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Magnetic Resonance Imaging Patterns of Acute Ischemic Stroke and the Role of Associated Vascular Risk Factors

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Abstract

Since stroke is the world's top cause of death, preventive and treatment results depend on early detection and treatment. Developing a tailored public health strategy requires estimating the number of ischemic stroke patients and their unique risk factors. Since stroke is linked to immobility, poor decision-making, speech difficulties, facial drooping, vision loss, and hearing impairment, it now ranks among the most prevalent brain illnesses globally and has a major impact on people's health. A descriptive cross-sectional study was conducted at PIC (Peshawar institute of cardiology) for evaluation of acute ischemic stroke and its risk factors on MRI in a period of 4-6 months. We calculated our sample size through open EPI calculator according to which our sample size was 201 for this study. Patients suffering from ischemic stroke were included in our research irrespective of the gender. Patients suffering from other diseases and were less than 30years of age were not included. In the present study hypertensive participants were n=107(53.2%) and non-

hypertensive participants were n=94(46.8%). Most of the participants suffer from headache n= 191(95%) and those does not experienced headache were n=10(5%). In total sample n=49(24.4%) was current smoker and n=152(75.6%) were non-smoker. Participants having symptoms like nausea were n=54(26.9%), symptoms of vomiting were n= 42(20.9%) and n=146(72.6%) and n=159(79.1%) experienced no such symptoms of nausea and vomiting respectively. The high prevalence of hypertension among participants is one of the study's most important findings. Given that a significant 53.2% of participants had hypertension, it is critical to address blood pressure management in the general population. The prevalence of hypertension in this study highlights the importance of preventative interventions and routine monitoring in the general population, as it is a known risk factor for cardiovascular illnesses, including stroke

Keywords: MRI, Stroke, Ischemic stroke

Introduction:

Stroke is a major neurological disorder and an important cause of mortality, long-term disability, and socioeconomic burden worldwide. Among the different types of stroke, acute ischemic stroke (AIS) is the most common, resulting from an abrupt reduction or interruption of cerebral blood flow due to arterial occlusion, leading to inadequate oxygen and glucose delivery to brain tissue. The resulting ischemic cascade causes cellular energy failure, ionic imbalance, cytotoxic edema, neuronal injury, and, if not rapidly treated, irreversible infarction. According to the Global Burden of Disease Study 2021, ischemic stroke accounted for approximately 65% of incident strokes globally, demonstrating its substantial contribution to the worldwide burden of cerebrovascular disease. The overall burden of stroke has continued to increase, particularly in low- and middle-income countries, where exposure to vascular risk factors and limitations in prevention and acute stroke services remain important concerns. [1,2] The development of ischemic stroke is strongly associated with a combination of non-modifiable and modifiable risk factors. Increasing age, male sex, and a family history of stroke are important non-modifiable factors, whereas hypertension, diabetes mellitus, dyslipidemia, cigarette smoking, obesity, physical inactivity, atrial fibrillation, ischemic heart disease, and previous cerebrovascular events are among the major modifiable or potentially modifiable risk factors. The Global Burden of Disease Study has demonstrated that high systolic blood pressure, high body-mass index, elevated fasting plasma glucose, smoking-related exposures, unhealthy dietary patterns, low physical activity, and other metabolic and environmental factors contribute substantially to stroke-related disability and mortality. [1,2] Identification of these risk factors in patients with AIS is therefore

