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Original Article

Diagnostic Accuracy of Duplex Ultrasonography Versus Computed Tomographic Angiography in the Detection of Significant Carotid Artery Atherosclerosis

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ABSTRACT

Objective: To determine the diagnostic accuracy Duplex of Ultrasonography in detecting clinically significant carotid atherosclerosis by keeping Computed Tomographic Angiography as a gold standard.

Study Design: Cross-Sectional study

Place and Duration of Study: Armed Forces Institute of Radiology and Imaging Rawalpindi Pakistan, from Jun to Nov 2019.

Methodology: All patients referred with neurological symptoms during the study were included. Duplex (Doppler) ultrasound and Computed Tomographic Angiography of bilateral carotid arteries were performed on all these patients. The percentage of carotid stenosis was calculated for both modalities. Data was recorded separately for both right and left carotid arteries.

Results: Out of 170 carotid arteries in 85 patients, Duplex ultrasound supported the diagnosis of clinically significant carotid atherosclerosis in 89 arteries (52.3%), and CTA confirmed it in 86 arteries (50.5%). Overall, the sensitivity, specificity, positive predictive value, negative predictive value and diagnostic accuracy of Duplex ultrasonography in the detection of clinically significant carotid atherosclerosis by taking computed tomographic angiography (CTA) as a gold standard was 92.0%, 89.0%, 89.8%, 92.5% and 91.1% respectively

Conclusion: Duplex ultrasonography is an accurate, non-invasive imaging investigation for detecting carotid atherosclerosis.

Keywords: Carotid atherosclerosis, Computed tomographic angiography (CTA), Duplex ultrasonography (USG), Carotid artery diseases, Atherosclerosis plaque.

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INTRODUCTION

Atherosclerosis-related cerebrovascular (CV) events are the most common etiologies of mortality and long-term morbidity globally.[1] According to the American Heart Association (AHA), stroke was found to be the second most common cause of global deaths (estimated as 6.5 million deaths worldwide) in 2013.[2] Pakistan also bears a significant burden of this disease, resulting in an exponential drain on financial resources, workforce, medical services and the overall economy.[3,4]

Stroke is classified depending upon its aetiology into either ischemic stroke or hemorrhagic stroke. Carotid artery atherosclerosis is an important and potentially preventable risk factor for ischemic stroke, the risk of stroke being proportional to the extent and severity of atherosclerosis.[5]

Early diagnosis and prompt management of carotid atherosclerosis can significantly reduce the risk of future ischemic cerebrovascular events.[6] The treatment options vary according to stenosis severity and include medical therapy, endovascular repair, or surgical reconstruction. Patients with less than 50% carotid stenosis are usually managed by medical therapy or by serial follow-up examinations.[7]

Carotid duplex ultrasound (USG) is a widely available, non-invasive diagnostic modality for evaluating carotid atherosclerosis and plays a central role in patient management and clinical decision-making.[8] Computed tomographic angiography (CTA) is based on spiral CT with an injection of an intravenous contrast agent. The main advantage of CTA is that it assesses extra-cranial and intracranial segments of carotid arteries and is also used prior to surgical intervention (endarterectomy).[9] The main disadvantages of CTA are the use of iodinated contrast media intravenously and the radiation hazards. Therefore, deranged renal function is a relative contraindication to CT angiography.[10]

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We found limited literature in Pakistan on the diagnostic accuracy of carotid Duplex ultrasound. Our study aimed to investigate the diagnostic accuracy of duplex USG as an imaging tool for extra-cranial carotid atherosclerosis and evaluate its suitability as a screening test.

METHODOLOGY

The cross-sectional study was conducted from June to November 2019 at the Armed Forces Institute of Radiology & Imaging (AFIRI) Rawalpindi after Hospital Ethical Committee approval (IERB Approval Certificate No: 06). The sample size was calculated with the expected sensitivity of 89%, expected specificity of 84%, significance level of 5%.[11] A total of 85 patients (i.e.,170 carotid arteries) were selected through a non-probability consecutive sampling technique, and data was recorded separately for right and left carotid arteries.

Inclusion Criteria: Patients referred to the Radiology Department with neurological symptoms such as instability and dizziness or those who had an ipsilateral ischemic cerebrovascular event (stroke or transient ischemic attack) within the last six months, were included.

