International Journal of Biomedicine 14(4) (2024) 640-648
http://dx.doi.org/10.21103/Article14(4)_OA17

ORIGINAL ARTICLE

Radiology

INTERNATIONAL JOURNAL OF BIOMEDICINE

Cross-Sectional Imaging and Risk Factors Associated with Stroke Features

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Abstract

Background: Among health problems that can damage the brain, stroke is one of the most dangerous. However, there is relatively little information on the risk factors related to stroke in Saudi Arabia, especially in Jeddah. This study aims to identify stroke features on cross-sectional imaging and stroke-associated risk factors in Jeddah, Saudi Arabia.

Methods and Results: This retrospective study included 131 patients admitted to governmental institutions (King Abdulaziz Hospital and East Jeddah Hospital) from 2017 to 2022. The present study included only patients with a brain CT scan without a contrast agent. MRI (1.5 Tesla) was considered for follow-up patients. Most of the stroke patients were over age 60 (66.4%). The distribution of stroke patients showed a higher percentage of males compared to females (59.5% versus 40.5%) (P=0.029). The most frequent attributable risk for stroke was found in 36 patients, of which 24 (66.7%) had hypertension, 22 (61.1%) - diabetes mellitus, 14 (38.9%) - previous stroke, and 6 (16.7%) had coronary heart disease. The majority of patients (85.5%) were diagnosed with ischemic stroke, and 11.5% had hemorrhagic stroke. Ischemic stroke was significantly associated with diabetes (100.0% versus 82.6% in nondiabetics) (P=0.042). The most common stroke site was intracranial (lobar) infarction (32.1%), followed by a middle cerebral artery (MCA) stroke (21.4%).

Conclusion: The study findings indicated that the males exhibited a higher stroke incidence rate than the females. The major type of stroke was ischemic stroke. Hypertension and diabetes mellitus are the most common vascular risk factors for stroke. Early controlling vascular risk factors could help prevent stroke at an older age.**(International Journal of Biomedicine. 2024;14(4):640-648.)**

Keywords: stroke • elderly patients • risk factors • CT scan • MRI

For citation: Aljondi RM, Alharthi WS, Alyanbaawi SM, Alghamdi AA, Alghamdi SS, Abdulrahman Tajaldeen A. Cross-Sectional Imaging and Risk Factors Associated with Stroke Features. International Journal of Biomedicine. 2024;14(4):640-648. doi:10.21103/Article14(4)_OA17

Abbreviations

CHD, coronary heart disease; **CHF,** congestive heart failure; **DM**, diabetes mellitus; **HTN**, hypertension; **MCA**, middle cerebral artery; **PS**, previous stroke.

Introduction

Stroke is a significant health problem that can lead to death.[1,2] In stroke, there is disrupted blood flow to the brain, preventing oxygen and nutrients from reaching brain cells, which can lead to death within minutes if not treated immediately. In addition, it may result in various injuries to brain and body functions.[3,4] Annually, 15 million people worldwide suffer a stroke.[5-7] Stroke is considered a disease of aging because most strokes occur in older people (over age 65). Moreover, the number of strokes is increasing worldwide due to the growth of elderly populations.[8]

Stroke is one of the main pathologies potentially harming the human brain. It is a serious global healthcare problem in developing and developed countries, harming individuals and families at all societal levels.[8-10] Between 2010 and 2030, it is predicted that stroke will affect 4.5 million people per

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year, resulting in a total of over 9 million stroke survivors worldwide during that period. [8,9,11]

