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ORIGINAL ARTICLE

Comparison between Duplex Ultrasound and Digital Subtraction Angiography in Extracranial Arterial Stenosis

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Abstract

Background: ***One of the leading causes of death and disability is stroke. Extracranial vascular stenosis is a significant and often occurring cause of ischemic stroke.***

Aim and objectives: ***To compare the speed and accuracy of Doppler ultrasonography (DUS) to digital subtraction angiography (DSA) to determine the degree of stenosis in the carotid and vertebral arteries.***

Patients and methods: ***180 patients were recruited for our study between the beginning of February 2023 and the end of October 2023 who had been admitted to the emergency room or stroke unit at Al-Azhar University Hospitals with a clinical suspicion of extracranial vascular stenosis. DUS and DSA were used on each patient to determine the stenosis grade in the internal carotid and vertebral arteries. The outcomes were contrasted.***

Results: ***The mean age among the studied participants was 55± 6.44, with 85% being≥ 50 years, 66.7% were male, 95% were married, and 48.3% were smokers. Regarding ICA stenosis, The groups with 100% stenosis (accuracy: 100%) and 0-15% stenosis (accuracy: 82.7%) showed the highest levels of sensitivity and specificity in DUS. Moreover, DUS was the least sensitive (accuracy: 70%) in the group with 50–69% stenosis. The group with 0–49% stenosis had the highest DUS sensitivity (84.3% accuracy), while the group with 50–100% had the highest specificity (85.6% accuracy).***

Conclusion: ***DUS may be a proper primary screening method. However, before deciding on a course of treatment, it is advised that DUS findings of 50–69% degree ICA stenosis be confirmed with additional modalities.***

Keywords: Duplex Ultrasound; Digital Subtraction Angiography; Extracranial Arterial Stenosis

1. Introduction

While DUS can serve as a suitable first screening method, it is advisable to verify DUS results indicating 50-69% degree ICA stenosis with additional diagnostic techniques before reaching a definitive treatment conclusion[1,] additional cranial vascular stenosis is a significant and frequent cause of ischemic stroke.[2,3]

The leading cause of carotid stenosis is the development of atherosclerotic plaques where the carotid artery splits and at the beginning of the internal carotid artery. For patients diagnosed with carotid stenosis, it is necessary to examine the extent of blockage to predict the risk of stroke and decide whether therapies might be beneficial.[4]

The objective of this study was to assess the efficacy and precision of Doppler ultrasonography (DUS) in estimating the degree of stenosis in the Carotid and Vertebral arteries, as compared to digital subtraction angiography (DSA), within a brief time frame.

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2. Patients and methods

A total of 180 patients who showed any clinical suspicion of extracranial vascular stenosis were included in our study. These patients were admitted to the Emergency Department and Stroke Unit at Al-Azhar University Hospitals between February 2023 and October 2023.

We enrolled individuals over 18 who exhibited any clinical indication of stenosis in the extracranial blood vessels. We have eliminated individuals who have yet to undergo assessment using combined Doppler and intra-arterial angiography techniques within three weeks.

A professional academic radiologist conducted a Doppler ultrasound (DUS) to assess the level of narrowing in the Internal Carotid arteries (ICA) and vertebral arteries. The occlusion percentages of the internal carotid artery (ICA) were classified into five categories: 0-15%, 16-49%, 50-69%, 70-99%, and 100% stenosis. The measurement was determined using the North American Symptomatic Carotid Endarterectomy Trial (NASCET) using the following formula: percentage of stenosis = (1 - minimal residual lumen ÷ normal distal cervical internal carotid artery diameter) × 100. The occlusion percentages of the arterial bed in the vertebral arteries were divided into two categories: stenosis of more than 50% and stenosis of less than 50%. The DSA procedure was conducted and analyzed by a skilled neurologist, using either general or local anesthetic. The femoral technique introduced a catheter. The degree of blockage in the specified blood vessels was evaluated and recorded. The ultrasound results for the internal carotid artery (ICA) and vertebral artery (VA) of each patient were compared to the results of digital subtraction angiography (DSA).

The study was carried out using the principles outlined in the Helsinki Declarations, and approval was received from the institutional review board at the Faculty of Medicine, Al-Azhar University.

2.1.STATISTICAL ANALYSIS

The acquired data was analyzed using SPSS (Statistical Package for the Social Science) program version 25.0 (IBM Inc., Chicago, USA), Microsoft Office Excel 2016, and Med CalC program software version 19.1. Numeric data were shown as a range (from least to maximum) and the mean and standard deviation (SD). The categorical data were represented using frequencies and percentages.

3. Results

Table 1. Description of age, sex, and mentality in all studied patients.

