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VARIABILITY OF COMMON CAROTID INTIMA-MEDIA THICKNESS MEASURED USING B-MODE AND M-MODE ULTRASOUND IMAGING

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ABSTRACT

Background: The thickness of the intima-media in the common carotid artery (cIMT) has been associated with cardiovascular diseases such as coronary heart disease and stroke. Limited studies addressed the variability of ultrasound imaging modes in measuring cIMT. Therefore, this study aimed to assess the agreement-level and inter-observer reproducibility of cIMT measurements using B-mode and M-mode.

Materials and Methods: The two ultrasound imaging modes (i.e. B-mode and M-mode) were used in measuring cIMT of healthy subjects using a linear-array transducer. Intraclass correlation coefficient (ICC) was used to evaluate Inter-imaging mode agreement and inter-observer reproducibility. Paired t-tests were used to identify differences in cIMT measurements between observers and imaging modes.

Results: Significant difference in cIMT between B-mode and M-mode (mean difference (MD), 0.03 mm, 95% CI 0.02 - 0.05, p<0.001). Intra-imaging mode agreement was poor with an ICC of 0.39. Inter-observer reproducibility of cIMT measured using B-mode and M-mode were good and moderate, respectively, (B-mode ICC of 0.76, 95% CI 0.64 - 0.84, p<0.01; M-mode ICC of 0.68, 95% CI 0.52 - 0.78, p<0.01). No significant difference between the two observers in measuring cIMT using B-mode (p=0.3) or M-mode (p=0.4).

Conclusion: Measuring cIMT using different ultrasound modes could be a source of variability. Further studies investigating the variability and agreement between ultrasound imaging modes of patients with thickened cIMT are required.

Keywords: cIMT, ultrasound, B-mode, M-mode

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1. INTRODUCTION

Cardiovascular diseases are the primary cause of both mortality and disability worldwide [1]. Atherosclerotic plaques in arteries are a major cause of cardiovascular diseases [2]. The thickness of the intima-media in the common carotid artery (cIMT), the measurement from the boundary of the lumen-intima to the media-adventitia interface, is a well-described surrogate marker for subclinical atherosclerosis [3]. Increased thickness of cIMT has been associated with cardiovascular diseases [4].

Ultrasound is widely used in detecting the early stage of atherosclerotic disease for being safe and non-expensive with the ability to measure and characterize changes in the arterial wall structure in real-time [5, 6]. It is a useful, and repeatable imaging tool for the assessment of cIMT which can be distinguished from the surrounding tissue [7]. A recent study done by [8] assessed the accuracy of cIMT measured using B-mode in patients with coronary artery disease and reported that B-mode provided precise measurements of cIMT [8]. Although B-mode is a common imaging method for measuring cIMT, M-mode ultrasound imaging can also be used and is easy to operate [9].

The use of different ultrasound imaging modes in measuring cIMT may be a source of variability leading to inconsistent findings that are unrepeatable and incomparable. A study comparing cIMT measured with B-mode and M-mode using image-analysis software of a pre-specified segment showed acceptable agreement with no remarkable difference between the two ultrasound imaging methods [10]. However, a single cIMT measurement is usually performed manually using ultrasound machine electronic calipers in a practical sitting. Therefore, this study aimed to assess the agreement-level and inter-observer reproducibility of a manual cIMT measurement using B-mode and M-mode.

2. METHODS

2.1 Study design

The pilot study was carried out in compliance with the Declaration of Helsinki and authorized by the Biomedical Ethics Research Committee at the Faculty of Medicine at King Abdulaziz University. Written consent was obtained from all the participants, who were enrolled from September to November 2021.

2.2 Participant

For this study, young healthy subjects with no underlying medical conditions and not on regular medications were included.

2.3 cIMT measurements

Ultrasound imaging of the cIMT was approached with the subject in a supine position using a high-frequency linear transducer (9-4 MHz) of Philips HD3 ultrasound imaging system. After locating the CCA in longitudinal view in B-mode, the ultrasound image was optimized for high image resolution to visualize cIMT (Figure 1A). Images of CCA from each subject were acquired bilaterally at end-diastolic. After that, using the exact machine settings, images of CCA were obtained in M-mode (Figure 1B). All images performed using the two modes (i.e. B-mode and M-mode) were stored for off-line analysis, and cIMT of the far wall was measured 1-2 cm proximal to the carotid bulb [11] following calibration for depth using ImageJ software by two operators in different days.