Strokes are divided into two types: ischemic and hemorrhagic.[12] Ischemic stroke is the most common type, and it occurs when a vessel supplying blood to the brain is obstructed (usually by a clot).[13] Various conditions can cause ischemic stroke, such as embolisms, thrombosis, or arterial stenosis.[14] Ischemic stroke is a common complication of congestive heart failure (CHF).[15-18] CHF is associated with an increased risk of thrombus formation and is accompanied by a 2- to 3-fold increased risk of stroke than in the general population. Approximately 15% of strokes can be attributed to CHF as a contributing factor.[19] Previous studies showed that approximately 10% to 24% of patients with stroke have heart failure.[20-23] Hemorrhagic stroke, about 13% of all strokes, occurs when a blood vessel in the brain ruptures, causing bleeding within the brain tissue. It is considered a life-threatening illness that can cause severe disability or death.[24,25] Subarachnoid hemorrhage (SAH) and intracerebral hemorrhage (ICH) are two types of hemorrhagic stroke. SAH is bleeding into the subarachnoid space, while ICH is bleeding into the brain parenchyma.[24-26]

Nevertheless, relatively little information exists on the risk factors related to stroke.[11] Still, various non-modifiable risk factors that may cause stroke have been identified, such as genetic factors, race, gender, and age.[27-29] For instance, approximately 25% of men and 20% of women over age 45 are likely to experience a stroke if they live to the age of 85.[27,28] Furthermore, modifiable risk factors for stroke have been identified, such as chronic diseases, cigarette smoking, obesity, physical inactivity, and trauma.[27,30-32] Hypertension (HTN) is considered the most important due to the long-term high blood pressure causing blood vessel damage.[33] The number of patients with stroke may increase in the future because of inadequate control of the major risk factors and demographic changes.[15-18]

Computed tomography (CT) imaging has become the first-line modality for diagnosing stroke in emergencies due to its widespread availability, speed, accuracy, and low cost in detecting subarachnoid and cerebral bleeding. CT scans of the brain can diagnose ischemic areas within 6 hours of stroke onset.[34] However, there is limited information on the identification of stroke type on cross-sectional imaging and associated risk factors among patients, especially in Saudi Arabia.[11,35] This study aims to identify stroke features on cross-sectional imaging and stroke-associated risk factors in Jeddah, Saudi Arabia.

Materials and Methods

Study Design

This retrospective study was conducted to evaluate the prevalence and incidence of stroke and risk factors among stroke patients. Stroke cases were collected from governmental institutions (King Abdulaziz Hospital and East Jeddah Hospital) in Jeddah from June 2020 to 2023, including demographic data, patients' medical history, radiological examination data, imaging findings, stage of stroke, type of stroke, and its location in the brain from radiological reports. The total sample size was 131 patients aged between 34 and 102 years. The current study defined a stroke case as a focal neurological deficit caused by a hemorrhage or cerebral infarction, as determined by a CT scan. Only patients who came to the hospital, presented with a stroke, underwent a CT scan, and/or had a follow-up MRI scan were included in this study.

The present study included only patients with a brain CT scan without a contrast agent. MRI (1.5 Tesla) was considered for follow-up patients. The bleeding site was assessed based on brain CT and /or MRI results.

CT Stroke Protocol

CT stroke studies were obtained using CT scanners. The image acquisition protocol was as follows: slice thickness: 10 mm; table increment: 10 mm; acquisition parameters: 120 kVp/300mA. A caudocranial scanning direction was selected, covering the foramen magnum to the vertex of the skull (Figure 1).

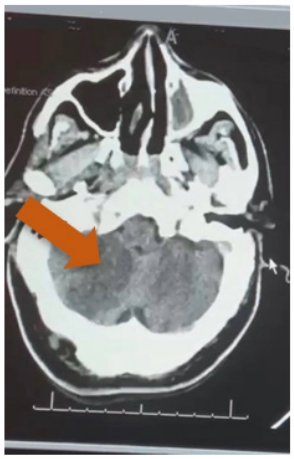

***Fig. 1**. A non-contrast CT brain image: A subacute infarction in the cerebellum (Arrow).*

MRI Stroke Protocol

MRI stroke protocols were obtained using MRI scanners. The suggested acquisition protocols included at least the following sequences:

- T1 weighted
  plane: sagittal (or volumetric 3D)
  sequence: fast-spin echo (T1 FSE) or gradient
- T2 weighted
  plane: axial
  sequence: T2 FSE
- FLAIR
  plane: axial
  sequence: FLAIR
- diffusion-weighted imaging (DWI)
  plane: axial (Figure 2)
- susceptibility-weighted imaging (SWI)
  plane: axial
- MR angiography (MRA)
  plane: axial with reconstructions