essential not only for understanding the possible etiology of stroke but also for guiding secondary prevention and reducing the risk of recurrent cerebrovascular events. Hypertension is consistently recognized as one of the most important risk factors for ischemic stroke. Chronic elevation of blood pressure contributes to endothelial dysfunction, arterial remodeling, atherosclerosis, and cerebral small-vessel disease, thereby increasing the likelihood of both large-artery and small-vessel ischemic infarction. Diabetes mellitus further increases stroke risk through hyperglycemia-associated endothelial injury, accelerated atherosclerosis, inflammation, and abnormalities of platelet and coagulation function. Dyslipidemia, particularly elevated low-density lipoprotein cholesterol and triglycerides, contributes to atherosclerotic plaque formation and arterial stenosis. Smoking promotes vascular endothelial injury, platelet activation, oxidative stress, and atherosclerosis and has been associated with adverse vascular outcomes in patients with ischemic stroke. [3-6] Studies conducted in Asian populations have similarly demonstrated strong relationships between hypertension, diabetes, dyslipidemia, smoking, and different ischemic stroke subtypes. [7] The importance of these risk factors is also evident in South Asian populations, where stroke occurs in the setting of a substantial burden of hypertension, diabetes, tobacco exposure, dyslipidemia, and cardiovascular disease. A nationwide population-based study from Bangladesh reported that ischemic stroke represented approximately four-fifths of confirmed stroke cases, with hypertension, dyslipidemia, tobacco use, diabetes mellitus, and ischemic heart disease among the most frequently observed risk factors.

[8] Research from Pakistan has also demonstrated that hypertension, diabetes mellitus, dyslipidemia, and smoking are important risk factors for ischemic stroke, including among younger patients. In a multicentric Pakistani study of young adults with ischemic stroke, hypertension was the most frequently identified risk factor, followed by diabetes mellitus, dyslipidemia, and smoking. [9] More recent evidence from Southern Punjab has additionally highlighted the clinical relevance of hypertension and diabetes among patients presenting with acute cerebral ischemia, emphasizing the continuing importance of these factors in the Pakistani population. [10] Atrial fibrillation represents another major risk factor for ischemic stroke, particularly through cardio embolism. The irregular cardiac rhythm can result in thrombus formation within the atria, with subsequent embolization to cerebral arteries. Other cardiovascular conditions, including ischemic heart disease and heart failure, may also increase the risk of cerebral ischemia. Previous stroke or transient ischemic attack is an important predictor of recurrent stroke, while sedentary lifestyle, obesity, poor diet, and inadequate control of metabolic abnormalities may further contribute to vascular risk. Importantly, some major vascular

risk factors may remain undiagnosed before the occurrence of stroke. A large clinical study found that a considerable proportion of patients with acute ischemic stroke had previously unrecognized vascular risk factors, with dyslipidemia, hypertension, atrial fibrillation, and diabetes among the newly detected conditions. [11] This emphasizes the importance of systematically documenting risk factors in patients presenting with acute ischemic stroke. Magnetic resonance imaging (MRI) has an important role in the evaluation of patients with suspected acute ischemic stroke because it provides detailed information about brain parenchyma, vascular structures, tissue perfusion, and the extent of ischemic injury. Among MRI techniques, diffusion-weighted imaging (DWI) is particularly valuable because restricted diffusion associated with cytotoxic edema can become visible very early after cerebral ischemia. DWI is therefore highly sensitive for detecting acute infarction, including small cortical, subcortical, lacunar, and posterior circulation lesions that may be difficult to identify using conventional imaging. [12,13] The combination of DWI with apparent diffusion coefficient (ADC) mapping improves the differentiation of true restricted diffusion from lesions that appear bright because of T2-related effects. MRI sequences such as fluid-attenuated inversion recovery (FLAIR), susceptibility-weighted or gradient-echo imaging, magnetic resonance angiography (MRA), and perfusion-weighted imaging can provide additional information regarding lesion age, hemorrhage, vascular occlusion, and potentially salvageable brain tissue.