Exclusion Criteria: Patients with a history of allergy or contraindications to IV contrast agents, pregnant patients and patients with carotid tumours, aneurysms and pseudo-aneurysms were excluded.

The patients' baseline demographic characteristics, information about pre-existing medical disorders, such as hypertension and diabetes mellitus, were recorded. The linear array transducer performed a Doppler ultrasound examination using the Toshiba (XARIO) system. The entire extra-cranial section of the carotid arteries was analyzed. End-diastolic velocities (EDVs) and peak systolic velocities (PSVs) were measured in these vessels. When an area of stenosis was present, the maximum velocities at the narrowed segment were recorded.

The quantification of carotid stenosis was done using the criteria given by the Society of Radiologists in Ultrasound (SRU) consensus,[12] according to which clinically significant carotid stenosis was defined as a percentage of carotid stenosis greater than 50%.[13]

Computed tomographic angiography (CTA) was carried out using 64-slice computed tomography equipment after administration of an intravenous contrast agent at the rate of 4.5ml/sec. Percentage carotid stenosis was calculated by using the North American Symptomatic Carotid Endarterectomy Trial (NASCET) criteria using the formula (Figure):% carotid stenosis =(1-[narrowest ICA diameter at the site of stenosis/diameter of normal distal ICA]) x 100.14.

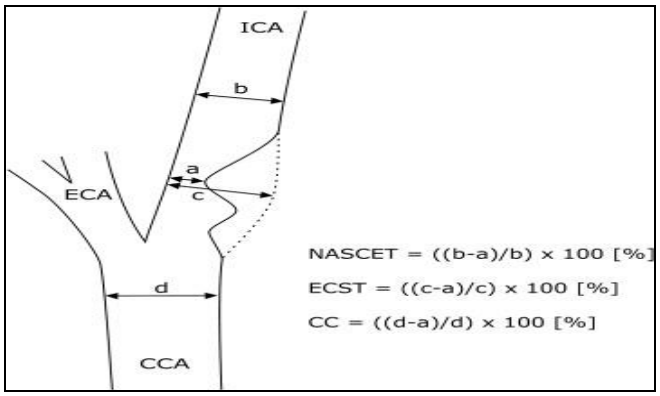

Figure: Method of Measurement of Severity of Carotid Stenosis: The North American Symptomatic Carotid Endarterectomy Trial (NASCET)

The data of carotid Doppler USG and the CT angiography findings (positive/negative) were recorded separately for the right and left carotid arteries on specially designed proforma.

Statistical Package for Social Sciences (SPSS) version 25.0 was used for the data analysis. Quantitative variables were expressed as Mean±SD and qualitative variables were expressed as frequency and percentages. Diagnostic parameters were calculated using a 2x2 contingency table. Sensitivity, specificity, positive predictive value, negative predictive value and diagnostic accuracy were determined by using the standard formulae.

RESULTS

Among the total 85 patients (170 carotid arteries), there were 48(56.4%) males and 37(43.5%) females, with a mean age of 58±10 years. 56(65.8%) patients were hypertensive, and 49(57.6%) patients were known to have diabetes mellitus.

Out of 170 carotid arteries studies, Duplex ultrasonography supported the diagnosis of clinically significant carotid atherosclerosis in 89 arteries (52.3%). CT angiography confirmed clinically significant carotid atherosclerosis in 86 arteries (50.5%). In Duplex ultrasonography positive cases, 80(47.05%) were true positive, and 09(5.29%) were false positive. While in Duplex ultrasonography negative cases, 75(44.11%) were true negative, and 06(3.52%) were false negative (Table-I).

Table-I: Accuracy of Duplex Ultrasound in Detection of Clinically Significant Carotid Atherosclerosis (n=170 Carotid Arteries)

	Significant (> 50%) Carotid Stenosis			
		Positive on Duplex USG	Negative on Duplex USG	*p*-value
Significant(> 50%)Carotid Stenosis	Positive on CTA	80(47.05%)	06(3.52%)	<0.001
	Negative on CTA	9 (5.29%)	75(44.11%)	

Overall, the sensitivity, specificity, positive predictive value, negative predictive value and diagnostic accuracy of Duplex ultrasonography in the detection of clinically significant carotid atherosclerosis by taking computed tomographic angiography (CTA) as a gold standard was 92.0%, 89.0%, 89.8%, 92.5% and 91.1% respectively (Table-II).

