ORIGINAL ARTICLE

Diagnostic Accuracy of Carotid Intima-MediaThickness to Detect Coronary Atherosclerosis. Usefulness in Clinical Practice

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ABSTRACT

Background

Carotid intima-media thickness (CIMT) is an independent marker of cardiovascular risk. Coronary artery calcium score (CACS) is better than CIMT to predict coronary artery disease; yet, few patients have access to this evaluation in our country due to its high cost.

Objectives

The aim of this study was: 1) to evaluate the diagnostic accuracy of CIMT to detect CACS > 0. 2) To determine an optimal cut-off point of CIMT to discriminate between the presence and the absence of coronary artery calcium.

Methods

We conducted a cross-sectional descriptive study of consecutive samples obtained in the outpatient clinic of cardiovascular prevention. Mean and maximum CIMT were measured using carotid Doppler ultrasound. Carotid artery atherosclerotic plaque (CAP) was evaluated with a 64-row multidetector computed tomography. The diagnostic accuracy of CIMT to detect CACS > 0 was determined by ROC analysis.

Results

A total of 202 consecutive subjects participating in a primary prevention program were included. Population characteristics were (mean ± standard deviation): age 57 ± 13 years, female gender: 49%, smokers: 13%, statins: 37%, diabetes mellitus: 13%, Framingham risk score in non diabetics: 9% ± 7%, mean CIMT: 0.953 ± 0.342 mm, maximum CIMT: 1.383 ± 0.679 mm, prevalence of carotid artery atherosclerotic plaque: 37% and of CACS > 0: 62%. The correlations between mean and maximum CIMT and CACS were poor (r = 0.393 and r = 0.376, respectively). The area under the ROC curve of maximum CIMT was 0.822 (95% CI 0.763-0.880) and that of mean CIMT was 0.829 (95% CI 0.771-0.888). The optimal cut-off point of maximum CIMT to discriminate between CACS > 0 or CACS = 0 was ≥ 1.01 mm and sensitivity (S), specificity (Sp), positive predictive value (PPV) and negative predictive value (NPV) were 78%, 75%, 83% y 67%, respectively. The optimal cut-off point of mean CIMT to discriminate between CACS > 0 or CACS = 0 was ≥ 0.82 mm and S, Sp, PPV and NPV were 77%, 78%, 85% and 67%, respectively.

Conclusion

In this low-risk population, the diagnostic accuracy of CIMT to detect CACS > 0 was moderate. A "normal" carotid Doppler ultrasound did not exclude the presence of subclinical coronary artery atherosclerosis. These results might improve selection of patients undergoing CACS to stratify cardiovascular risk.

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Key words > Coronary calcium score - Carotid intima-media thickness - Cardiovascular risk

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Abbreviations >

AUC	Area under the curve	**OCP**	Optimal cut-off point
HDL-C	High density lipoprotein-cholesterol	**CVR**	Cardiovascular risk
LDL-C	Low density lipoprotein-cholesterol	**CIMT**	Carotid intima-media thickness
TC	Total cholesterol	**BMI**	Body mass index
SD	Standard deviation	**MESA**	Multi-ethnic study of atherosclerosis
SP	Specificity	**ROC**	receiver operating characteristic
S	Sensitivity	**FRS**	Framingham risk score
NRI	Net reclassification improvement	**PPV**	Positive predictive value
CAP	Carotid atherosclerotic plaque	**NPV**	Negative predictive value

BACKGROUND

The identification of patients at risk of suffering cardiovascular events and, therefore, requiring intensive intervention strategies is the greatest challenge in cardiovascular prevention. The most recent guidelines for the diagnosis and management of dyslipidemia recommend target LDL-cholesterol (LDL-C) levels less than 70 mg/dl in patients with increased or markedly increased risk. (1-3)

However, 75% to 85% of cardiovascular events occur in subjects with low or moderate Framingham risk score (FRS), complicating the process of decision making in clinical practice and population-based strategy planning. (4)

Traditional scores estimate a 10-year risk period of suffering a cardiovascular event. This temporal horizon limits the possibility of identifying high-risk subjects among men under 40 years and women under 70. (5-7)

Three strategies have been developed to improve this drawback in patients with low or moderate baseline risk. The first strategy, applied to young or middle-aged subjects, is long-term risk estimation (30-year risk or lifetime risk) using new scoring systems. (8) The second strategy includes measurement of metabolic or genetic biomarkers, and the third strategy incorporates detection of subclinical atherosclerosis. (9, 10)

Carotid intima-media thickness (CIMT) is an independent marker of cardiovascular risk. (11-12) Recent studies have demonstrated that coronary artery calcium score (CACS) assessment to detect coronary atherosclerosis is a better predictor of cardiovascular risk (CVR) than CIMT. (13, 14) However, a reduced number of patients have access to this method in our country.