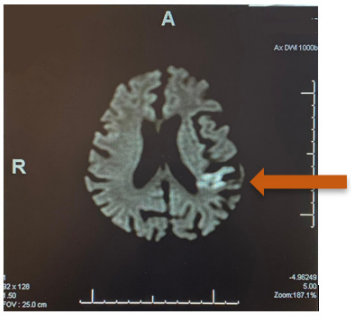

Fig. 2. *MRI brain image (DWI sequence): An acute infarction in the left parietal lobe (Arrow) with an underlying hemorrhagic component.*

Risk Factors

The medical records of the patients were reviewed to determine the probable etiology of the stroke, independently of any imaging findings, for age, sex, ethnicity, smoking history, history of diabetes mellitus (DM), HTN, and clinical diagnosis at the time of the imaging reviews. Upon review of the imaging studies of brain parenchyma, as well as previous studies, we concluded that the main common risk factors were as follows: HTN (ESC/ESH, 2018),[36] DM (ADA,2022),[37] and smoking (smoking status was categorized as either "never smokers" or "currently smokers"). Other factors, such as previous stroke (PS) or presenting with coronary heart disease (CHD), were categorized as no/yes.

Statistical analysis

Statistical analysis was performed using the statistical software package SPSS version 26.0 (SPSS Inc, Armonk, NY: IBM Corp). Baseline characteristics were summarized as frequencies and percentages. Group comparisons were performed using the chi-square test. A *P*-value of <0.05 was considered statistically significant. However, many of the variables were collinear, indicating overlap. We used only the most statistically significant variable in the final analysis in these cases.

Ethical Considerations

The study protocol was approved by the Institutional Review Board at the Ministry of Health in Saudi Arabia, IRB number A01362. Patients were informed that their personal information would be kept confidential and that their clinical data and radiological images would only be used for research purposes in this project. A written consent form was waived due to the retrospective, observational nature of the study.

Results

This study included 131 patients admitted to governmental institutions (King Abdulaziz Hospital and East Jeddah Hospital) from 2017 to 2022. All patients received a brain CT at baseline and subsequent follow-up brain MRI later. Furthermore, remote or old carotid infarcts were observed at baseline in 166 patients. All patients without confirmed stroke were excluded.

The most frequent attributable risk for stroke was found in 36 patients, of which 24 (66.7%) had HTN, 22 (61.1%) - DM, 14 (38.9%) - PS, and 6 (16.7%) had CHD (Table 1). Most of the stroke patients were over age 60 (60.5%). The distribution of stroke patients showed a higher percentage of males compared to females (78[59.5%] versus 53[40.5%]) (*P*=0.029).

Table 1.
Clinical characteristics of the study patients

Variable	Category	Freq.	%
Gender	Male	78	59.5
	Female	53	40.5
	Total	131	100.0
Age^	< 40	9	7.0
	40–49	14	10.9
	50–59	28	21.7
	60–70	45	34.9
	> 70	33	25.6
	Total	129	100.0
Smoking	No	130	99.2
	Yes	1	0.8
	Total	131	100.0
Comorbidities (having at least one of four diseases: HTN, DM, PS, and CHD)	No	95	72.5
	Yes	36*	27.5
	Total	131	100.0

^ There were two patients with missing age information.
** Among the 36 patients, 24 (66.7%) had HTN, 22 (61.1%) - DM, 14 (38.9%) - PS, and 6 (16.7%) had CHD.*

Approximately two-thirds of the patients (60.3%) presented with acute stroke, and 34.4% developed chronic stroke, whereas only 15.3% of patients were diagnosed with subacute stroke. The majority of patients (85.5%) were diagnosed with ischemic stroke, and 11.5% had hemorrhagic stroke (Table 2),

Table 2.
Stroke characteristics of the study participants.

