

Automated measurement of intima-media thickness of carotid arteries in ultrasonography by computer software

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PURPOSE

Intima-media thickness (IMT) has been proposed to be a morphological criterion of atherosclerosis. The purpose of this study was to investigate the interobserver variability of manual and also of computer software measurements of IMT.

MATERIALS AND METHODS

High-resolution common carotid artery (CCA) images of 88 patients that have been obtained by a linear broadband L5-12 MHz transducer and archived in PACS were retrospectively evaluated. Two separate investigators, who were unaware of the former results, evaluated the same images by using computer software that had a dedicated tool for automatic measurement of IMT. The results of the investigators were compared.

RESULTS

According to the two investigators who have performed manual measurements, mean values of IMT of right CCA were 0.6396 mm and 0.6356 mm; of the left CCA were 0.6662 mm and 0.6575 mm, respectively. The interobserver variability of measurements revealed the mean IMT as 0.6071 mm and 0.6048 mm for the right, 0.6216 mm and 0.6227 mm for the left CCA. Manual measurements of both investigators were found to be higher than the automatic measurements and the differences were statistically significant. Interobserver correlation of manual measurements was between 0.80-0.88 and of the automated measurements was between 0.93-0.98.

CONCLUSION

Manual measurements reveal higher values than the automated measurements of IMT. The interobserver correlation of automated measurements is higher than manual measurements. The use of dedicated software may be proposed to reduce the measurement errors.

Key words: carotid artery, common • ultrasonography • arteriosclerosis

B-mode ultrasonography is a diagnostic method which allows measurement of intima-media thickness (IMT) at the level of the carotid artery and femoral artery. The relationship between the common carotid artery (CCA) IMT and coronary artery disease, the changes in the IMT after drug therapy and its relation with heart attack and sudden death risk, the association between the IMT and systemic diseases mainly diabetes mellitus, hypercholesterolemia and hypertension all had been investigated by many researchers (1-6). As pointed out by the collected data to date, measurement of IMT by ultrasonography has become a morphological criterion for the detection of atherosclerosis.

Manual measurement methods are generally used to measure the IMT values sonographically but results show variations secondary to subjective parameters when manual measurement methods are employed (7). Additionally studies have demonstrated that CCA IMT values may show interobserver variability in repeated measurements (8, 9). To decrease the interobserver variability during the IMT measurements computer software programs were developed which allow automated measurements.

The aim of this study is to determine whether a correlation exists between the manual and computer assisted IMT measurements of CCA.

Materials and methods

A total of 88 patients were included the study which consisted of 39 males and 49 females (mean age, 37.7 years) who were referred for ultrasonographic IMT analysis of the carotid artery. The study was conducted between January 2004 and June 2004 and consisted of selected cases from the archives in which the cases were either part of various studies conducted to measure IMT thickness in situations where IMT thickness were expected to increase or were normal cases which formed the control groups of these studies. Ultrasonographic images of the right and the left CCA of each case at the lower 1/3 cervical region proximally and 1 cm above the carotid bulb distally in longitudinal plane were obtained digitally and archived in the PACS system utilizing a sonography device with a high definition L12-5 linear wide band probe (Philips HDI 5000, Bothell, WA, USA). Care was taken to keep the frequency level and other imaging parameters (general 2D optimization, low persistency) the same in each patient. Archived images were analyzed retrospectively in a blinded fashion by two investigators using a PACS workstation separately. CCA IMT measurements of the proximal and distal CCA posterior wall were done manually by the provided distance measurement system of the sonography device after magnification of the images (Figure 1). The two investigators measuring manually used the grading method from the ARIC (atherosclerosis risk in community) study and three measurements were made in a non-neighboring fashion within an approximately 1 cm

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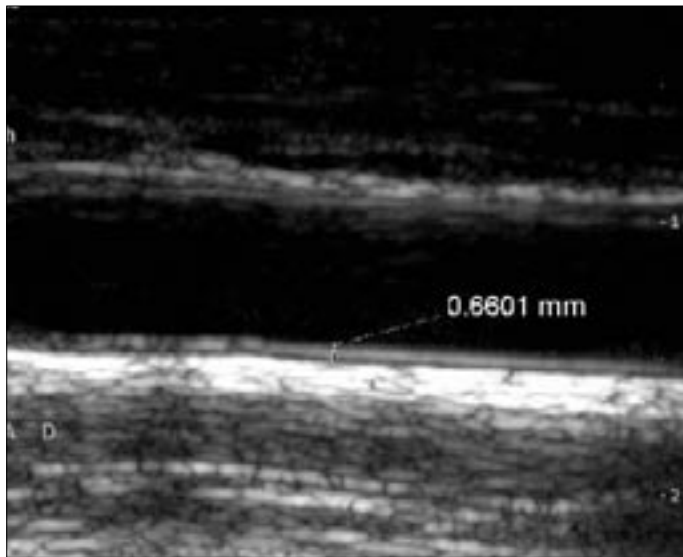


Figure 1. The measurement sample of the left common carotid artery distally on longitudinal plane ultrasonography image in the PACS workstation. The value obtained using the measurement method provided by the system is 0.66 mm.