For this reason, the goals of our study were: 1) to evaluate the diagnostic accuracy of CIMT to detect CACS >0, and, 2) to determine an optimal cut-off point (OCP) of CIMT to discriminate between the presence or the absence of coronary artery calcium.

METHODS

We conducted a cross-sectional descriptive study of consecutive samples obtained in the outpatient clinic of cardiovascular prevention.

Inclusion criteria: subjects > 18 years attending the outpatient clinic of cardiovascular prevention.

Exclusion criteria: history of cardiovascular disease (myocardial infarction, unstable angina, chronic stable angina, coronary artery bypass graft surgery, percutaneous coronary intervention, stroke, peripheral vascular disease, and disease of the aorta or its branches).

The FRS was used to calculate the 10-year risk of fatal or non fatal coronary events, and risk was classified as very low (<6%), low (6-10%), moderate (11-19%) or high (≥ 20%).

A 64-row multi-detector computed tomography scan (Toshiba Aquilion™ Software Vitrea version 5.2) was used for CACS evaluation, and the result was expressed in Agatston units. (15)

The carotid arteries were explored noninvasively using two-dimensional ultrasound with a Logiq Book XP ultrasound scanner (General Electric™) with a 7.5 MHz linear probe. Carotid intima-media thickness was measured in six places: common carotid artery (1 cm before the bifucartion), carotid bifurcation and internal carotid artery (1 cm after bifurcation) at both sides of the neck. Maximum CIMT and mean CIMT were obtained and calculated as the mean value of the six measurements. Presence of CAP was defined as: 1) abnormal wall thickness (defined as intima-media thickness > 1.5 mm); 2) abnormal structure (protrusion towards the lumen, loss of alignment with the adjacent wall); and 3) abnormal wall echogenicity.

Statistical analysis

The prevalence of CAP associated with CACS >0 was compared among the different risk categories of the FRS and in diabetic subjects.

Univariate analysis was performed to determine the differences between subjects with and without CACS >0. Then, three multivariate models were developed to analyze the association between CACS >0 and presence of CAP, maximum CIMT and mean CIMT, adjusting for those variables with significant differences at univariate analysis, for gender (as it was considered as having clinical relevance), and for diabetes (which showed a trend that was not statistically significant).

A ROC (receiver operating characteristic) curve was built and the area under the curve (AUC) was determined to ascertain how accurately maximum and mean CIMT discriminate between subjects with or without CACS>0. The Younden index, which corresponds to the maximum vertical distance between the ROC curve and the statistical chance line (CJ point), was used to determine the OCP. (15) Sensitivity, specificity, positive predictive value (PPV) and negative predictive value (NPV) were calculated.

Continuous data between two groups were analyzed using the t test for normal distributions or the Wilcoxon Mann-Withney test for abnormal distributions. Categorical data were analyzed with the chi-square test. Spearman's correlation coefficient was used to analyze the correlation between maximum CIMT and mean CIMT. Continuous variables were expressed as mean ± standard deviation and categorical variables as percentages. A p value < 0.05 was considered statistically significant.

The study was conducted following the recommendations established by the Declaration of Helsinki, Good Clinical Practice Guidelines and the local Ethics Committee regulations regarding medical research.

RESULTS

Population characteristics

A total of 202 subjects (49% women) were included in the study. Mean age was 57 ± 13 years. Thirty-six percent had a family history of early vascular disease, 49% were under antihypertensive treatment and 37% were receiving statins. Mean total cholesterol (TC), LDL-C and HDL-C plasma levels were 207 ± 57, 130 ± 51, 49 ±15 and 148 ± 106 mg/dl, respectively. Excluding diabetic patients, the FRS classified 41, 26, 21 y 12% of patients as being at very low, low, moderate or high risk, respectively.