[12-15] MRI has become particularly important in patients with an uncertain time of symptom onset, including wake-up stroke. The presence of a DWI-positive lesion without corresponding marked FLAIR hyperintensity, known as a DWI-FLAIR mismatch, can provide information regarding the relative age of the infarct and may assist in selecting appropriate patients for reperfusion therapy. Clinical implementation studies have demonstrated that emergency MRI can be incorporated into acute stroke pathways, although availability, scanning time, patient stability, and access to experienced radiological interpretation remain important practical considerations. [14,16] Advanced neuroimaging has consequently contributed to a shift from a purely time-based approach toward a tissue-based assessment of acute ischemic stroke in selected patients. Despite its high sensitivity, MRI does not identify every clinically diagnosed ischemic stroke. DWI-negative ischemic stroke may occur, particularly in patients with minor neurological deficits, very early imaging, small infarct volumes, or posterior circulation involvement. A prospective multicenter study from China found that approximately 7.7% of patients with acute ischemic stroke had negative baseline DWI findings, with DWI negativity being more common in patients with milder stroke. [17] A subsequent systematic review and meta-analysis involving more than 16,000 patients

estimated that approximately 16% of clinically diagnosed ischemic strokes may have negative DWI findings, with an even higher proportion among patients with minor stroke. [18] These findings demonstrate that MRI results should always be interpreted alongside clinical findings and risk-factor profiles rather than being considered in isolation. The relationship between clinical risk factors and MRI findings is therefore of considerable research interest. Different vascular risk factors may be associated with distinct mechanisms and patterns of cerebral ischemia. For example, hypertension and diabetes are strongly associated with small-vessel disease, while dyslipidemia and smoking may contribute to large-artery atherosclerosis. A study comparing ischemic stroke caused by cerebral small-vessel disease and large-artery atherosclerosis identified hypertension, diabetes mellitus, high cholesterol, hypertriglyceridemia, and smoking as important risk factors, while also demonstrating differences in the risk-factor profiles of specific ischemic stroke mechanisms. [7] Such relationships may be clinically relevant when interpreting MRI findings and determining the probable underlying mechanism of infarction. MRI can also demonstrate ischemic lesions that have clinical and prognostic implications beyond the initial infarct. Recent research using serial MRI has shown that incident ischemic lesions may occur following stroke and are associated with older age and pre-existing small-vessel disease. These lesions were associated with poorer cognitive and functional outcomes and a greater risk of recurrent stroke. [19] Furthermore, advanced MRI techniques and vascular imaging can provide additional information about arterial stenosis, atherosclerotic plaque characteristics, vessel-wall abnormalities, infarct distribution, and tissue viability. Recent work combining computed tomography angiography with high-resolution MR vessel-wall imaging has further emphasized the potential of multimodal imaging for evaluating factors associated with acute cerebral ischemic events. [20]

Material and Methods:

The study was conducted following ethical approval from the Clinical Research Ethics Committee of the Asian Institute of Medical and Management Sciences (AIMMS), Peshawar. Permission for data collection was obtained from the Peshawar Institute of Cardiology (PIC), Peshawar, including approval from the Head of the Radiology Department. The study was conducted using a cross-sectional design at the Peshawar Institute of Cardiology, Peshawar. A total sample size of 201 participants was calculated using the Statistical Cochrane formula sample size calculator. A non-probability convenience sampling technique was employed for participant recruitment. Patients diagnosed with acute ischemic stroke who were referred for magnetic resonance imaging (MRI) of the brain were eligible for inclusion. Participants of either gender and

aged above 30 years were included in the study. Patients aged 30 years or younger and those diagnosed with conditions other than acute ischemic stroke were excluded. All eligible participants were recruited according to the predefined inclusion and exclusion criteria. Data were collected using a predesigned, standardized, and validated proforma developed according to the objectives of the study. The data collection instrument consisted of sections covering demographic characteristics, relevant clinical information, vascular and other potential risk factors, and MRI findings. Patients with acute ischemic stroke who were referred for MRI brain examination were approached for participation. The purpose and procedures of the study were explained clearly to the participants, and informed consent was obtained before data collection. Participants were assured that the information obtained would be kept confidential and used solely for research purposes. Appropriate permissions were obtained from the Ethical Review Committee, the Head of the Radiology Department at Peshawar Institute of Cardiology, and the Ethical Research Committee of the Asian Institute of Medical and Management Sciences, Peshawar. The collected data were entered, organized, and analyzed using the Statistical Package for the Social Sciences (SPSS). Categorical variables were summarized using frequencies and percentages and presented where appropriate through tables, bar charts, and pie charts. Continuous variables were summarized using mean and standard deviation. The association between categorical variables, including demographic characteristics, clinical risk factors, and MRI findings, was assessed using the chi-square test. The statistical analysis plan was developed according to the study design and the nature and distribution of the variables. Appropriate statistical tests were selected to determine associations between independent variables and relevant study outcomes. Potential confounding factors and effect modifiers were considered during analysis, where applicable, through stratification and subgroup comparisons. Results were presented using appropriate tables and graphical representations, and statistical significance was assessed at a predefined significance level of $p < 0.05$.

