plasma (AIP) revealed slight change between stroke subtypes, indicating a low diagnostic value. Diabetes had no significant effect on stroke subtype distribution; however, it was related with an increased incidence of vascular risk factors and poor glycemic control. Elevated HbA1c and higher BMI were associated with poor results, whereas those with normal BMI recovered better. As a whole, stroke outcomes appear to be complex, highlighting the relevance of early risk factor treatment, particularly glycemic control and weight regulation, in improving prognosis and lowering stroke-related disability.

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Ethical Approval: No Ethical approval needed as the data collection done from the patient records.

Confidentiality: All the information regarding the patient data were confidential.

CONFLICTS OF INTEREST: Nil

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