		STUDIED PATIENTS (N = 180)	
SEX	Male	120	66.7%
	Female	60	33.3%
AGE (YEARS)	Mean ±SD	55 ± 6.44	
	Min - Max	40 – 66	
	Less than 50	27	15%
	50 years or more	153	85%
MARITAL STATUS	Married	171	95%
	Not married	9	5%
SMOKING	Smoker	87	48.3%
	Non-smoker	93	51.7%

This table shows the description of age and sex in all studied participants. Regarding age, the average age of all participants in the study was 55 ± 6.44 years, and the percentage of the studied participants ≥ 50 was 85%. As regard sex, there were 120 males (66.7%) and 60 females (33.3%) in the studied participants. As regard marriage, 95% of our studied participants were married. As regard smoking, 51.7% of our studied participants were non-smoker.

Table 2. Comparison between DUS and DSA measurement for detection of Carotid artery stenosis (0-15).

DUS *(TOTAL N= 180)*	DSA *Positive (n = 86)*	DSA *negative (n= 94)*	*SENSITIVITY*	*SPECIFICITY*	*PPV*	*NPV*	*ACCURACY*
TEST *POSITIVE (0-15) (83)*	69	14	80.2%	85.1%	83.1%	82.4%	82.7%
TEST *NEGATIVE (NOT 0-15) (97)*	17	80					

This table illustrates that DUS can detect Carotid artery stenosis (0-15) with a sensitivity of 80.2 percent. There were falsely positive results noted by 14participants. The sixty-nine Carotid artery stenosis participants (0-15) diagnosed by DUS and confirmed by DSA each had 85.1% specificity with accuracy of 82.7%.

Table 3. Comparison between DUS and DSA measurement for detection of Carotid artery stenosis (16-49%).

DUS (TOTAL N= 180)	DSA		SENSITIVITY	SPECIFICITY	PPV	NPV	ACCURACY
	Positive (n=30)	Negative (n=150)					
TEST POSITIVE (16-49) (15)	12	3	40%	98%	80%	89%	88.3%
TEST NEGATIVE (NOT 16-49)(165)	18	147					

This table illustrates that DUS can detect Carotid artery stenosis (16-49) with a sensitivity of 40 percent. There were falsely positive results noted by 3 participants. The twelve Carotid artery stenosis participants (16-49) diagnosed by DUS and confirmed by DSA each had 98% specificity with accuracy of 88.3%.

Table 4. Comparison between DUS and DSA measurement for detection of Carotid artery stenosis (50-69%).

DUS (TOTAL N=180)	DSA		SENSITIVITY	SPECIFICITY	PPV	NPV	ACCURACY
	Positive (n=19)	negative (n=161)					
TEST POSITIVE (16-49) (47)	6	41	31.5%	74.5%	12.7%	90.2%	70%
TEST NEGATIVE (NOT 16-49)(133)	13	120					

This table illustrates that DUS can detect Carotid artery stenosis (50-69) with a sensitivity of 31.5 percent. There were falsely positive results noted by 41 participants. The six Carotid artery stenosis participants (50-69) diagnosed by DUS and confirmed by DSA each had 74.5% specificity with accuracy of 70%.

Table (5): Comparison between DUS and DSA measurement for detection of Carotid artery stenosis (70-99%).

DUS (TOTAL N=180)	DSA		SENSITIVITY	SPECIFICITY	PPV	NPV	ACCURACY
	Positive (n=32)	Negative (n=148)					
TEST POSITIVE (70-99)(26)	21	5	65.6%	96.6%	80.7%	92.8%	91.1%
TEST NEGATIVE (NOT70-99)(154)	11	143					

This table illustrates that DUS can detect Carotid artery stenosis (70-99) with a sensitivity of 65.6 percent. There were falsely positive results noted by 5 participants. The twenty-one Carotid artery stenosis participants (70-99) diagnosed by DUS and confirmed by DSA each had 96.6% specificity with accuracy of 91.1%.

Table 6. Comparison between DUS and DSA measurement for detection of Carotid artery stenosis (100%).

DUS (TOTALN=180)	DSA		SENSITIVITY	SPECIFICITY	PPV	NPV	ACCURACY	
	Positive (n =6)	negative (n=174)						
TEST POSITIVE (100)(6)	6	0	100%	100%	100%	100%	100%	
TEST NEGATIVE (NOT100)(174)	0	174						

This table illustrates that DUS can detect Carotid artery stenosis (100) with a sensitivity of 100 percent. There were falsely positive results noted by 0 participants. The six Carotid artery stenosis participants (100) diagnosed by DUS and confirmed by DSA each had 100% specificity with accuracy of 100%.

Table 7. Comparison between DUS and DSA measurement for detection of vertebral artery stenosis (0-49).