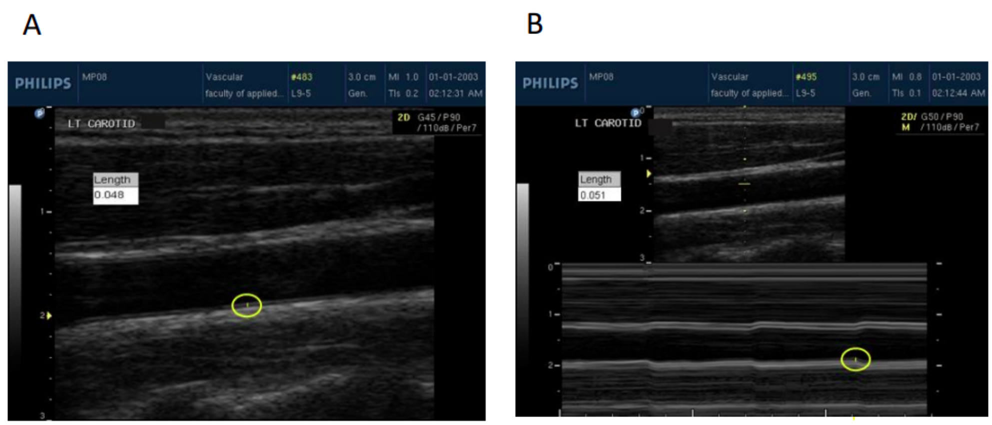

Figure 1 Common carotid arteryintima-media thickness was obtained in B-mode (A) and M-mode (B) using a linear-array transducer.

2.4 Study assessment

Each participant attended an ultrasound assessment room at the Department of Radiologic Sciences, Faculty of Applied Medical Sciences, King Abdulaziz University. Subjects were screened for eligibility and provided written informed consent. Then, height and weight were measured and participants were asked to be seated for 15 minutes for pre-blood pressure and heart rate measurements using a microlife blood pressure monitor. After that, cIMT was measured by placing the participant in supine and slightly elevate their neck.

2.5 Statistical analysis

Intraclass correlation coefficient (ICC) and Bland-Altman plot were used for assessing inter-imaging modes and inter-observer reproducibility and limit of agreement in cIMT measurements using B- and M-modes [12, 13]. Paired t-test was used to compare cIMT measurements in both imaging modes, and between observers. IBM SPSS and GraphPad PRISM 7 were used for statistical analysis.

3. RESULTS

A total of 200 cIMT images were obtained bilaterally (B-mode, n=100, M-mode, n=100) from fifty young healthy subjects (25 were males). The age, weight, height, BMI, blood pressure, and heart rate were: 21.04±1.79 years, 65.15.1±18.56 kg, 1.65±0.1 m, 23.58±5.37, SBP 127.14±11.49 mmHg, DBP 80.96±9.65 mmHg and 84.8±19 pbm, respectively.

3.1 Inter-imaging mode agreement in measuring cIMT

Inter-imaging mode agreement in measuring cIMT (total number (n)=200, n=100 per imaging mode) was poor between B-mode and M-mode with ICC values of 0.39 (95% confidence interval (CI) 0.09 – 0.59, p=0.007, Figure 2A). The bias in measurements was 0.03±0.07 mm (limit of agreement (LoA) -0.1 – 0.17, Figure 2B). There was a significant difference between B-mode and M-mode in measuring cIMT (mean difference (MD), 0.03 mm, 95% CI 0.02 - 0.05, p<0.001, Figure 3).

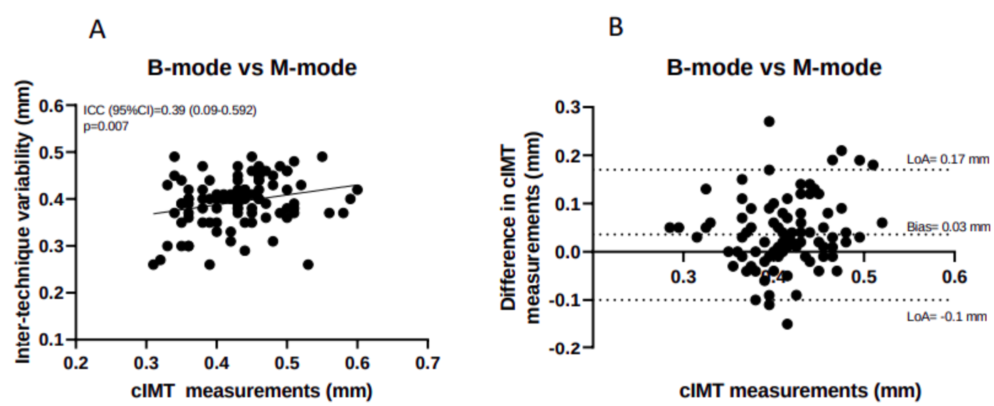

Figure 2 Inter-technique and Bland-Altman agreement for cIMT measurements. Intraclass correlation and linear regression of cIMT measurements using B-mode and M-mode (A). Bland-Altman assessment of cIMT measurements between B-mode and M-mode (B) (total number of cIMT measurements (n)=200; n=100 per technique). ICC: Intraclass correlation; CI: confidence interval; LOA = limit of agreement.

