Original Article

Duplex Sonographic Protocol for establishment of reference luminal diameters and intima-media thickness of Carotid Arteries in a West African Population

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ABSTRACT

Duplex sonography is the primary imaging modality for carotid artery disease, but its accuracy depends on a standardized protocol and population-specific reference values, which are lacking for West Africa. We describe a detailed sonographic protocol applied to a cohort of 104 healthy Nigerian adults. Using a 7.0 MHz linear transducer, the luminal diameters of the common, internal, and external carotid arteries were measured in end-diastole, 1 cm from the bifurcation. The study presents a step-by-step imaging protocol that is feasible in a resource-limited setting. The resulting reference ranges for carotid luminal diameters are: Common Carotid Artery: 0.45-0.76 cm, Internal Carotid Artery: 0.44-0.75 cm, and External Carotid Artery: 0.30-0.67 cm. These values were consistent across sexes and sides. We provide a standardized, reproducible duplex sonography protocol and the first set of normative reference values for carotid luminal diameters in a West African population. This resource will aid sonographers and clinicians in improving the accuracy and reliability of carotid ultrasound examinations in the region.

Keywords: Duplex scan protocol, Carotid artery, Luminal diameter, Intima-media thickness, West African population

INTRODUCTION

Carotid duplex ultrasonography is a cornerstone in the diagnosis and management of cerebrovascular disease. Its diagnostic power, however, is highly dependent on the use of a standardized imaging protocol and the availability of appropriate reference values for comparison.[1,2] Its use serves as an invaluable adjunct to current tools for assessment of cerebrovascular risk in asymptomatic patients.[3] Furthermore, Duplex ultrasound scan is an ideal tool for evaluating the carotid arteries with focus on prevention of cerebrovascular diseases, which is the best form of treatment. Importantly, beyond measurement of luminal stenosis, carotid sonography may be utilized for risk assessment of ischaemic stroke and hence the need for reference values.[4] Several radiological methods have been used to study the carotid artery. Using any method, the clinician is able to see a picture of the status of the vessel of interest of his/her patient depending on the indication and interest.[5] Modalities like magnetic resonance angiography (MRA) are very reliable non-invasive and cost-effective method to assess and monitor carotid artery in comparison to ultrasonography when dealing with arterial stenosis.[6–8] In addition, computed tomographic angiography (CTA) has been reported as the most used for the evaluation of arterial stenosis, as it portrays the whole vascular tree of interest.[9] However, ultrasonography gives better measurement of pulse wave velocity, intima-media thickness and real-time assessment of luminal diameter. Ultrasonography is the gold standard for assessing arterial wall stiffness and can be used to predict risk of cardiovascular events and prognosticate cerebrovascular disease alongside intima-media thickness (IMT) and luminal diameter in patients.[10–12] Among clinicians, ultrasound of carotid artery has gained wide and popular recognition as a result of its affordability, accessibility, and reliability in clinical practice.[13] Medical ultrasound technology utilizes the sonographic power of a machine and acoustic features of organs of the body acquired through a transducer to produce an image on a screen.[14]

Numerous guidelines exist from bodies like the American Institute of Ultrasound in Medicine (AIUM), the Japan Society of Ultrasonics in Medicine (JSUM), the German Society of Ultrasound in Medicine (DEGUM) criteria, the Society of Radiologists in Ultrasound (SRU) criteria, the Joint recommendations for reporting carotid ultrasound

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investigations in the United Kingdom, Standards of the Polish Ultrasound Society but these are based on data from Western and Asian populations.[2,4] For example, the "American Institute of Ultrasound in Medicine" recommends a real-time scanning machine that has Doppler capability with a linear transducer. They recommend that the machine should have imaging frequency of 5.0 MHz or greater but frequency of 3.0 MHz or greater for doppler flow analysis of the artery.[1] Whereas the Japan Society of Ultrasonics in Medicine (JSUM) recommends the use of frequencies of 7.0 MHz or higher if the accuracy of measurement for the intima-media complex (IMC) is also considered alongside diameter. In addition, the Japanese recommend a convex probe or a sector probe with the center frequency of about 5 MHz for deeply located arteries.[2]

Anatomical and anthropometric differences across ethnic groups necessitate the validation of such protocols and the establishment of local normative data.[15] In West Africa, a standardized protocol and reference values are absent, leading to diagnostic uncertainty. This paper aims to detail a feasible duplex sonography protocol to enable different groups in West Africa establish reference ranges for carotid luminal diameters in their populations. The intent of this paper is not to review all known protocols but to explain in detail the chosen protocol and how it produces best outcome in our environment.

MATERIALS AND METHODS

Study design and population: This was a population (non-hospital) based study conducted in Bayelsa state, southern part of Nigeria in 2020. Study was a prospective observation of healthy adult Nigerians without any known cardiovascular, cerebrovascular or metabolic disease between the ages of 18 and 64. All enrollees were recruited after an informed consent and study followed all guidelines of the Helsinki declaration[16] and received approval of the Research Ethics Committee of the University of Port Harcourt with approval number UPH/CEREMAD/REC/MM71/003.

Sample Size and Sampling Technique: The sampling technique used was a simple random sampling for clinical studies with consideration for male and female gender to give adequate cover of sampling.[17]

The sample size was derived from the formula applied by the University of Boston School of Public Health:[18]

$$n = \left(\frac{Z\sigma}{E}\right)^2$$

where, n = minimum sample size, Z = (1.96) critical value of statistical significance for probability with confidence interval at 95%, σ = (1.19) standard deviation from a previous study in the same population zone.[19] E = (0.25) the desired margin of error from a clinical or practical standpoint.[18] $n = (1.96 \times 1.19 / 0.25)^2$, n = 86.88. To cover for attrition, 10% (0.1) of the sample size was added. Then, n= 95.58. However, to give adequate representation of all sampled age groups in both sexes and in comparison, with similar studies and for the purpose of making correct inferences, our sample size was increased to 104. With both sides of neck scanned, the total scans were 208, which was deemed to be adequate for sampling for this clinical study.

