

Diagnostic Validity of Doppler Ultrasonography in Carotid Stenosis

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ABSTRACT

Objective: The goal of the study is to appraise the diagnostic validity of carotid Doppler ultrasound in stroke patients.

Design: Retrospective

Setting: Aseer central Hospital, Abha, Saudi Arabia

Methods: A total of 77 stroke patients, admitted to Asir Central Hospital (ACH), Saudi Arabia, from January 2017 to December 2018 were enrolled. The degree of carotid artery stenosis was assessed by CT-angiography and carotid Doppler ultrasonography. The degree of stenosis was classified as: <70% or >70% and <50% or >50%. Considering CT-angiography the gold standard reference test, the diagnostic validity of carotid Doppler ultrasonography was calculated.

Results: The location of stenosis was in the internal carotid artery among 69% of patients, while in 19%, it involved both the common carotid and the internal carotid arteries. Doppler ultrasonography had a sensitivity of 100%, a specificity of 87.5%, a positive predictive value of 94.6%, a negative predictive value of 87.5%, and an overall accuracy of 96.1%, when considering cut-off point of 50% stenosis.

Conclusion: Carotid Doppler ultrasound offers high diagnostic validity among stroke patients. It is highly recommended for screening cases with symptoms of transient ischemic attacks or for differential diagnosis of stroke. However, since it is operator-dependent, continued training of radiographers and the use of enhanced technology are essential to improve its diagnostic validity.

Keywords: Stroke, Carotid artery stenosis, Carotid Doppler Ultrasonography, Diagnostic validity.

INTRODUCTION

Stroke, or cerebrovascular accident, occurs due to abrupt interruption of blood flow to the central nervous system, with sudden onset of "focal neurological deficit" (FND), which lasts for more than twenty-four hours. It constitutes a major cause of mortality and disability. According to etiology, 87% of strokes are ischemic, 10% due to intracerebral hemorrhage, while 3% are due to aneurysmal subarachnoid hemorrhage¹. The most common cause of ischemic stroke is atherosclerosis, causing thrombosis and subsequent narrowing or occlusion of vessels². Hemorrhagic stroke results from the rupture of these diseased arteries³.

There are several neuroimaging modalities useful for imaging of stroke patients, such as computerized tomography (CT), magnetic resonance angiography, and ultrasonography, each with its own advantages and disadvantages. Doppler ultrasound is the most widely used modality for the diagnosis of carotid artery stenosis, with excellent accuracy comparable to angiography⁴.

Shafaat and Sotoudeh⁵ stated that, in patients suspected of stroke, carotid ultrasonography is a common screening modality. Compared to other neuroimaging modalities, ultrasonography is a non-invasive, safe, and cheap bedside tool with a short examination time. Currently, it is widely used to assess carotid artery blood flow velocity in a cardiac cycle⁶.

Kristensen and colleagues⁴ noted that stenosis of the internal carotid artery is an important cause for both stroke and transient ischemic attacks. Endarterectomy for patients with narrowing of internal carotid artery lumen of $\geq 70\%$ demonstrated great benefit⁷. However, its effectiveness is highly dependent on patients' selection and its timing. The absolute risk reduction is highest if carotid endarterectomy is performed within two weeks after the index event, but it is rendered almost ineffective if performed after three months. Therefore, timely screening of stroke patients is considered crucial³.

In order to decrease the complications of stroke, secondary prevention by early diagnosis is important. Simple clinical findings are valuable in characterizing the type of stroke, but diagnostic imaging remains

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largely needed. Ultrasound evaluation of carotid intima-media thickness of the arteries on both sides is used for risk assessment⁸. However, Eiamthong⁹ stated that carotid Doppler ultrasound is an operator-dependent modality. It is sometimes challenging to obtain the proper acoustic window of visualization on the area of interest. There is a wide variation in its sensitivity for detecting carotid plaque ulceration (30–80%).

There is a paucity of data regarding the diagnostic validity of carotid Doppler ultrasound among stroke patients in Saudi Arabia, and relevant studies are still so scarce. Therefore, the present study aimed to appraise the diagnostic validity of carotid Doppler ultrasound in the assessment of stroke patients in ACH hospital.