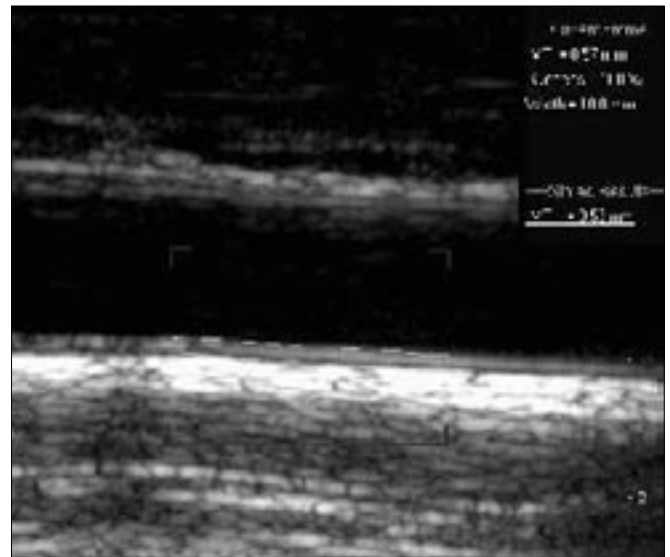


Figure 2. The measurement sample of the same image as in Figure 1 where the intima-media thickness is automatically measured by the computer software program. The value computed by the program is 0.57 mm.

segment both from the left and right CCA proximal and distal portions. IMT values were then calculated by obtaining the arithmetic means of the measured values (10). Later the same images were transferred to a special workstation and IMT values were again analyzed by two different investigators again in a blinded fashion using a computer software program (Q-LAB, ATL-Philips, Bothell, WA, USA) in which IMT measurements were automatically made. The program can differentiate the posterior wall intima and media layers of a 10 cm arterial segment and automatically can measure the thickness and report the mean values of the measured segment (Figure 2). The automated measurements were carried out by placing the region of interest to

the left and right proximal and distal CCA and the values measured by the program were recorded. Both the results of the investigators who used the manual measurements and the results of the other two investigators who used the automated measurements were compared. Paired t-test was used for statistical analysis and p values less than 0.05 were considered significant. Interobserver correlations were evaluated by Pearson correlation coefficient analysis.

Results

The results from the investigators who used manual measurements and the results from the investigators who used automated measurements were presented in the Table. In both groups,

no statistically significant difference was found when results were compared within groups. However, the general mean and the mean values from all segments obtained using the manual system were generally higher than the results from the automated measurements and the difference was statistically significant ($p < 0.05$). The investigators who used the manual system measured 1.3% to 8.7% higher values.

When all measured segments were considered, interobserver correlation was higher in the automated measurements when compared with the manual measurements. Interobserver correlation coefficients (r) among the investigators who used the manual measurement method was changing according to the segment measured

Table. The results of measurements and the rates of differences

| | Manual measurement (mm) | | | Automated measurement (mm) | | | Difference between manual and automated measurements | |
|----------------------|--------------------------|--------------------------|-------------------------------|----------------------------|--------------------------|-------------------------------|--|--------------------------|
| | 1 st observer | 2 nd observer | Interobserver correlation (r) | 1 st observer | 2 nd observer | Interobserver correlation (r) | 1 st observer | 2 nd observer |
| Right CCA proximally | 0.6426 | 0.6311 | 0.83 | 0.5866 | 0.5880 | 0.93 | 8.4%-8.7% | 6.8%-7.0% |
| Left CCA proximally | 0.6478 | 0.6402 | 0.87 | 0.5941 | 0.6017 | 0.95 | 6.2%-8.2% | 6.0%-7.2% |
| Right CCA distally | 0.6365 | 0.6401 | 0.80 | 0.6276 | 0.6216 | 0.98 | 1.3%-2.3% | 1.9%-2.8% |
| Left CCA distally | 0.6847 | 0.6748 | 0.88 | 0.6492 | 0.6436 | 0.98 | 5.1%-6.0% | 3.7-4.6% |
| Right CCA mean | 0.6396 | 0.6356 | 0.87 | 0.6071 | 0.6048 | 0.96 | 5.0%-5.4% | 4.4%-4.8% |
| Left CCA mean | 0.6662 | 0.6575 | 0.81 | 0.6216 | 0.6227 | 0.97 | 6.5%-6.6% | 5.3%-5.4% |

CCA: common carotid artery

There are no statistical differences within the groups but there are statistical differences between the groups by paired t test.

and the lowest was 0.80 and the highest 0.88. In the same related segments the correlation coefficients (r) of the investigators who measured using the automated program was 0.93 the lowest and 0.98 the highest.

Discussion

IMT measurements of the carotid artery are accepted as a criterion of atherosclerosis in many clinical and radiological studies and are widely used in clinical practice (10). According to the epidemiological studies, the normal upper limit of IMT is set at 0.6 mm and an increase of about 0.1 mm or more is associated with a 2- 6 times increase in myocardial infarct and/or cerebrovascular disease incidence (4). If one takes into account that analysis is made about values which are 1/10 of a millimeter, it becomes more clear, how much important the measurement sensitivity is.