Protocol Development: The protocol was synthesized from international guidelines[1,2,4,20] and adapted for local feasibility. Following the recommendation of two bodies (the Japan Society of Ultrasonics in Medicine and the American Society of Echocardiography), measurements of diameter are made on two-dimensional (2D) ultrasound images in end-diastolic phase. The diameter is basically obtained as the distance between one intimal layer and its opposite intimal layer or between the adventitia (pseudo layer) and the opposite adventitia (pseudo layer) of the vessel.[2,21]

Subject Preparation: Participants were placed in a supine position with a pillow under the shoulders to slightly extend the neck. The head was rotated 45 degrees away from the side being examined. The examining radiologist sits by the side facing the participant and the machine.

Equipment and Settings: A portable EcoMed VERTU-3 USG machine with a high-frequency (7.0 MHz) linear array transducer was used. The machine was set to a vascular preset with B-mode and colour Doppler capabilities.

Scanning Procedure:

1. The transducer was placed perpendicular to both vessel walls visualizing them to assess the vessel in the longitudinal plane at an angle of insonation about 30^0. Measurements were only taken when both walls are distinctive.
2. The common carotid artery (CCA) was identified and followed proximally and distally.
3. The carotid bulb and the bifurcation into the internal (ICA) and external (ECA) carotid arteries were then visualized.
4. Measurement Points: Luminal diameter was measured in the end-diastolic phase (peak of the R-wave on ECG, if available, or the smallest diameter in the cardiac cycle) from the intima-lumen interface of the near wall to the lumen-intima interface of the far wall.
   - CCA: 1 cm proximal to the bulb.
   - ICA: 1 cm distal to the flow divider.
   - ECA: 1 cm distal to the flow divider.
5. Measurements were taken bilaterally.

Safety: The ALARA (As Low As Reasonably Achievable) principle was adhered to throughout.[22]

RESULTS

The protocol was successfully implemented in all 104 participants. The common carotid artery was differentiated from the internal jugular vein by its depth (deeper in location), compressibility (non-compressible), pulsation (pulsatile) and doppler waveform (high velocity and pulsatile waveform). And the internal carotid artery was identified as the deeper branch after the carotid bulb towards the mastoid process, while the external carotid artery traced towards the face as the superficial branch. A notable finding was the lack of significant difference between sexes or sides, allowing for simplified clinical application. The key reference ranges for the total population were:

- Common Carotid Artery (CCA): diameter = 4.5 – 7.6 mm; IMT = 0.20–0.75 mm
- Internal Carotid Artery (ICA): diameter = 4.4 – 7.5 mm; IMT = 0.20–0.75 mm
- External Carotid Artery (ECA): diameter = 3.0 – 6.7 mm; IMT = 0.18–0.78 mm


Figure 1: Carotid duplex scan showing both walls

DISCUSSION

This paper provides a crucial technical resource for sonographers and physicians in West Africa. There are several sonographic protocols for carotid artery assessment and none is without critique in our literature review. The protocols differ either in scanning procedure or reporting criteria. So, choosing the one that best applies to a certain population should not be left to individual examiners alone but also based on provable validation of such protocol among healthy individuals in that population in our opinion.[4] It has been noted that despite the ease with access and cost to doing it, inexperienced examiners may have challenges with performing the procedure that would be reproducible, if standardized protocols are not strictly adhered to.[23] Our protocol was adapted from the American and Japanese groups as neither of the groups indicated superiority of outcome as they focused on vessel stenosis and atherosclerotic plague identification. The described protocol is deliberately detailed to ensure reproducibility, which is vital for reducing inter-observer variability.

In terms of procedure, both the AIUM and JSUM emphasize use of doppler spectrum analysis and colour imaging to rule out abnormalities, whereas the JIUM further provides modifications as necessary option the AIUM is specific on angulation (<60^0), frequency of probe (5MHz) and location of CCA measurement (2-3 cm proximal to the bifurcation).[1,2] Encountering pathologies like luminal stenosis or atherosclerotic plagues while assessing the carotids or measuring their diameters require choosing a classification method out of the different types and require velocity measurements and waveforms and flow direction depending on the guideline. The resulting normative data, derived from these standardized measurements have been previously presented.[24,25] The provided reference ranges of luminal diameter and intima-media thickness are the first of their kind for the region and offer a definitive benchmark against which pathological states like stenosis (>50% reduction in diameter) or aneurysm (>150% of expected diameter) and stroke risks can be diagnosed.[23]

The finding that a single set of values can be used for both sexes and sides simplifies clinical use.[24] We encourage the adoption of this protocol in regional training programs and clinical practice to standardize carotid imaging and improve patient care outcomes.

CONCLUSION

We have detailed a standardized protocol for carotid duplex sonography and provided population-specific reference values for luminal diameters in a West African population. This work fills a critical gap in vascular imaging resources for the region and is expected to enhance the diagnostic accuracy and clinical utility of carotid ultrasound.

RECOMMENDATIONS

We recommend that a unified protocol as described above be adopted in our region for uniformity of reporting carotid artery morphometry. In addition, we also recommend that the above normative ranges of luminal diameter and intima-media thickness reported above be used as references for making pathological assessment or making diagnosis.

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