METHODS

In the present study, all patients with neurologic deficits underwent brain non-contrast computed tomography and the diagnosis of acute ischemic stroke was made. Subsequently, the patients were evaluated retrospectively by carotid Doppler sonography to estimate the prevalence of stenosis and its percentage in acute ischemic stroke patients. Association between carotid artery stenosis and various risk factors such as diabetes mellitus, hypertension, hyperlipidemia, smoking and age was determined by taking a detailed clinical history, laboratory investigations, and examination of the patients.

This study followed a retrospective research design. Data were collected from hospital records of all stroke patients admitted to ACH hospital from January 2017 to December 2018. The inclusion criteria were stroke patients who underwent CT-angiography and carotid Doppler ultrasonography. The data of stroke patients who did not undergo CT-angiography or carotid Doppler ultrasonography were not included.

The doppler studies are performed with Ultrasound General 4D advance, EPIQ7, Philips, USA, and the CTA is performed with 128 slice Somatom CT, Siemens, Germany.

This study included a total of 77 stroke patients, of whom 44 (57.1%) were men. Their ages ranged from 44 to 110 years (Mean±SD: 67.8±12.8 years). The presence of carotid artery stenosis and its degree were assessed in the same patients by CT-angiography and carotid Doppler ultrasonography. The degree of stenosis was calculated according to the North American Symptomatic Carotid Endarterectomy Trial¹⁰.

Ethical approval was obtained from IRB of combined IRB boards of King Khalid University and General Directorate of Health Affairs, Asir region, Saudi Arabia. Data was collected from ACH hospital were analyzed using the Statistical Package for Social Sciences (IBM Corp., SPSS, version 25 Armonk, NY, USA). The frequency, percentage, mean, and standard deviation of descriptive statistics were determined. Considering CT-angiography the gold standard reference test, the diagnostic validity of the degree of carotid artery stenosis by Doppler ultrasonography was calculated according to Khoury and colleagues¹¹.

RESULTS

Table 1 shows that about two-thirds of stroke patients (63.6%) were aged 60–80 years, with a Mean ± SD of 67.8±12.8 years. More than half of the patients (57.1%) were women. The majority was Saudi (87%). Only 2.6% had a positive family history of stroke, while 70.1% were diabetic, 20.8% were hypertensive, 85.7% had high serum cholesterol levels, and 5.2% had transient ischemic attacks. Stroke subtype was a large vessel disease among 42.9% of patients, while it was cardioembolic among 57.1%.

Table 1: Personal characteristics of stroke patients

| Personal characteristics | No. | % |
|-------------------------------|-----------------|------|
| Age | | |
| <60 years | 17 | 22.1 |
| 60–80 years | 49 | 63.6 |
| >80 years | 11 | 14.3 |
| Mean±SD | 67.8±12.8 years | |
| Gender | | |
| Men | 44 | 57.1 |
| Women | 33 | 42.9 |
| Nationality | | |
| Saudi | 67 | 87.0 |
| Non-Saudi | 10 | 13.0 |
| Family history | | |
| Positive | 2 | 2.6 |
| Negative | 75 | 97.4 |
| Associated comorbidity | | |
| Diabetes | 54 | 70.1 |
| Hypertension | 16 | 20.8 |
| Hypercholesterolemia | 66 | 85.7 |
| Transient ischemic attacks | 4 | 5.2 |
| Stroke subtypes | | |
| Large vessel disease | 33 | 42.9 |
| Cardioembolic | 44 | 57.1 |

Table 2: of carotid arteries stenoses among stroke patients as assessed by Doppler ultrasonography (at a cut-off of 70% stenosis) compared with CT-angiography and the resultant diagnostic validity for ultrasonography

| Percentage of stenosis by carotid Doppler ultrasonography | Percentage of stenosis as assessed by CT-angiography | | |
|---|--|---------------|-------|
| | Mild/Moderate (0–69%) | Severe (≥70%) | Total |
| 0–69% | 43 | 3 | 46 |
| ≥70% | 8 | 23 | 31 |
| Total | 51 | 26 | 77 |
| Diagnostic validity | | | |
| Sensitivity | 88.5% | | |
| Specificity | 84.3% | | |
| Positive predictive value | 74.2% | | |
| Negative predictive value | 84.3% | | |
| Overall accuracy | 85.7% | | |