Variable	Category	Freq.*	%
Stroke stage	Chronic	45	34.6
	Acute	79	60.3
	Subacute	20	15.3
Type of stroke	Ischemic stroke	112	85.5
	Hemorrhagic stroke	15	11.5
	Unspecified (please check)	4	3.0
Side of the brain	Left hemisphere	50	48.1
	Right hemisphere	43	41.3
	Bilateral	11	10.6
Bleeding site within brain**	Anterior cerebral artery (ACA)	2	1.5
	Middle cerebral artery (MCA)	28	21.4
	Posterior cerebral artery (PCA)	2	1.5
	Cerebellar stroke	21	16.0
	Intraventricular hemorrhage	4	3.1
	Basal ganglia stroke	19	14.5
	Lobar stroke	42	32.1
	Lacunar stroke	14	10.7
	Thalamus stroke	9	6.9

** There were 131 patients, but some of them had two or more different stages, and one patient did not have information regarding the stage; for the brain side, 27 data were missing.*
*** The percentage sum is more than 100% because a single patient may be placed in multiple categories. The percentage is calculated for 131 cases.*

The most common stroke site was intracranial (lobar) infarction (32.1%), followed by a middle cerebral artery (MCA) stroke (21.4%). The least common stroke sites were the anterior cerebral artery and posterior cerebral artery (both 1.5%) (Table 2). Of the 104 identified strokes, nearly half of the strokes affected the left side of the brain (48.1%), somewhat fewer affected the right side (41.3%), and only 11(10.6%) patients had bilateral strokes.

A total of 130 cases were included in the analysis by stroke stage (Table 3).

Table 3.

Identification of stroke stages

Chronic Stage					
Risk factors	Categories	N	Chronic		*P*-value
			No	Yes	
Gender	Male	78	70.5%	29.5%	0.138
	Female	52	57.7%	42.3%	
Age*	< 40	9	55.6%	44.4%	0.883
	40–49	14	71.4%	28.6%	
	50–59	28	71.4%	28.6%	
	60–70	44	63.6%	36.4%	
	> 70	33	63.6%	36.4%	
HTN	No	106	68.9%	31.1%	0.098
	Yes	24	50.0%	50.0%	
DM	No	108	68.5%	31.5%	0.13
	Yes	2	50.0%	50.0%	
PS	No	116	67.2%	32.8%	0.239
	Yes	14	50.0%	50.0%	
CHD	No	124	65.3%	34.7%	1.000
	Yes	6	66.7%	33.3%	
Acute Stage					
Risk factors	Categories	N	Acute		*P*-value
			No	Yes	
Gender	Male	78	35.9%	64.1%	0.363
	Female	52	45.3%	54.7%	
Age*	< 40	9	33.3%	66.7%	0.589
	40–49	14	28.6%	71.4%	
	50–59	28	50.0%	50.0%	
	60–70	44	42.2%	57.8%	
	> 70	33	33.3%	66.7%	
HTN	No	106	42.1%	57.9%	0.356
	Yes	24	29.2%	70.8%	
DM	No	108	37.6%	62.4%	0.341
	Yes	22	50.0%	50.0%	
PS	No	116	39.3%	60.7%	0.781
	Yes	14	42.9%	57.1%	
CHD	No	124	40.8%	59.2%	0.402
	Yes	6	16.7%	83.3%	

**Age was not reported in the files of three patients.*

No significant association was found between risk factors and the chronic stage of stroke. However, women were slightly more likely to be in the chronic stage. In addition, patients with hypertension were also slightly more likely to be in the chronic stage (50% versus 31.1% in non-hypertensive patients). The same can be noted for a history of diabetes and old stroke. Moreover, no significant association was found between risk factors and the acute stage of stroke. However, men were slightly more likely to be in the acute stage (64.1% versus 54.7% in women). In addition, patients with hypertension were also slightly more likely to be in the acute stage (70.8% versus 57.9% in non-hypertensive patients). Still, the opposite trend was observed in patients with diabetes (50.0% versus 62.4% in nondiabetics). In addition, patients with coronary artery disease were also slightly more likely to be in the acute stage (83.3% versus 59.2% in patients without coronary artery disease).