Mean and Maximum CIMT were 0.953±0.342 and 1.383±0.679 mm, respectively. The prevalence of CAP and of CACS >0 was of 37% and 62%, respectively. The characteristics of the population are described in the supplementary Table 1.

Correlation between the 10-year FRS and the presence of CAP and CACS >0

When the population without diabetes was analyzed, the prevalence of CACS >0 was 50, 69, 96 and 88% in the very low, low, moderate and high risk FRS categories, respectively. The same analysis was conducted on subjects not treated with statins, with similar results (49, 68, 91 and 80%). The prevalence of CAP progressively increased in each risk category. In patients with type 2 diabetes, the prevalence of CACS >0 and CAP was 78% and 59%, respectively. The prevalence of CAP and CACS >0 in diabetic subjects and across the different FRS categories can be observed in the supplementary Figure 1 (total population) and Figure 2 (population without statins).

Differences between the population with or with CACS >0

Subjects with CACS >0 were older, and had higher blood pressure and BMI. Total cholesterol and LDL-C levels were lower due to greater use of statins. Table 1 shows the differences between the population with CACS =0 and CACS >0.

Correlation between CIMT and CACS

Moderate correlations were observed between CACS and mean and maximum CIMT: r=0.56 and r=0.55, respectively (Figures 1A and 1B).

An independent association was observed between mean and maximum CIMT and CACS >0. After adjusting for age, gender, systolic blood pressure, BMI, FRS, history of diabetes and presence or absence of treatment with antihypertensive agents or statins, the probability of CACS >0 increased by 38% (OR

Table 1. Differences between the population with CACS =0 and CACS >0.

	CACS =0 (n=75)	CACS >0 (n=127)	p value
Continuous variables, mean (SD)			
Age, years	448±13	62±10	<0.001
Systolic blood pressure, mm Hg	125±17	135±15	<0.001
Total cholesterol, mg/dl	220±49	199±60	0.01
LDL-C, mg/dl	140±43	123±55	0.03
HDL-C, mg/dl	51±17	48±14	0.24
Triglycerides, mg/dl	153±95	145±112	0.63
Body mass index, kg/m2	26±4	28±5	<0.005
Mean Intima-media thickness, mm	0.74±0.20	1.08±0.34	<0.001
Maximum Intima-media thickness, mm	0.97±0.35	1.64±0.71	<0.001
Framingham risk score	4.8±4.7	10.7±7.3	<0.001
Categorical variables, (%)			
Male gender	46	54	0.3
Current smokers	13	13	0.96
Antihypertensive treatment	29	61	<0.001
Family history of CVD	36	37	0.97
10-year Framingham risk score (excluding type 2 diabetes)			
Very low risk	67	30	
Low risk	26	26	<0.001
Moderate risk	2	29	
High risk	5	16	
Statins	25	44	<0.01
Diabetes	8	17	0.07
CAP	7	56	<0.001

Presence of subclinical coronary artery atherosclerosis was associated with metabolic risk factors (HT, overweight), higher FRS and more severe carotid artery atherosclerosis.

1.38; 95% CI 1.09-1.75, p<0.01) for every 0.1 mm increment in mean CIMT (Supplementary Table 2).

After adjusting for the same variables, the probability of CACS >0 increased by 15% (OR 1.15; 95% CI 1.04-1.27, p<0.01), for every 0.1 mm increment in maximum CIMT (Supplementary Table 2).

Finally, the presence of CAP produced an independent nine-fold increase in the probability of CACS >0 (OR 8.8; 95% CI 2.7-29.5, p<0.001).

ROC analysis

The area under the ROC curve of mean and maximum CIMT was 0.829 (95% CI 0.771-0.888) and 0.822 (95% CI 0.763-0.880), respectively. The OCP of mean CIMT to discriminate between CACS >0 or CACS =0 was ≥ 0.82 mm (Youden index: 0.548), and sensitivity, specificity, PPV and NPV were 77, 78, 85 and 67%, respectively. The OCP of maximum CIMT to discriminate between CACS >0 or CACS =0 was ≥ 1.01 mm (Youden index: 0.524), and sensitivity, specificity, PPV and NPV were 78, 75, 83 and 67%, respectively. (Figures 2A and 2B).

Complementary ROC analyses were performed. For mean CIMT, the high specificity cut-off point was ≥1.03 mm with a PPV of 95.2% and the high sensitivity cut-off point was ≥0.67 mm with a NPV of 90% (Figure 3A).