Table 3: Percentages of carotid arteries stenoses among stroke patients as assessed by Doppler ultrasonography (at a cut-off of 50% stenosis) compared with CT-angiography and the resultant diagnostic validity for ultrasonography

| Percentage of stenosis by Carotid Doppler Ultrasonography | Percentage of stenosis as assessed by CT-Angiography | | |
|---|--|--------|-------|
| | (0–49%) | (≥50%) | Total |
| 0–49% | 21 | 0 | 21 |
| ≥50% | 3 | 53 | 56 |
| Total | 24 | 53 | 77 |
| Diagnostic validity | | | |
| Sensitivity | 100.0% | | |
| Specificity | 87.5% | | |
| Positive predictive value | 94.6% | | |
| Negative predictive value | 87.5% | | |
| Overall accuracy | 96.1% | | |

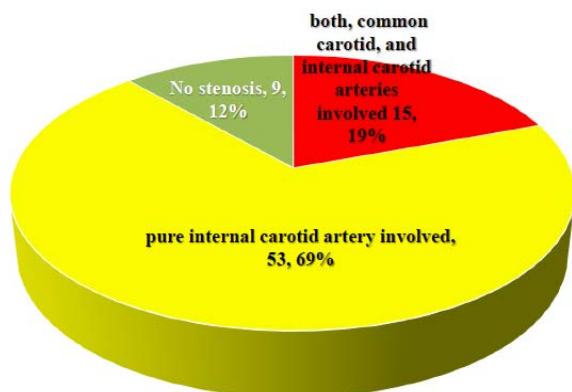


Figure 1: Location of stenosis among stroke patients

Figure 1 illustrates that the location of stenosis for more than two-thirds of patients was in the internal carotid artery (69%), with stenosis in the common carotid artery among 19% of stroke patients.

Table 2 demonstrates that, at a cut-off of 70% stenosis, the agreement between results of CT-angiography and carotid Doppler ultrasonography regarding stroke patients with 0–69% stenosis was present in 43 patients (true negative), and that for stroke patients with >70% was present in 23 stroke patients (true positive). However, the results of 3 stroke patients were <70% stenosis by ultrasonography and >70% stenosis by CT-angiography (false negative), and those of 8 stroke patients were >70% stenosis by ultrasonography, and <70% by CT-angiography (false positive). Therefore, at a cut-off of 70% stenosis, carotid Doppler ultrasonography had a sensitivity of 88.5%, a specificity of 84.3%, a positive predictive value of 74.2%, a negative predictive value of 84.3%, and an overall accuracy of 85.7%.

Table 3 shows that at a cut-off of 50% stenosis when considering recent guidelines,³ the agreement between results of CT-angiography and carotid Doppler ultrasonography regarding stroke patients with 0–49% stenosis was present in 21 patients (true negative), and that for stroke patients with >50% was present in 53 stroke patients (true positive). No stroke patients showed <50% stenosis by ultrasonography and >70% stenosis by CT-angiography (false negative), while those of 3 stroke patients were >50% stenosis by ultrasonography, and <50% by CT-angiography (false positive). Therefore, at a cut-off of 50% stenosis, carotid Doppler ultrasonography had a sensitivity of 100%, a specificity of 87.5%, a positive predictive value of 94.6%, a negative predictive value of 87.5%, and an overall accuracy of 96.1%.

DISCUSSION

The findings of the present study revealed that the age of most stroke patients ranged from 60 to 80 years with a mean of 67.8 years. There were more men than women patients, while only 2.6% had a positive family history of stroke. Moreover, our study revealed that the location of stenosis of more than two-thirds of stroke patients was purely in the internal carotid artery, while stenosis involving both common carotid and internal carotid arteries was present among 19% of stroke patients.

Characteristics of our stroke patients are in accordance with those described in several other studies. Appelros and colleagues¹² reported that the incidence of stroke among men is 30% higher than among women, but its risk increases with age among women, possibly due to the decrease in the protective effects of female sex hormones, which decline later in life^{13,14}. Kissela and colleagues¹⁵ noted that the mean age for the incidence of stroke in the USA was 69.2 years.