Ischemic stroke was significantly associated with diabetes (100.0% versus 82.6% in nondiabetics, *P*=0.042) (Table 4). The results also demonstrate that patients with PS have a relatively higher likelihood of ischemic stroke (100% versus 83.8% of patients without PS). Patients with CHD also have a relatively higher likelihood of ischemic stroke (100% compared to 84.8% without CHD).

Table 4.

Identification of ischemic stroke

Risk factors	Categories	N	Ischemic Stroke		*P*-value
			No	Yes	
Gender	Male	78	15.4%	84.6%	0.805
	Female	52	13.2%	86.8%	
Age*	< 40	9	0.0%	100.0%	0.402
	40–49	14	21.4%	78.6%	
	50–59	28	10.7%	89.3%	
	60–70	44	15.6%	84.4%	
	> 70	33	18.2%	81.8%	
HTN	No	106	14.0%	86.0%	0.751
	Yes	24	16.7%	83.3%	
DM	No	108	17.4%	82.6%	0.042
	Yes	22	0.0%	100.0%	
PS	No	116	16.2%	83.8%	0.220
	Yes	14	0.0%	100.0%	
CHD	No	124	15.2%	84.8%	0.592
	Yes	6	0.0%	100.0%	

**Age was not reported in the files of three patients.*

The age was significantly associated with the MCA stroke (*P*=0.028, Table 5). This is evident in the percentage of this type of stroke in each age group, which is 43–44% in the age groups under 50, while it is 9–25% in the age groups 50 and over. Therefore, the chances of MCA stroke seemed relatively higher at younger ages.

The patients with HTN and DM had a relatively low likelihood of stroke in this location (Table 5). There was a relatively low likelihood of stroke in the thalamus for patients with HTN. Only DM was significantly associated with stroke in the thalamus (18% compared to 5% for nondiabetics, *P*=0.043) (Table 5).

Regarding gender and diabetes, female patients had a relatively higher likelihood of stroke in this position than men without statistical significance. Patients with CHD had a rela-

tively higher likelihood of stroke at this position than patients without CHD (*P*=0.353).

Table 5.

Stroke location on cross-sectional imaging

Risk Factors	Categories	N	Middle Cerebral Artery (MCA)		*P*-value
			No	Yes	
Gender	Male	78	80.8%	19.2%	0.518
	Female	52	75.5%	24.5%	
Age*	< 40	9	55.6%	44.4%	0.028
	40–49	14	57.1%	42.9%	
	50–59	28	75.0%	25.0%	
	60–70	44	91.1%	8.9%	
	> 70	33	78.8%	21.2%	
HTN	No	106	76.6%	23.4%	0.285
	Yes	24	87.5%	12.5%	
DM	No	108	76.1%	23.9%	0.159
	Yes	22	90.9%	9.1%	
PS	No	116	78.6%	21.4%	1.000
	Yes	14	78.6%	21.4%	
CHD	No	124	78.4%	21.6%	1.000
	Yes	6	83.3%	16.7%	
Risk Factors	Categories	N	Thalamic Hemorrhage		*P*-value
			No	Yes	
Gender	Male	78	96.2%	3.8%	0.157
	Female	52	88.7%	11.3%	
Age*	< 40	9	100.0%	0%	0.348
	40–49	14	100.0%	0%	
	50–59	28	92.9%	7.1%	
	60–70	44	93.3%	6.7%	
	> 70	33	87.9%	12.1%	
HTN	No	106	94.4%	5.6%	0.365
	Yes	24	87.5%	12.5%	
DM	No	108	95.4%	4.6%	0.043
	Yes	22	81.8%	18.2%	
PS	No	116	93.2%	6.8%	1.000
	Yes	14	92.9%	7.1%	
CHD	No	124	93.6%	6.4%	0.353
	Yes	6	83.3%	16.7%	