Table-II: Diagnostic Accuracy Parameters of Duplex Ultrasonography (n=170 Carotid Arteries)

Diagnostic accuracy Parameters	Duplex Ultrasound
Sensitivity	92.0%
Specificity	89.0%
Positive Predictive Value (PPV)	89.8%
Negative Predictive Value (NPV)	92.5%
Accuracy	91.1%

DISCUSSION

Carotid artery atherosclerosis (AS) strongly predicts ischemic cerebrovascular events. It is, therefore, important to diagnose and treat carotid atherosclerosis at an earlier stage to reduce stroke-related mortality and morbidity.[14]

Atherosclerosis could affect any segment of the carotid arteries with a predilection at the point where it bifurcates into internal and external carotid arteries. Diagnostic imaging has a pivotal role in managing patients with carotid atherosclerosis. With the advent of Doppler ultrasound in the 1980s, it became possible to diagnose atheromatous plaques at the carotid bifurcation by non-invasive means. While conventional angiography is the "gold standard" for determining the extent of carotid artery disease, it is an invasive investi-gation. It is associated with a 0.3-1% risk of peri-procedural complications, e.g. thromboembolic phenomenon.[15]

Similarly, CT angiography risks radiation exposure and contrast media reactions. Carotid Doppler ultrasound is an accurate, cost-effective imaging modality with no radiation hazard. This has resulted in its widespread use for initial screening of asymptomatic patients having neck bruits (or having risk factors for atherosclerosis) and in symptomatic patients for clinically significant carotid artery disease detection.[16] Early screening of high-risk patients is of paramount importance because detection and management of pre-clinical carotid atherosclerosis can help in the prevention of future ischemic stroke and its complications. Similarly, identification and stratifi-cation of the degree of stenosis in already symptomatic patients can help in the selection of the appropriate treatment modality (whether medical or surgical) to decrease the incidence of recurrent stroke.[17] Hence, carotid duplex ultrasound may also predict the clinical outcome of patients having carotid artery disease and risk of recurrent strokes. A study carried out in Pakistan showed that the frequency of carotid stenosis in ischemic stroke patients was 56%.[18] Rojoa *et al*. performed a meta-analysis to determine the diagnostic accuracy of Duplex USG for extra-cranial carotid atherosclerosis. They concluded that the pooled estimates for sensitivity and specificity of Doppler ultrasound were 0.97 and 0.99, respectively.[19] A systematic review was carried out by Forjoe *et al*. comparing pre-operative carotid duplex ultrasound with CT angiography and concluded that the sensitivity and specificity of Doppler ultrasound were 92.3% and 89%, respectively, which is similar to the results of our study.[9] Adla *et al*. reported that the sensitivity and specificity of carotid Duplex ultrasound for clinically significant carotid stenosis are 0.89 and 0.84, respectively.[12]

The general approach in patients with suspected carotid stenosis is first to perform a Doppler ultrasound. Patients having clinically non-significant stenosis (i.e., <50% stenosis) are managed by medical therapy and serial follow-up ultrasounds to determine the progression of stenosis. Patients with clinically significant carotid stenosis (i.e., ≥50%), particularly those with ≥70% stenosis, can further be evaluated by CT angiography prior to surgical intervention (carotid endarterectomy/stenting).

LIMITATION OF STUDY

This study included the luminal diameter of carotid arteries. Our study did not include the composition and morphology of atherosclerotic plaques, which may be evaluated in future studies.

CONCLUSION

This study concluded that Duplex ultrasonography performed by an experienced radiologist could accurately predict the extent of carotid stenosis. It can be performed routinely to screen carotid artery disease in high-risk patients

to determine appropriate treatment modality and for long-term follow-up. CT angiography can be employed in ambiguous cases or in patients being planned for surgical revascularization to provide the complete pre-operative vascular road map. Moreover, being non-ionizing and widely available, carotid Duplex ultrasound can also be used in patients with contraindications to CTA and in settings where CTA is unavailable.

Conflict of Interest: None.

Authors' Contribution

Following authors have made substantial contributions to the manuscript as under:

IA & MN: Conception, study design, drafting the manuscript, approval of the final version to be published.

IM & S: Data acquisition, data analysis, data interpretation, critical review, approval of the final version to be published.

Authors agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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