Flaherty and colleagues¹⁶ stated that extracranial internal carotid artery stenosis is especially notable and of great importance to clinicians caring for stroke patients. It was noted that atherosclerosis is the most common cause for large vessel stroke, while early endarterectomy or stenting significantly reduce the risk of recurrent strokes.

In Saudi Arabia, only a few studies reported gender differences among stroke patients, indicating that there were more men with strokes than women, and men formed a higher risk group compared to women¹⁷. Moreover, Robert and Zamzami¹⁸ reported that 68.4% of stroke patients were men, while a family history of stroke proved to be a significant risk factor among 14% of patients. Ahmed and colleagues¹⁹ reported that the mean age of stroke patients was 61 years, and the age of half of them ranged from 70 to 80 years. Men constituted 83.3% of them. The variations in personal characteristics of stroke patients may be due to differences in study populations or adopted diagnostic imaging tools.

Our study showed that, at a cut-off of 70% stenosis, carotid Doppler ultrasonography had high diagnostic validity, with a sensitivity of 88.5%, a specificity of 84.3%, a positive predictive value of 74.2%, a negative predictive value of 84.3%, and an overall accuracy of 85.7%. However, at a cut-off of 50% stenosis, carotid Doppler ultrasonography showed higher diagnostic validity, with a sensitivity of 100%, a specificity of 87.5%, a positive predictive value of 94.6%, a negative predictive value of 87.5%, and an overall accuracy of 96.1%. These findings may contribute to avoiding contrast studies when lesions are less than 50, as the sensitivity was 100%, and adoption of such practice could evade unnecessary contrast angiography and its potential complications and reduce the hustle on hospital services.

Several studies consider ultrasonography the test of choice to diagnose and to screen carotid artery diseases, with high diagnostic validity. The application of ultrasonography for large scale screening and accurately determining carotid artery stenosis is strongly recommended since it is a non-invasive, easy-to-operate imaging modality. It is also reliable, inexpensive, and safe. Moreover, its sensitivity and specificity for screening for carotid stenoses are quite high (94.4% and 91.7%, respectively)¹⁰.

Henry and colleagues²⁰ also reported high diagnostic validity for carotid Duplex scanning for the diagnosis of carotid artery occlusive disease >70%, with a sensitivity of 96.1%, a specificity of 88%, a positive predictive value of 92.5%, a negative predictive value of 93.6%, and an overall accuracy of 92.9%.

Ferrer and colleagues²¹ found that, compared to conventional carotid angiography, contrast-enhanced ultrasonography showed an excellent diagnostic validity, with as high as 100% sensitivity, specificity, and overall diagnostic accuracy. Antipova and colleagues²² attributed this exceptional diagnostic validity of contrast-enhanced transcranial ultrasonography to its better visualization compared to non-enhanced examination.

Antipova and colleagues²² explained the variability in reported diagnostic validity of carotid Doppler ultrasonography as an operator-dependent modality. Therefore, used ultrasound equipment, technology, operators' skills, and test protocols, as well as criteria for the diagnosis of hemodynamically significant disease necessitate periodic reassessment. Nevertheless, AbuRahma and colleagues²³ stressed that Doppler ultrasonography is an important tool to evaluate patients with symptoms related to the cerebrovascular system or those without symptoms but with risk factors of extracranial arterial disease.

Therefore, Saxena and colleagues²⁴ concluded that Doppler ultrasonography plays an important role in improving the diagnosis

of carotid artery stenosis. They added that with the progressive technological developments over the past few decades, the diagnostic accuracy of carotid artery stenosis has substantially improved, from carotid artery diameter narrowing measurement to the assessment of an increased velocity field near lesion sites. Additionally, computer-aided imaging modalities proved to offer higher diagnostic validity for the diagnosis of carotid artery stenosis.

CONCLUSION

Carotid Doppler ultrasound offers high diagnostic validity among stroke patients. Being a non-invasive, safe, and cheap bedside tool with short examination time and easy operability, it is highly recommended for screening cases with symptoms of transient ischemic attacks or for differential diagnosis of stroke. However, since it is operator-dependent, continued training of radiographers and the use of enhanced technology are essential steps to improve the diagnostic validity for screening patients with symptoms related to the cerebrovascular system or those without symptoms but with risk factors of extracranial arterial disease.

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Competing Interest: None.

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