**Age was not reported in the files of three patients.*

Discussion

The current study was conducted to identify the risk factors associated with different stroke types and locations. The distribution of stroke patients showed a higher percentage of males compared to females (59.5% versus 40.5%, *P*=0.029). This agrees with a study conducted in Al-Madinah Al-Munawarah that examined the rate of first-time stroke incidents in males and females. The distribution of stroke in the sample was 55.49% for men and 44.51% for women.[38] Our results were also in line with another study conducted in the Ha'il Region in Saudi Arabia that examined the stroke-associated comorbidities of stroke patients, reporting that 59% were males and 41% were females.[11]

A similar study conducted in the Riyadh Region, Saudi Arabia, assessed knowledge about stroke risk factors and willingness to make behavioral changes among individuals living in the Kingdom of Saudi Arabia who had experienced a stroke, finding that 58.4% were male and 41.6% were female.[39]

Although strokes among women are severe, stroke is more frequently encountered among men. Although strokes are more severe in women, strokes are more common in men.[40] The main reason for sex-related differences in stroke is because of the differences in the sex steroid hormones, principally estrogen hormone. Vascular structure can be affected by sex hormones.[41, 42] Estradiol, a primary form of estrogen, can help protect against stroke in premenopausal women by influencing cholesterol metabolism. However, after menopause, the protection gradually decreases as the levels of estradiol decrease. Previous studies have demonstrated an increase in female ischemic stroke after menopause. Vascular structure can be affected by sex hormones.[41,42] Estradiol, a primary form of estrogen, can help protect against stroke in premenopausal women by influencing cholesterol metabolism. [38] However, after menopause, the protection gradually decreases as the levels of estradiol decrease. Previous studies have demonstrated an increase in female ischemic stroke after menopause and a decrease in sexual hormones.[43-45] Testosterone was found to be a great antiatherogenic agent; however, while normal levels of testosterone can have a protective effect against atherosclerosis, having excessively high testosterone levels, either naturally or through external supplementation, can increase the risk of developing atherosclerosis.[41,42,46,47]

Several studies of integrative systems have identified gene regulatory networks (GRNs) characteristic of atherosclerosis and CHD.[41,48,49] Hartman et al.[49] compared sex-specific GRNs and observed clear sex differences in network activity within the atherosclerotic tissues. Genes more active in females were associated with mesenchymal and endothelial cells, whereas genes more active in males were associated with the immune system.

As in previous studies, we found that the incidence of stroke increases with age.[6,47,50] The results of our study showed that the average age of most stroke patients was 50 years, representing 81% of the sample. This is in line with a study with a Saudi Arabian cohort that found that the incidence of stroke increased with age, especially at the age of 75 and above, in both men and women.[38] A study from the Ha'il Region in Saudi Arabia showed that men are more susceptible to stroke when they are younger, whereas older women are more susceptible as they age.[11]

A prospective observational study by Rukn et al.[51] examined the baseline characteristics of 13,822 stroke patients living in the Middle East and North African (MENA) and non-MENA countries. The mean age among 5897 MENA patients was 65 (56-76). Hypertension (66%) and diabetes (38%) were the prevailing risk factors; large artery stenosis > 50% (25.3%) and lacunar strokes (24.1%) were the most common ischemic stroke etiologies. In comparison, non-MENA countries displayed a median age of 66 (56-76), with other large vessel diseases and cardiac embolism as the main ischemic stroke etiologies.