DUS (TOTAL N= 153)	DSA		SENSITIVITY	SPECIFICITY	PPV	NPV	ACCURACY
	Positive n=120)	Negative (n= 33)					
TEST POSITIVE (0-49) (144)	120	24	100%	72.7%	83.3%	100%	84.3%
TEST NEGATIVE (NOT 0-49) (9)	0	9					

This table Illustrates that DUS can detect vertebral artery stenosis (0-49) with a sensitivity of 100 percent. There were falsely positive results noted by 24 participants. The one hundred and twenty vertebral artery stenosis participants (0-49) diagnosed by DUS and confirmed by DSA each had 72.7% specificity with accuracy of 84.3%.

Table 8. Comparison between DUS and DSA measurement for detection of vertebral artery stenosis (50-100).

DUS (TOTAL N= 153)	DSA		SENSITIVITY	SPECIFICITY	PPV	NPV	ACCURACY
	Positive(n=31)	Negative (n=122)					
TEST POSITIVE (50-100) (9)	9	0	29%	100%	100%	84.7%	85.6%
TEST NEGATIVE (NOT 50-100) (144)	22	122					

This table illustrates that DUS can detect vertebral artery stenosis (50-100) with a sensitivity of 29 percent. There were falsely positive results noted by 0 participants. The nine vertebral artery stenosis participants (50-100) diagnosed by DUS and confirmed by DSA each had 100% specificity with accuracy of 85.6%.

4. Discussion

Carotid and vertebral artery stenosis are frequently implicated in the occurrence of stroke or cerebrovascular accident. Timely detection of this illness can result in enhanced and more efficient therapy.[5]

Angiography, specifically digital subtraction angiography (DSA), is the established and most reliable method for diagnosing carotid artery stenosis. The angiography operation is known for its highly intrusive protocol and the administration of high X-ray doses to both the patient and medical staff.6 The advancement of noninvasive or minimally invasive diagnostic techniques such as ultrasonography, MR angiography (MRA), and CT angiography (CTA), along with various dose reduction techniques, has led to improved detection and evaluation of stenosis lesions. Angiography offers the benefit of simultaneous implementation of the angioplasty technique. Nevertheless, given the relatively low proportion of patients who require angioplasty, the diagnostic techniques must be minimally invasive and pose minimal risk to the patients.[6,7]

Ultrasonography (US) is the primary technology for screening and diagnosing carotid artery stenosis. This is a way of measuring hemodynamics that does not need invasion or ionizing radiation. Nevertheless, the results' precision relies on the user's proficiency and, more importantly, on a clearly established inspection protocol.[8]

This study aimed to assess the efficacy and precision of Doppler ultrasound (DUS) in estimating the degree of stenosis in the Carotid and Vertebral arteries, compared to digital subtraction angiography (DSA), within a brief time frame.

A total of 180 patients who showed clinical signs of extracranial vascular stenosis were included in our study. These patients were

admitted to the Emergency Department and Stroke Unit at Al-Azhar University Hospitals between February 2023 and October 2023. A qualified academic radiologist conducted a Doppler ultrasound to assess the extent of narrowing in the Internal Carotid arteries (ICA) and vertebral arteries. The occlusion percentages of the internal carotid artery (ICA) were classified into five categories: 0-15%, 16-49%, 50-69%, 70-99%, and 100% stenosis. The measurement was determined using the North American Symptomatic Carotid Endarterectomy Trial (NASCET) using the formula for calculating the percentage of stenosis, which is (1 - minimal residual lumen divided by average distal cervical internal carotid artery diameter) multiplied by 100. The occlusion percentages of the arterial bed in the vertebral arteries were divided into two categories: stenosis of more than 50% and stenosis of less than 50%. The DSA procedure was conducted and analyzed by a skilled neurologist under general or local anaesthesia. A catheter was placed using the femoral technique. The degree of blockage in the specified blood vessels was evaluated and recorded. The ultrasound results for the internal carotid artery (ICA) and vertebral artery (VA) of each patient were compared to the results of digital subtraction angiography (DSA).

The demographic analysis of our study indicated that the average age of the participants was 55± 6.44, and 85% of them were 50 years or older. Out of the people who were studied, 66.7% were males, 95% had been married, and 48.3% were smokers.

We evaluated the extent of narrowing in the internal carotid artery (ICA) and vertebral arteries using Doppler ultrasound (DUS) compared to digital subtraction angiography, which served as the benchmark for accuracy. Our findings indicate that Doppler ultrasound (DUS) is a beneficial diagnostic technique for detecting cerebral arterial stenotic episodes compared to digital subtraction angiography (DSA).