3.2 Inter-observer reproducibility of cIMT

Inter-observer reproducibility of cIMT measured using B-mode (cIMT n=100 per operator) was good with an ICC of 0.76 (95% CI 0.64 - 0.84, p<0.01, Figure 4A). The bias in mea-

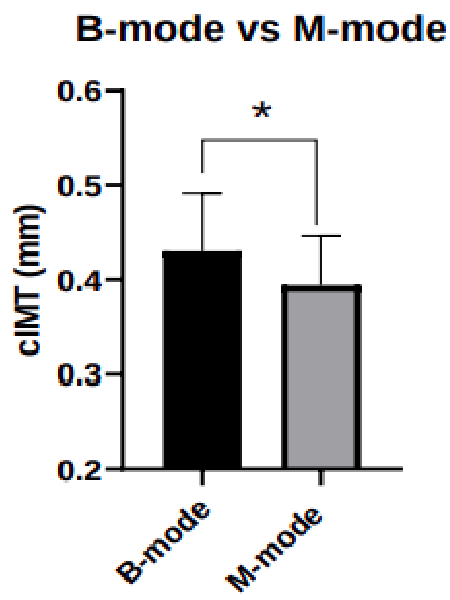

Figure 3 Comparison between cIMT measured using B-mode and M-mode. There were significant differences between cIMT measured in B-mode and M-mode (mean difference 0.03 mm, p=0.007). Mean, SD (* $p<0.05$ using Paired t-test between cIMT measurements, the total number (n)= 200, n per technique= 100).

surements was -0.007±0.04 mm (LoA -0.1–0.08, Figure 4B). Inter-observer reproducibility of cIMT measured using M-mode (cIMT n=100 per operator) was moderate with an ICC of 0.68 (95% CI 0.52 - 0.78, $p<0.01$, Figure 5A). Bias in measurements was -0.006±0.04 mm (LoA -0.09 – 0.08, Figure 5B). There was no significant difference between the two observers in measuring cIMT measured using B-mode or M-mode (B-mode: MD -0.004 mm, 95% CI -0.01 - 0.004, p=0.3; M-mode: MD -0.004 mm, 95% CI -0.01 - 0.005, p=0.4).

4. DISCUSSION

Ultrasound measurement of cIMT is a clinical index for assessing the risk of cardiovascular diseases. Both ultrasound imaging modes (i.e. B-mode and M-mode) can be used for assessing cIMT. Thus, determining the potential presence of variability and reproducibility of imaging modes in measuring cIMT is important. This study aimed to assess the agreement-level and inter-observer reproducibility of a manual cIMT measurement using B-mode and M-mode in a method similar to clinical sitting. There was a significant difference in cIMT between B-mode and M-mode (mean difference of 0.03 mm) with poor intra-imaging mode agreement. Inter-observer reproducibility of cIMT mea-

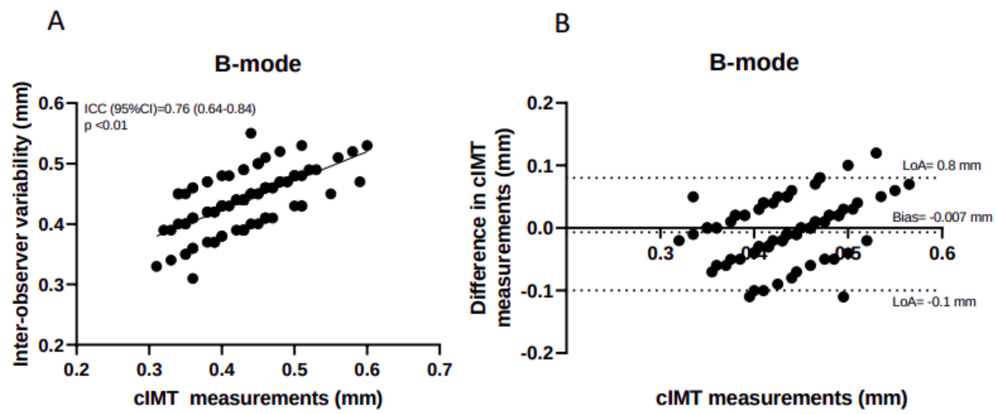

Figure 4 **Inter-observer and Bland-Altman agreement for cIMT measurements.** Intraclass correlation and linear regression of cIMT measurements using B-mode(A). Bland-Altman assessment of cIMT measurements between observers(B) (total number of cIMT measurements (n)= 200; n=100 per observer). ICC: Intraclass correlation; CI: confidence interval; LOA = limit of agreement.