For maximum CIMT, we identified a high sensitivity cut-off point ≥ 0.8 mm with a NPV of 89.5% and a high specificity cut-off point ≥ 1.47 mm with a PPV of 93% (Figure 3B).

The presence of CAP had high specificity and PPV for the diagnosis of CACS >0 (93.4 and 93.3%, respectively); however, sensitivity and the NPV were low (56 and 57%, respectively) (Supplementary Figure 3).

Comparison between subgroups treated or not treated with statins

Subjects not treated with statins were younger, received less treatment with antihypertensive agents, had lower BMI, lower prevalence of CAP and CACS and lower mean and maximum CIMT. The characteristics of the population treated or not treated with statins can be observed in the supplementary Table 3.

When the populations treated or not treated with statins were analyzed, the correlations between CACS and maximum and mean CIMT did not differ significantly (mean CIMT: without statins, r =0.53, and with statins, r =0.49; maximum CIMT: without statins, r =0.51, and with statins, r =0.49).

In subjects not treated with statins, the area under the ROC curve for maximum CIMT was 0.793 (95% CI 0.715-0.872) and 0.818 (95% CI 0.744-0.891) for mean CIMT. The OCP of maximum CIMT to discriminate between CACS >0 or CACS =0 was ≥ 1.01 mm and the sensitivity, specificity, PPV and NPV were 72, 77, 77 and 69%, respectively. The OCP of mean CIMT to discriminate between CACS >0 or CACS =0 was ≥ 0.78 mm and the sensitivity, specificity, PPV and NPV were 77, 73, 78 and 71%, respectively (Figure 4 A and B).

In subjects not treated with statins, the area under the ROC curve for maximum CIMT was 0.834 (95% CI 0.723-0.944) and 0.821 (95% CI 0.697-0.945) for mean CIMT.

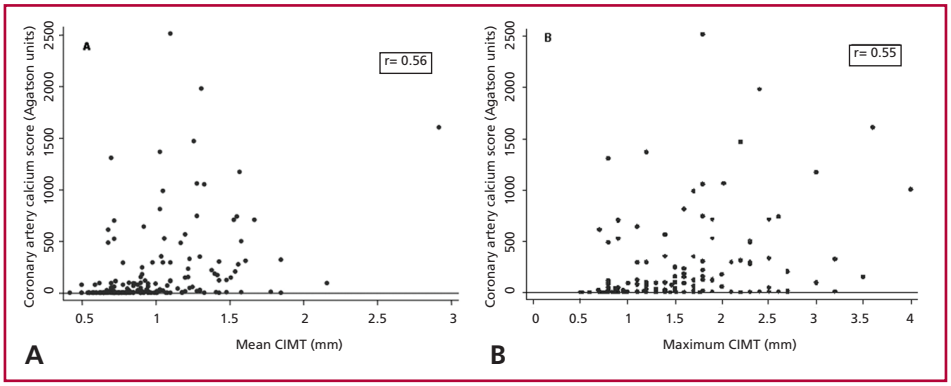

Figure 1. Correlations between CIMT and CACS. **A.** Mean CIMT. **B.** Maximum CIMT.

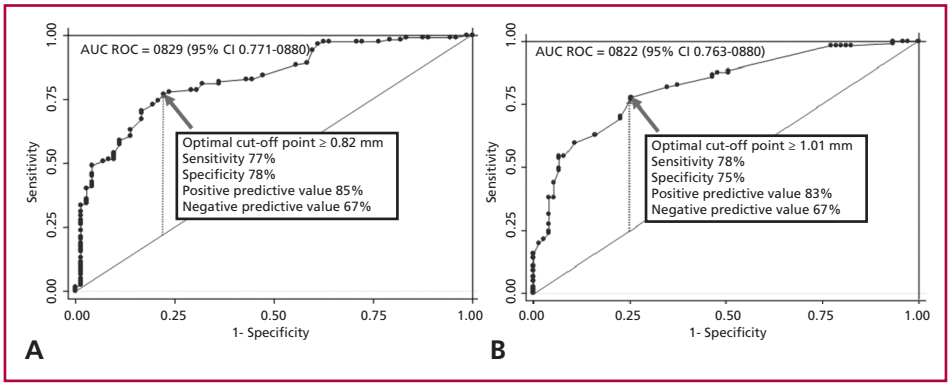

Figure 2. A. ROC analysis to determine the diagnostic accuracy of mean CIMT to detect coronary artery calcium and to discriminate between subjects with CACS >0 and CACS =0. **B.** ROC analysis to determine the diagnostic accuracy of maximum CIMT to detect coronary artery calcium and to discriminate between subjects with CACS >0 and CACS =0.