Results:

Demographic Characteristics of Study Participants:

In the current study enrolled 201 patients irrespective of gender with age greater than 30years that fulfilled our inclusion criteria from Peshawar institute of cardiology (PIC) Peshawar KPK Pakistan. Participants having age in between 30-40years was n= 72(35.8%), 41-50years n= 49(24.4%), 51-60 years n=36(17.9%), 61-70 years n=24(11.9%), 71-80 years n=13(6.5%) and having age between 81-90years was n=7(3.5%) as shown in a figure 4.1. Male ratio was higher (n=112 accounting for 55.7% of total sample size) than females (n=89 accounting for 44.3% of total sample size).

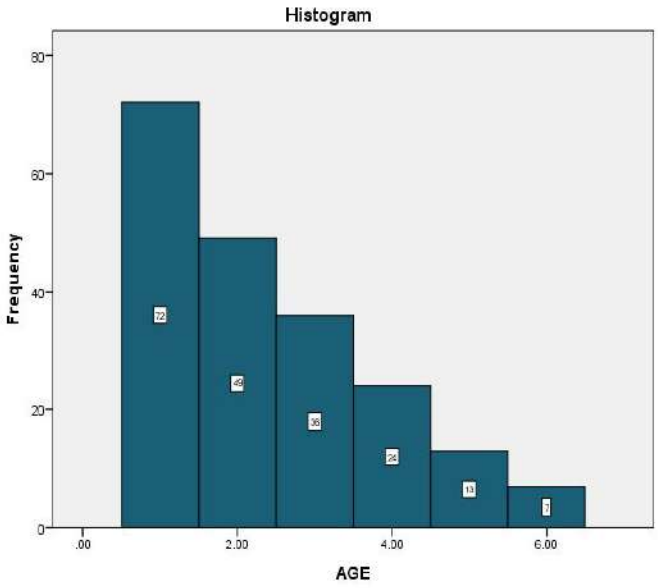

Fig 3.1: Age wise distribution of patients

Clinical Characteristics and Presenting Symptoms

In the present study hypertensive participants were n=107(53.2%) and non-hypertensive participants were n=94(46.8%). Most of the participants suffer from headache n= 191(95%) and those does not experienced headache were n=10(5%) as shown in fig 4.2. In total sample n=49(24.4%) was current smoker and n=152(75.6%) were non-smoker. Participants having symptoms like nausea were n=54(26.9%), symptoms of vomiting were n= 42(20.9%) and n=146(72.6%) and n=159(79.1%) experienced no such symptoms of nausea and vomiting respectively.