It has been shown that older females who had a stroke at an older age had unpleasant outcomes, as they faced a decrease in life quality, mental issues such as depression, and cognitive deficits.[52]

Stroke is a rapidly expanding health concern in Saudi Arabia, where it is regarded as a leading cause of illness and death.[53] This is related to the country's rapidly changing lifestyle and the high prevalence of cardiovascular diseases, such as HTN, DM, dyslipidemia, and obesity, all of which are key risk factors for stroke.[54-56] Studies conducted in Saudi Arabia have shown that HTN and DM are the two main causes of ischemic stroke.[11,57] The results of our study demonstrated that 27.5% of the sample proved to have at least 1 of 4 comorbidities (HTN, DM, PS, and CHD). HTN and DM are the most common risk factors associated with stroke. It is known that HTN is the main cause of hemorrhagic stroke due to increased blood pressure.[58] Previous studies and trials have also highlighted a significant relationship between stroke and HTN.[11,58,59-61] DM is also considered a risk factor for all types of strokes, and the disease is more common in ischemic stroke patients than in hemorrhagic stroke patients. [13,62-66]

The results of our study identified the types of strokes, their location, and the side of the brain affected by stroke. Overall, the most prevalent stroke type was ischemic (85.5%), which was found to be more likely to affect diabetic patients. Shiber et al.[67] conducted a retrospective review for 1 year of all patients discharged from the hospital, a regional stroke center. Among 757 patients included in the study, 41.9% had a hemorrhagic stroke, and 58.1% had an ischemic stroke.

Regarding the stages of stroke, males were more likely to have an acute stroke than females, while females had a relatively higher risk of chronic stroke. In our study, 48.1% of patients had a stroke in the left hemisphere, 41.3% in the right hemisphere, and 10.6% had bilateral strokes.

The findings suggest that the locations with the highest likelihood of stroke are the lobar area (32%) and MCA (21%, mostly occurring in younger patients). Diabetic patients exhibited a higher rate of stroke and thalamic hemorrhage compared to nondiabetic patients. The previous evidence further revealed that the pattern of risk factors associated with ischemic stroke included valve heart disease, transient ischemic attack, atrial fibrillation, previous brain infarction, ischemic heart disease, hyperlipidemia, hypertension, chronic liver disease, previous cerebral hemorrhage, oral anticoagulant therapy.[68] Knowledge of vascular risk factors and cerebral anatomy is crucial for understanding the mechanisms involved in stroke localization.[69]

The main limitations of this study included the sample size and the unequal distribution of vascular risk factors in stroke patients. It was difficult to retrospectively identify the vascular risk factors and distribution of strokes, as there was not enough follow-up data for measurable risk factors. In most cases, the results were obtained on patients visiting hospitals for the first time. Furthermore, there was a lack of information on the patients in the medical records system due to the rapid and urgent methods of treatment; most stroke patients were admitted through the emergency room. Therefore, the results cannot be generalized to the entire population. Further expanded longitudinal studies that include larger sample sizes are needed, with follow-up assessments to clarify the relationship between risk factors and their distribution in stroke patients.

Conclusion

The findings of this study highlight that hypertension and diabetes mellitus are the most common vascular risk factors for stroke. The stroke rates are higher in men than women. The majority of strokes were of the ischemic type, and diabetic patients had a relatively higher likelihood of ischemic stroke. The middle cerebral artery is most commonly involved in acute stroke, especially in younger patients (under age 40), and the thalamus is the region most affected by stroke in diabetic patients. Early controlling vascular risk factors could help prevent stroke at an older age. Finally, it is strongly recommended that the awareness of the vascular risk factors of stroke be raised in the Kingdom of Saudi Arabia.

Competing Interests

The authors declare that they have no competing interests.

Sources of Funding

This work was funded by the University of Jeddah, Jeddah, under grant No. (1RIT-22-U).

Acknowledgments

The authors thank Dr. Adnan Al-Homaidan, President of the University of Jeddah, and the Vice-President for Graduate Studies and Scientific Research, Dr. Shatha Khusaifan, for their support and encouragement. In addition, the authors would like to thank the College of Applied Medical Sciences and the Department of Applied Radiologic Technology at the University of Jeddah for their full support. We would also like to thank the technicians and radiologists in the radiology departments of the King Abdul-Aziz Hospital and Oncology Center and East Jeddah General Hospital in Jeddah, Saudi Arabia, for their help in gathering the essential data for the study. This work was funded by the University of Jeddah, Jeddah, under grant No. (1RIT-22-U). The authors, therefore, thank the University of Jeddah for its technical and financial support.

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