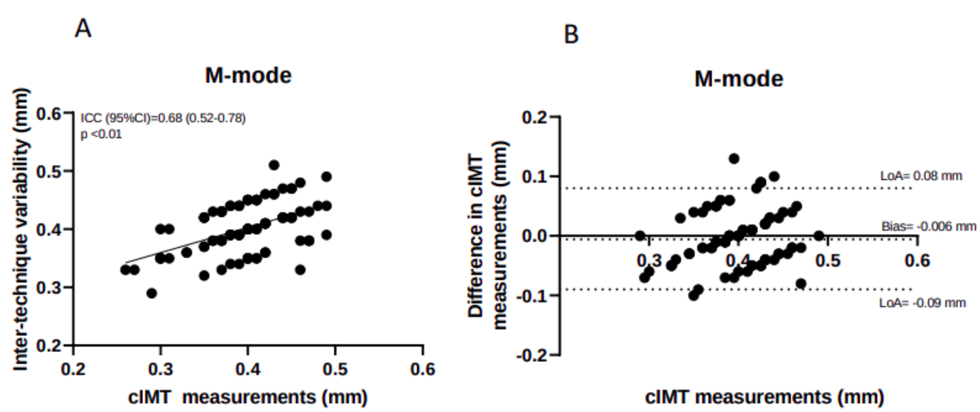

Figure 5 **Inter-observer and Bland-Altman agreement for cIMT measurements.** Intraclass correlation and linear regression of cIMT measurements using M-mode(A). Bland-Altman assessment of cIMT measurements between observers(B) (total number of cIMT measurements (n)=200; n=100 per observer). ICC: Intraclass correlation; CI: confidence interval; LOA = limit of agreement.

surement using B-mode and M-mode was good and moderate, respectively, with no significant difference between observers using the same imaging mode in measuring cIMT. These findings suggest that B-mode is more reliable than M-mode in providing reproducible cIMT measurements and using the same imaging mode when assessing cIMT for a high level of consistency.

Our analysis showed a significant difference in cIMT between B-mode and M-mode with poor intra-imaging mode agreement using a manual electronic caliper. Conversely, a previous study in which image-analysis software reported acceptable agreement between the two imaging modes [10]. This is related to manual vs automated analysis methods. Manual measurement of cIMT could be the source of variability between the two imaging modes and the use of an automated computerized analysis reduces the variability in measuring cIMT and is a preferable method for cIMT assessment [3, 14]. However, it is worth mentioning that in clinical practice a manual measurement of cIMT is usually performed for being faster and more feasible in practice and might be available in centers due to lack of funding. These suggest that the same imaging mode be used when measuring cIMT taking into consideration methods (i.e. manual vs automated) used for analysis.

cIMT reproducibility can be affected by anatomical (e.g. carotid segment used for measurement) and technical factors, including imaging acquisition, interpretation methods, and ultrasound equipment setup, such as overall gaining, time-gain compensation, and depth [3, 15]. It has been reported that the reproducibility of both B-mode and M-mode in measuring cIMT is acceptable [9]. However, we found that B-mode has higher reproducibility when compared to M-mode; this could be related to that cIMT can be identified in a large segment of the common carotid artery in which the best possible site can be chosen for measurements using B-mode imaging, whereas, in M-mode, cIMT can only be assessed on one point in time based on the position of the sample [16] which might not be the best area in term of image resolution for cIMT measurement. In addition, changing the sample position for the best area for cIMT assessment may be a time-consuming process. These factors are to be considered when measuring cIMT using an ultrasound imaging system.

Limitations to consider in the present study include that cIMT was assessed in healthy subjects and that reproducibility of cIMT measurements using ultrasound imaging modes may be affected in patients with thickened carotid intima-media layer. A single cIMT measurement was considered for analysis. Further studies investigating the variability and agreement between ultrasound imaging modes of patients with thickened cIMT and using the average of multiple cIMT measurements at different carotid segments for analysis are required.

5. CONCLUSION

There was a significant difference and poor intra-imaging mode agreement between B-mode and M-mode in measuring cIMT. B-mode showed higher inter-observer reproducibility of cIMT measurement than M-mode. These findings suggest that B-mode is more reliable than M-mode in providing reproducible cIMT measurements and using the same imaging mode when assessing cIMT for a high level of consistency. Further studies investigating the variability and agreement between ultrasound imaging modes of patients with thickened cIMT are required.

CONFLICT OF INTEREST

All authors declare no conflict of interest.

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Non

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