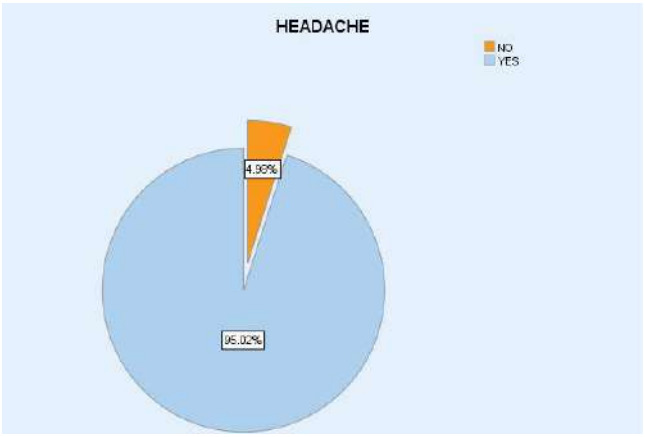

Fig3.2: Participants headache status

Metabolic and Medical Risk Factors

In the present study n=64(31.8%) participants were diabetic and n=137(68.2%) were non-diabetic. Among total sample only n=18(9%) has hyperlipidemia while majority of participants have normal lipid profile (n=182 accounting for 90.5% of total sample size). Participants having family history of stroke or cardiovascular diseases (CVD) were n= 155(77.1%) while participants having no such history were n= 45(22.4%) as shown in fig 4.3. Similarly, participants having pervious history of transient ischemic attack (TIS) or history of stroke were n= 47(23.4%) while n=154(76.6%) have no such history. Participants having cardiac diseases (like atrial fibrillation or heart failure) accounts for n= 41 (20.4%) and participants having no history of such cardiac diseases were n= 160(79.6%).

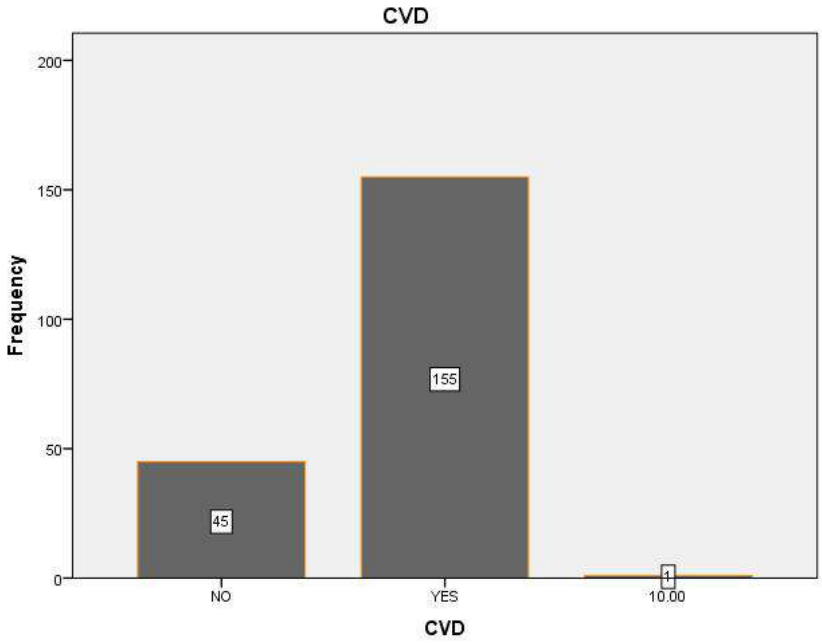

Fig3.3: Family history of cardiovascular diseases/ stroke of participants

MRI Findings and Distribution of Acute Ischemic Stroke

Among total sample size n=68(33.8%) of participants were diagnosed with acute ischemic stroke while in n= 133(66.2%) no such changes were observed. Among participants diagnosed with acute ischemic stroke n= 50 (73.5%) have ischemic changes at multiple location, n=14(20.5%) has ischemic changes at anterior location and n=4 (5.88%) have ischemic changes at posterior location. Among all the participants along with standard sequence of MRI DWI, ADC and only in some individuals (n=8) MRA was also performed. Further evaluation shows that in all cases of acute ischemic changes

have hyper intense signal on Diffusion weighted imaging (DWI), apparent diffusion coefficient (ADC), fluid attenuated inversion recovery sequence (FLAIR), T2- weighted imaging (T2WI) and have hypo intense signal on T1 weighted image (T1WI).