Until recently, manual measurement methods have been used in most of the IMT evaluation studies. However, parallel with the technological innovations, computer software assisted automated measurement systems have been developed recently and introduced to clinical use. When the manual method is employed, IMT measurements were done on the screen of the sonography device using the measurement system provided by the device. Such measurements are done during of the sonographic exam and if not supported by a digital archiving system, it is impossible to repeat the measurements retrospectively for recheck. Among the restrictions of the method, the most important are the variability between the investigators (interobserver) and variability between the studies performed by the same investigator at different times (intraobserver). This variability is related to the skill and the knowledge of the sonographer and the interpreter, the method employed for measurement and the biological differences of the cases (tortuous arterial anatomy, eccentrically located atherosclerotic plaque and lumen irregularity) (11). Most of the studies in the literature which analyzed the interobserver variability employed the manual method for measurement of CCA IMT (12). While in some of the studies no significant differences related to interobserver variance were found (12, 13), in some others, possible presence of an

interobserver variability up to 10.6% among investigators were reported in repeated IMT measurements (8, 9). In our study, the limitations related to image acquisition were prevented because the investigators used the same images archived in the PACS for measurement. Therefore it became possible for authors to compare the difference related to measurements only. The reason why no interobserver differences were present within the manual measurement group and within the automatic measurement group may be because the analyses were made using the same images and limitations related to recapture of the images were not observed. In our study, in which the measurement method variant was analyzed only, the interobserver correlation of the investigators who used the automated program was higher than the investigators who used the manual measurements. The two investigators using the manual method measured up to 8.7% higher values when compared with the investigators using the automated program.

The program in the automated measurement method can differentiate the layer interfaces using significant echo intensity differences (maximum gradient) between the layers of the vessel wall. In the manual method, differentiation of the layers is related to perception of the echo interface by the human eye or, in other words, it is dependent on the threshold of echo interface visualization of the eye. This is proposed as the main reason why there are differences between the two methods (7). Another possible explanation is that the point marked is affected by the cursor, the mouse and the hand sensitivity of the sonographer during a manual measurement.

In a study by Lemne et al. reported in 1995, the left CCA IMT values were found higher than the right CCA IMT values regardless of the measurement method and the observers (14). The authors have proposed that this difference is either stemming from possible differences in the atherosclerotic process progression between the right and the left CCA or presence of a significant anatomic difference that might reflect upon the measurements (14). Also in our study both with manual and automated measurements, IMT values in the left CCA distally were higher when compared with the right.

The computer software-assisted automated measurement method, which is being used in many IMT measurement studies recently, is decreasing the error rate related to repeated measurements in long studies and variability between the measurements. Automated IMT measurements are performed on clear sonographic images where the vessel wall layers of the arterial segments are distinctly visible for evaluation. The program measures many parameters such as echo intensity, intensity gradient and contour linearity in the vessel lumen repeatedly many times and calculates a mean IMT value taking all these parameters into consideration (7). In studies where IMT measurements were done using automated method and compared with the results from the manual measurement method, the interobserver variability among the investigators was less in the automated methods (7, 15, 16). Along with studies where maximum IMT values were used, there are also many studies where mean IMT values were taken into account. In a study by Schmidt and Wendelhag where IMT values were evaluated with the axial resolution computation of the sonography device, the error was reported as 0.03 mm if a single maximum measurement was employed; however, if means of 10 point pair measurements were used the error was computed as 0.009 mm (16). Because of this, the generally accepted method of measurement in automated systems is to obtain a mean value from a 1 cm segment. Likewise, in our study the automated measurements were done by calculating the mean values in a 1 cm segment. Manual measurements were carried on as advised by the ARIC in which only three measurements were done in a single area. The less number of sampling is a factor increasing the error rate. Even though performed in accordance with the generally accepted methods of measurement, inequality in the times of repeated measurements is one of the limitations of our study.

When IMT measurements were automatically done in cases where intima-media complex layer showed irregularity in a small segment or in cases where a good quality sonographic image could not be obtained, the program estimated the IMT levels in irregular segments or in segments where continuity of a focal segment in the vessel wall could not be visual-

ized, by taking the IMT values in the adjacent segments to the irregularities or focal discontinuities proximally and distally as a base and calculated IMT by skipping one numeric value. This type of measurement is reported as a limitation since it may result in uncorrect evaluations in daily practice when we consider how frequently we evaluate the middle aged and elderly patients who may have vessel wall irregularities. Because of this, selection of images is of importance especially if the measurements will be carried on automated programs (16). Inclusion of carefully selected ultrasonographic images obtained in the beginning of the exam is important both for the manual and the automated measurement programs.

Automated programs when compared with the manual measurement methods provide measurements which depend on objective criteria, are easy to perform and require less time. The quality of the sonographic images affects the results of the study regardless of the measurement method. Higher values are obtained when manual methods are employed as compared with the automated programs in the carotid artery IMT measurements. The interobserver correlation of automated measurements is higher than manual measurements for these values.

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