We assessed the degree of constriction in the internal carotid artery (ICA) and vertebral arteries by employing Doppler ultrasound (DUS) to compare to digital subtraction angiography, which was used as the standard for measuring accuracy. Our research suggests that Doppler ultrasonography (DUS) is a highly effective diagnostic method for identifying episodes of cerebral artery stenosis when compared to digital subtraction angiography (DSA).[9,10]

Netuka et al. Upon comparing histology findings with the noninvasive imaging modalities, it was discovered that carotid DUS (Duplex Ultrasonography) underestimated the presence of mild stenosis and overestimated the presence of severe stenosis.[11]

About ICA stenosis, DUS had the highest sensitivity and specificity in both the group with 100% stenosis (sensitivity: 100%, specificity: 100%, accuracy: 100%) and the group with 0-15% stenosis (sensitivity: 80.2%, specificity: 85.1%, accuracy: 82.7%). In addition, DUS demonstrated the lowest level of sensitivity in the group with 50-69% stenosis, with a sensitivity of 31.5%, specificity of 74.5%, and accuracy of 70%. Furthermore, due to the ordinal nature of our DUS output, we could not accurately determine whether our DUS overestimated or underestimated within a specific range.

In Banaei's study,[12], a strong correlation (0.812) was observed between Doppler sonography and DSA, suggesting that DUS can be a viable noninvasive approach for assessing carotid stenosis over 50%. The authors discovered that the significant association between Doppler sonography and DSA, compared to other investigations, may be attributed to their utilization of the most suitable hemodynamic variables based on previous studies. This allowed them to identify reliable hemodynamic parameters for assessing artery stenosis.

It can be deduced that Doppler ultrasound performed by a skilled sonographer may be a suitable first screening method. However, it is recommended that Doppler ultrasound findings indicating 50-69% narrowing of the internal carotid artery should be verified using additional techniques before making a definitive treatment choice.

Regarding vertebral artery stenosis, Doppler ultrasound (DUS) demonstrated the highest sensitivity in the group, with stenosis ranging from 0% to 49% (sensitivity: 100%, specificity: 72.7%, accuracy: 84.3%). However, it exhibited the highest specificity in the group with stenosis ranging from 50% to 100% (sensitivity: 29%, specificity: 100%, accuracy: 85.6%).

In the study of Hua et al.,[13], The authors' objective was to evaluate hemodynamic parameters using colour Doppler imaging and find the appropriate thresholds for assessing proximal vertebral artery stenosis, utilizing digital subtraction angiography as the reference standard. The researchers determined that colour Doppler imaging is a dependable technique for assessing the narrowing of the vertebral artery. The findings can serve as a basis for defining specific ultrasound criteria for diagnosing proximal vertebral artery stenosis.

The vertebral artery duplex might present technical challenges, particularly regarding its posterior and deep origin, as well as the presence of calcified lesions or a short neck stature, which

can significantly contribute to the complexity of the procedure.

An advantage of our investigation is the substantial sample size compared to other studies, as well as the relatively brief gap between DUS and DSA. These factors contribute to the precision of the results. However, certain constraints exist in the present investigation. Initially, our investigation centred on arterial stenosis rather than plaque architecture. Furthermore, this study has been conducted at only a few centres, and the evaluation of modalities is limited to a single academic institution. Hence, it is necessary to exercise caution when making generalizations.

DSA is a costly and intrusive technique that involves the administration of contrast agents and radiation exposure. Therefore, although it is not regarded as the primary method for detecting carotid and vertebral stenosis, it remains the most reliable and widely accepted method for evaluating the severity of artery narrowing.14 However, Doppler ultrasonography (DUS) can be suggested as the primary diagnostic method for finding vascular stenotic episodes.[14] DUS, compared to other modalities, provides numerous benefits, such as its noninvasive nature, cost-effectiveness, and absence of hazardous radiation.

Moreover, including anatomical details of the vasculature enhances the diagnostic value of DUS in identifying the underlying cause of a stroke. This is especially apparent in cases of posterior circulation stroke or transient ischemic attack (TIA), where the cause is more likely to be a thromboembolic event rather than hemodynamic. Nevertheless, as previously stated, the comprehensive assessment of plaque morphology in the vertebral arteries is challenging with ultrasonography due to the inherent limitations of the imaging technique, sometimes referred to as the "poor widow.".[3,14,15,16]

The drawbacks of DUS include its dependence on the sonographer's skill and potential challenges in detecting stenosis and measuring flow due to anatomical abnormalities in the neck region.[14] In addition, the study's power is diminished by the fact that only thirty-one individuals with spinal stenosis had a severity level of over 50%.

4. Conclusion

Performing Doppler ultrasonography under the supervision of a skilled sonographer can be a suitable initial screening method. However, verifying that Doppler ultrasound findings indicate a 50-69% narrowing of the internal carotid artery (ICA) with other diagnostic techniques is recommended before making a definitive treatment choice.

Disclosure

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Authorship

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