S.NO	Variable		Frequency(F)	Percentage (%)
1	Age (years)	30-40	72	35.8
		41-50	49	24.4
		51-60	36	17.9
		61-70	24	11.9
		71-80	13	6.5
		81-90	7	3.5
1	Gender	Male	112	55.7
		Female	89	44.3
2	Hypertension	YES	107	53.2
		NO	94	46.8
3	Headache	YES	191	95
		NO	10	5
4	Smoking	YES	49	24.4
		NO	152	75.6
5	Nausea	YES	54	26.9
		NO	146	72.6
6	Vomiting	YES	42	20.9
		NO	159	79.1
7	Diabetes mellitus	YES	64	31.8
		NO	137	68.2
8	Hyperlipidemia	YES	18	9
		NO	182	90.5
9	Family history of stroke or CVD	YES	155	77.1
		NO	45	22.4
10	History of stroke/ TIA	YES	47	23.4
		NO	154	76.6
11	Cardiac condition (AF, HF)	YES	41	20.4
		NO	160	79.6
12	Acute ischemic stroke (AIS)	YES	68	33.8
		NO	133	66.2
13	Location of stroke	Anterior	14	20.5

	posterior	4	5.88
	Multiple	50	73.5

Table3.1: characteristic of participants (AF=Atrial fibrillation, CVD= cardiovascular diseases, AIS=Acute ischemic stroke, TIA=Transient ischemic stroke)

MRI Findings and Distribution of Acute Ischemic Stroke

For assessing relationship between two categorical variable (dependent and independent) we apply chi- square test in which acute ischemic stroke was taken is a dependent variable and age, gender, hypertension, headache, smoking, nausea, vomiting, diabetes mellitus, Hyperlipidemia, family history of stroke/TIA, cardiac condition (like atrial fibrillation, heart failure). Participants included in our study with age of both gender greater than our study shows that age of participants are most significantly associated with acute ischemic stroke (X^2 =41.599, P=.000). This study also shows that gender of participants is significantly associated with acute ischemic stroke (X^2 =4.553, P= 0.036) as shown in fig3.4.

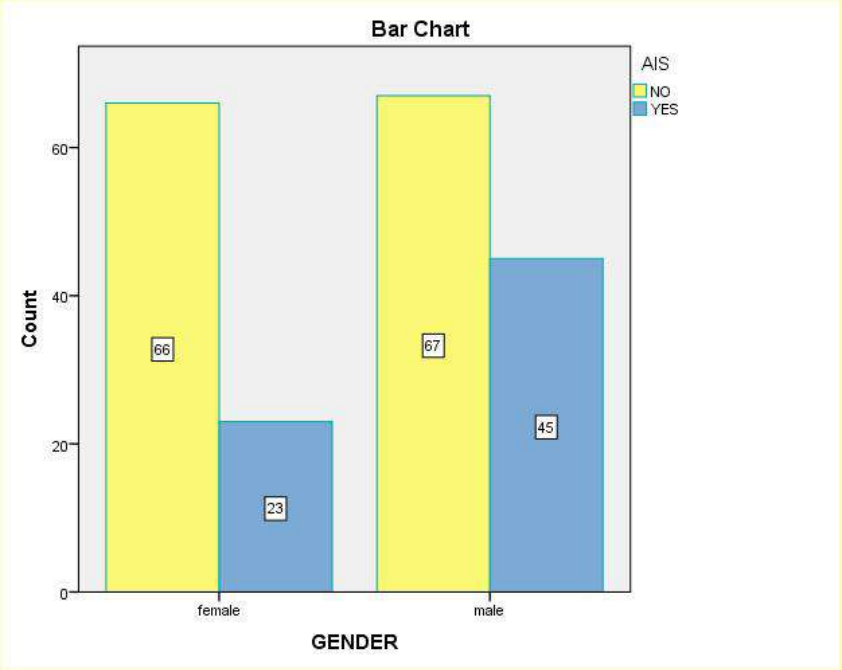

Figure3.4: Association between acute ischemic stroke and gender of participants (AIS= acute ischemic stroke)