DISCUSSION

The most recent guidelines for the diagnosis and treatment of dyslipidemias agree in the need of achieving very low LDL-C targets (<70 mg/dl) or intensive reductions (≥50%) in LDL-C levels in patients with high cardiovascular risk. However, there is no agreement regarding patient management with low or moderate risk. The Adult Treatment Panel III (ATP III) of the National Cholesterol Education Program and the European Guidelines recommend LDL-C targets <130 and 115 mg/dl, respectively. The Canadian guidelines suggest a reduction of 50% or greater in LDL-C levels independently of the baseline risk. The guidelines do not agree about the predictive value or the accurate approach in subclinical atherosclerosis. (1-3)

A recent meta-analysis demonstrated that the proportional reduction of risk observed after treating with statins patients with CVR less than 2% is very significant, with a trend towards greater reduction of relative risk in subjects with lower baseline risk. (17) These results not only expand the indication of statins but also suggest the need of identifying patients categorized as having "low or moderate risk" by traditional guidelines. When these patients are evaluated with new prognostic markers, they are reclassified as having greater risk. This approach might allow adopting intensive yet more selective strategies, improving the cost-benefit relation and the adherence to long-term hypolipidemic treatment.

The implementation of different methods to reclassify CVR will depend on health care resources. In a low resource scenario, CVR may be recategorized using long-term scoring tools. (8) Our group demonstrated the clinical usefulness of the 30-year FRS for the detection of subclinical CAP. (18, 19)

The use of biomarkers of inflammation or lipid biomarkers might help the decision making process in a moderate resource scenario. (9, 20, 22) Several studies have demonstrated that biomarkers provide only a modest increase in risk prediction assessed according to the C-statistic or NRI in subjects without previous cardiovascular disease. (23-26)

Detection of subclinical carotid atherosclerosis by carotid artery ultrasound is another option in a moderate resource scenario. This method is safe and relatively accessible in our country. Carotid atherosclerosis is an independent predictor of cardiovascular events but produces a modest increase in the net reclassification index (7.3% in the presence of CAP). (12)

Finally, in a high resource scenario, CVR may be recategorized by screening subclinical coronary artery atherosclerosis using CACS, which is an independent and stronger predictor of cardiovascular events compared to CIMT. (13, 14) In the MESA study, the NRI was 0.25 (95% CI, 0.16-0.34), with a marked increase in the moderate risk population (NRI, 0.55; 95% CI, 0.41-0.69). (27, 28)

Coronary artery calcium score is evaluated by a multi-slice computed tomography without injection of contrast material and low radiation exposure. The indication of this test is limited due to its high cost, low availability and limited coverage by the health care system.

The detection of CACS >0 is a direct marker of

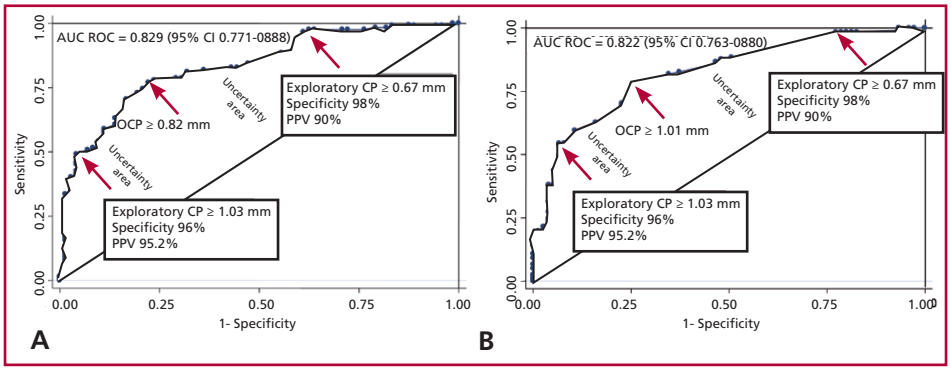

Figure 3. A. Complementary ROC analysis of mean CIMT. See explanation in the text. **B.** Complementary ROC analysis of maximum CIMT. See explanation in the text.