Association of Demographic Factors with Acute Ischemic Stroke

Hypertension is most significant risk factor for the development of acute ischemic stroke (X^2=25.199, P=.000). Furthermore headache (X^2=1.229, P= .268), smoking (X^2= .708, P= .400), nausea (X^2=5.098, P=.078), vomiting (X^2=.656, P=.418) has no significant

association with development of acute ischemic stroke. Acute ischemic stroke is more prevalent in participants with diabetes mellitus (X^2=27.370, P=.000) and hyperlipidemia (X^2=1.478, P= .478), participants having family history of cardiovascular diseases/stroke (X^2=4.112, P=.128) has no such association with acute ischemic stroke. Furthermore, participants having previous history of transient ischemic attack (TIA) (X^2=60.686, P= .000) as shown in fig3.5 and cardiac diseases (X^2=35.609, P=.000) are most prevalent risk factors for acute ischemic stroke as shown in fig3.6.

S.NO	Variable		Acute ischemic stroke(n=68)	X^2	P
1	Age	30-40	6	41.599	.000
		41-50	17		
		51-60	17		
		61-70	15		
		71-80	9		
		81-90	4		
1	Gender	Female	23	86.868	.000
		Male	45		
2	Hypertension	Yes	53	25.199	.000
		No	15		
3	Headache	Yes	63	1.229	.268
		No	5		
4	Nausea	Yes	12	5.098	.078
		No	56		
5	Smoking	Yes	19	.708	.400
		No	49		
6	Vomiting	Yes	56	. 656	.418
		No	12		
7	Diabetes mellitus	Yes	38	27.370	.000
		No	30		
8	Hyperlipidemia	Yes	8	1.478	.478
		No	60		
9	Family history of CVD/ Stroke	Yes	58	4.112	.128
		No	10		
10	History of transient ischemic attack (TIA)	Yes	38	60.686	.000
		No	30		
11	Cardiac diseases (AF, HF)	Yes	30	35.609	.000

No	38

Figure3.5: Risk factor associated with acute ischemic stroke.

Discussion:

The present study evaluated 201 patients aged above 30 years who were referred for brain MRI at the Peshawar Institute of Cardiology, Peshawar, and assessed the relationship between acute ischemic stroke (AIS) and selected demographic and clinical risk factors. Acute ischemic stroke was identified in 68 (33.8%) participants, while 133 (66.2%) showed no acute ischemic changes. The relatively high proportion of AIS in this MRI-referred population highlights the importance of MRI in confirming acute cerebral ischemia. Diffusion-weighted imaging (DWI) is particularly sensitive for the early detection of ischemic injury and can demonstrate cerebral ischemia within minutes of symptom onset. Multimodal MRI also provides valuable diagnostic and prognostic information and can assist in identifying the location and extent of ischemic lesions. [21,22] In the present study, the largest proportion of participants belonged to the 30–40-year age group (35.8%), followed by 41–50 years (24.4%). Age demonstrated a statistically significant association with AIS (χ^2=41.599, $p<0.001$), indicating that the distribution of ischemic stroke differed significantly across age groups. This finding is consistent with recent evidence showing that vascular risk factors are increasingly observed across younger age groups and that ischemic stroke is not exclusively a disease of the elderly. A Pakistani multicentric study of young adults identified hypertension, diabetes mellitus, dyslipidemia, and smoking as important risk factors for ischemic stroke. [23] Similarly, recent longitudinal evidence from Pakistan has reported changing stroke patterns, including increasing stroke occurrence among younger individuals and increasing clustering of hypertension, diabetes, atrial fibrillation, and smoking. [24] In our study, males constituted 55.7% of the sample compared with 44.3% females, and gender was significantly associated with AIS (χ^2=4.553, $p=0.036$). This male predominance is also compatible with observations from other ischemic stroke cohorts in which men have represented a larger proportion of patients. Hypertension was one of the most important findings in the present study. More than half of the participants (53.2%) were hypertensive, and a highly significant association was observed between hypertension and AIS (χ^2=25.199, $p<0.001$). This finding supports the well-established role of hypertension as a major modifiable risk factor for ischemic stroke. Chronic elevation of blood pressure promotes endothelial injury, arterial remodeling, atherosclerosis, and cerebral small-vessel disease, thereby increasing the risk of cerebral ischemia. Recent research has also demonstrated that patients with hypertension may present with different ischemic stroke mechanisms, particularly small-vessel and

subcortical disease. [25] The high prevalence and significant association of hypertension in our study emphasize the need for early detection and effective blood pressure control as an important component of stroke prevention in the local population. Diabetes mellitus was present in 31.8% of participants and demonstrated a statistically significant association with AIS (χ^2=27.370, p<0.001). This finding is consistent with previous research from Pakistan, where diabetes has been identified as one of the major risk factors for ischemic stroke. [23] Diabetes may contribute to ischemic stroke through accelerated atherosclerosis, endothelial dysfunction, inflammation, and abnormalities of platelet and coagulation function. In contrast, smoking, headache, nausea, vomiting, hyperlipidemia, and family history of stroke/CVD did not show statistically significant associations with AIS in the present study. The absence of statistical significance for these variables should not necessarily be interpreted as evidence that they have no biological relationship with stroke, as the relatively small sample size and distribution of individual risk factors may have limited the statistical power of the study. For example, only 18 participants (9.0%) were reported to have hyperlipidemia, which may have reduced the ability to detect a significant association. A particularly important finding was the strong association between previous TIA/stroke and AIS (χ^2=60.686, p<0.001). Participants with a previous cerebrovascular event were substantially more likely to have acute ischemic changes, emphasizing the importance of previous cerebrovascular disease as a marker of recurrent stroke risk. Cardiac conditions, including atrial fibrillation and heart failure, were also significantly associated with AIS (χ^2=35.609, p<0.001). This finding is clinically important because atrial fibrillation is a recognized source of cardioembolic cerebral infarction. Recent research has emphasized the importance of identifying previously undiagnosed vascular and cardiac risk factors among patients presenting with acute ischemic stroke, particularly hypertension, dyslipidemia, atrial fibrillation, and diabetes mellitus.

[26] Therefore, systematic cardiovascular assessment in patients with suspected AIS may contribute to identifying potentially preventable causes of recurrent stroke. Regarding MRI findings, 68 participants demonstrated acute ischemic changes, with multiple cerebral locations being the most frequent pattern (73.5%), followed by anterior circulation involvement (20.5%) and posterior circulation involvement (5.88%). The acute ischemic lesions demonstrated characteristic signal abnormalities on the reported MRI sequences, supporting the diagnostic value of MRI in the evaluation of AIS. DWI is highly sensitive for detecting acute ischemic lesions; however, interpretation should be performed together with ADC, FLAIR, T1-weighted, and T2-weighted sequences because diffusion abnormalities may have potential pitfalls, particularly

during the early stages of ischemia. [21] Overall, the findings of this study demonstrate that hypertension, diabetes mellitus, previous TIA/stroke, cardiac conditions, age, and gender were significantly associated with AIS in the studied population. These findings reinforce the importance of identifying and controlling modifiable vascular risk factors and using MRI as an important diagnostic tool for the evaluation of patients with suspected acute ischemic stroke.

Conclusion:

It was concluded that the acute ischemic stroke was identified in 33.8% of the study participants undergoing MRI. Age, gender, hypertension, diabetes mellitus, previous stroke/TIA, and cardiac conditions showed significant associations with AIS. Hypertension, diabetes, previous cerebrovascular events, and cardiac disease were particularly important risk factors in the studied population. Early identification and management of these risk factors, along with timely MRI evaluation, may help improve stroke prevention and clinical outcomes.

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