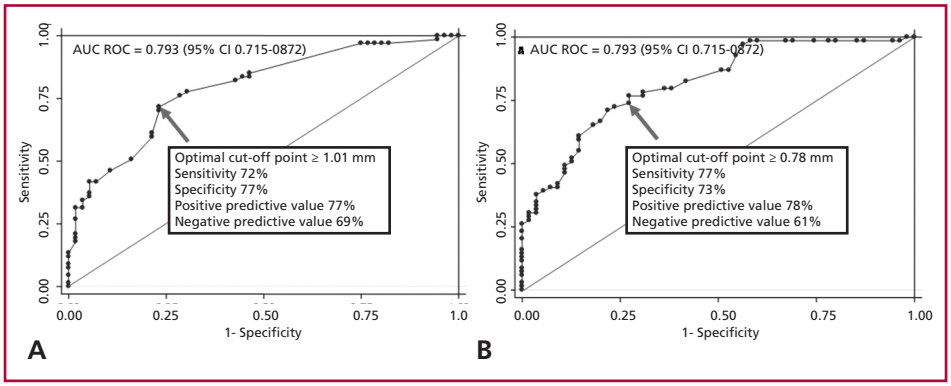

Figure 4. A. ROC analysis to determine the diagnostic accuracy of maximum CIMT to detect CACS >0 in subjects not treated with statins (n = 123). **B.** ROC analysis to determine the diagnostic accuracy of mean CIMT to detect CACS >0 in subjects not treated with statins (n = 123).

coronary artery atherosclerosis and the method allows the assessment of the temporal progression of the disease. (29) The CACS value provides prognostic information independently of the risk score, LDL-C or C-reactive protein levels. (30-32) It is important to point out that a low CACS (an Agatston index 1-10) is associated with significantly increased CVR. (33)

In our study, we evaluated a population of subjects without history of vascular disease attending the cardiovascular prevention outpatient clinic. In 66% of non diabetic subjects not treated with statins, the 10-year FRS was very low or low, with a 56% prevalence of CACS >0. This finding demonstrates the low concordance between the traditional risk score and the detection of subclinical atherosclerosis in this population. A FRS of low risk with a CACS >0 is associated with greater risk of events and mortality due to coronary artery disease. (34)

Atherosclerosis is a diffuse disease; therefore, increased CIMT or presence of CAP should have an adequate correlation with CACS. In our study, we found a poor correlation between CIMT and CACS, suggesting different stages in the development of atherosclerotic disease and/or dissimilar atherogenic mechanisms in different vascular territories. (35)

The diagnostic accuracy of maximum and mean CIMT to discriminate between the presence or the absence of CACS >0 was moderate. Optimal cut-off point value of 0.82 mm for mean CIMT and of 1.01 for maximum CIMT had an acceptable PPV; however, sensitivity and the NPV were low, suggesting that, in our population, about 35% of patients with normal carotid artery ultrasound had a certain degree of coronary artery atherosclerosis. The detection of CAP showed an independent association with a 9-fold increase in the probability of presenting CACS >0, with a high PPV (93%) and a low NPV (55%).

In Figure 3A we performed an exploratory analysis of mean CIMT. We selected a high sensitivity cut-off point (≥ 0.67 mm) and a NPV of 90%. A cut-off point ≥1.03 mm increases the specificity and therefore raises the PPV for the detection of CACS >0 to 95%. Three areas with different clinical consequences are defined in the ROC curve. The extremes of the curve, below the high specificity exploratory cut-off point (red area) and above the high sensitivity exploratory cut-off point (grey area), confirm or rule out the presence of coronary artery atherosclerosis with acceptable accuracy. The area between both exploratory cut-off points corresponds to the values with greater uncertainty, in which the detection of coronary artery calcium might provide additional prognostic information to the measurement of CIMT. In the area between the OCP and the high specificity exploratory cut-off point, the probability of detecting coronary calcium increases from 85% to 95%. Finally, the probability of detecting CACS >0 decreases from 35% to 10% in the area between the OCP and the high sensitivity cut-off point. The decision of which cut-off point value in the uncertainty area will be chosen to indicate screening of coronary artery calcium will depend on the criterion of the physician and on the level of available resources.

A similar analysis was conducted by exploring maximum CIMT. We identified a high sensitivity cut-off point (≥ 0.8 mm) with a NPV of 89.5% and a high specificity cut-off point (≥ 1.47 mm) with a PPV of 93% (Figure 3B).

Finally, the correlations and ROC curve analysis in the subgroup not treated with statins were very similar to those of the general population. Therefore, we may assume that the results of this study might be applicable to patients treated with statins.

Study limitations

A selection bias cannot be excluded as the patients attending a cardiovascular prevention outpatient clinic do not necessarily represent the general population. Our results may be only applied in another center using a similar method for measuring CIMT.

CONCLUSIONS

In this population, the diagnostic accuracy of CIMT to detect CACS >0 was moderate. The prevalence of CACS >0 was high even in subjects with very low or low CVR. A "normal" carotid artery ultrasound did not exclude the presence of subclinical coronary artery atherosclerosis.

Clinical implications

Patients with coronary risk factors should undergo carotid artery ultrasound independently of their 10-year risk level. The thorough evaluation of its result may help to estimate the risk of subclinical coronary artery atherosclerosis and to select patients requiring CACS measurement for an adequate CVR stratification.

Supplementary material

Additional tables and figures are available at the web site of the Argentine Journal of Cardiology.

RESUMEN

Precisión diagnóstica del espesor íntima-media carotídeo para la detección de aterosclerosis coronaria. Utilidad en la práctica clínica

Introducción

El espesor íntima-media carotídeo (EIMC) es un marcador independiente de riesgo cardiovascular. El puntaje de calcio coronario (PCC) es un predictor superior al EIMC, pero de costo elevado y en nuestro país pocos pacientes pueden acceder a su medición.

Objetivos

1) Evaluar la precisión diagnóstica del EIMC para la detección de un PCC > 0. 2) Determinar el punto de corte óptimo del EIMC para discriminar entre la presencia o la ausencia de calcio coronario.

Material y métodos

Estudio descriptivo transversal de muestras consecutivas

obtenidas en los consultorios de prevención cardiovascular. Se midió el EIMC medio y máximo mediante un eco-Doppler carotídeo. Se efectuó una tomografía computarizada de 64 pistas para la evaluación del PCC. Se determinó la precisión diagnóstica del EIMC para la detección de un PCC > 0 mediante un análisis ROC.

Resultados

Se incluyeron 202 sujetos consecutivos que participan de un programa de prevención primaria. Características de la población (media ± desviación estándar): edad 57 ± 13 años, sexo femenino: 49%, tabaquismo: 13%, estatinas: 37%, diabetes mellitus: 13%, puntaje de Framingham en no diabéticos: 9% ± 7%, EIMC medio: 0,953 ± 0,342 mm, EIMC máximo: 1,383 ± 0,679 mm, prevalencia de placa aterosclerótica carotídea: 37% y de PCC > 0: 62%. Las correlaciones entre el EIMC medio y máximo y el PCC fueron pobres (r = 0,393 y r = 0,376, respectivamente). El área bajo la curva ROC del EIMC máximo fue de 0,822 (IC 95% 0,763-0,880) y la del EIMC medio fue de 0,829 (IC 95% 0,771-0,888). El punto de corte óptimo del EIMC máximo para discriminar entre PCC > 0 o PCC = 0 fue de ≥ 1,01 mm y la sensibilidad, la especificidad, el valor predictivo positivo (VPP) y el valor predictivo negativo (VPN) fueron del 78%, 75%, 83% y 67%, respectivamente. El punto de corte óptimo del EIMC medio para discriminar entre PCC > 0 o PCC = 0 fue ≥ 0,82 mm y la sensibilidad, la especificidad, el VPP y el VPN fueron del 77%, 78%, 85% y 67%, respectivamente.

Conclusiones

En esta población predominantemente de riesgo bajo, la precisión diagnóstica del EIMC para detectar PCC > 0 fue moderada. Una ecografía Doppler carotídea "normal" no excluyó la presencia de aterosclerosis subclínica coronaria. Estos resultados podrían mejorar la selección de pacientes que requieran la medición del PCC para estratificar el riesgo cardiovascular.

Palabras clave > Score de calcio coronario - Espesor íntima-media carotídeo - Riesgo cardiovascular

Conflicts of interest

None declared.

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