The echogenecity of the intima–media complex in the common carotid artery is closely related to the echogenecity in plaques

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Abstract

Objective: The echogenecity measured by ultrasound of atherosclerotic plaques is related to future cardiovascular events. The aim of the present study is to relate the grey scale median of the intima–media complex (IM-GSM) of the common carotid artery (CCA) to the echogenecity of carotid plaques.

Material and results: In the Prospective Study of the Vasculature in Uppsala Seniors (PIVUS) study, a population-based study of 1016 subjects aged 70, carotid artery intima–media thickness (IMT) and IM-GSM were evaluated by ultrasound and computerized analysis. Also the occurrence of plaque and plaque GSM were measured. The echogenecity of the plaques was also visually estimated by the Gray-Weale classification.

In subjects with a carotid plaque (n = 582), IM-GSM in CCA was correlated to GSM in the plaque (r = 0.60, p < 0.0001) independently of plaque size and IMT. IM-GSM in CCA was also correlated to the visually estimated echogenecity (p < 0.0001 for trend).

Conclusion: IM-GSM of the CCA is closely related to the echogenecity in overt carotid plaques, regardless if evaluated by the same computerized method or evaluated visually. This finding suggests that IM-GSM of CCA could be an important and easily measurable characteristic of the carotid artery wall that could be obtained in almost all subjects and not only those with an overt plaque.

Keywords: Ultrasound; Carotid artery; Atherosclerosis; Echogenecity; Intima–media thickness

1. Introduction

By use of ultrasound, plaques in the carotid artery could be identified and characterized by size and echogenecity, and both of these characteristics have been shown to predict future cardiovascular events [1,2].

Also the intima–media thickness (IMT) of the carotid artery is a commonly used measure of atherosclerosis, shown to predict cardiovascular events in cohort studies [3].

Although several studies have evaluated the echogenecity of carotid artery plaque as the grey scale median (GSM) by image analysis [4,5], few attempts have been made to characterize the intima–media complex with a similar grey scale analysis. It is evident from the visual inspection of the intima–media complex in the carotid artery that a great variation in echogenecity does exist. However, the usefulness of this information has however not yet been studied.

In the Prospective Investigation of the Vasculature in Uppsala Seniors (the PIVUS study), a population-based cohort study initiated in more than 1000 subjects aged 70 living in the community of Uppsala, Sweden [6], we measured GSM in both the intima–media complex in the common carotid artery (CCA) and in overt carotid plaques with the hypothesis that the grey scale median of the intima–media complex (IM-GSM) of the CCA mirrors the echogenecity in the carotid plaques.
2. Material and methods

This section has previously been given in detail together with basic characteristics of the cohort [6].

2.1. Subjects

Eligible were all subjects aged 70 living in the community of Uppsala, Sweden. The subjects were randomly chosen from the register of community living. One thousand and sixteen subjects participated giving a participation rate of 50.1%.

The study was approved by the Ethics Committee of the University of Uppsala.

All subjects were investigated in the morning after an over-night fast. No medication or smoking was allowed after midnight.

2.2. Carotid artery ultrasound evaluation

The carotid artery was assessed by external B-mode ultrasound imaging (Acuson XP128 with a 10 MHz linear transducer, Acuson Mountain View, California, USA). The common carotid artery, the bulb and the internal carotid artery (ICA) were visualised and the occurrence of plaque was recorded on both sides. The IMT was evaluated in the far wall in the CCA 1–2 cm proximal to the bulb.

The images were digitised and imported into the Artery Measurement Software (AMS) automated software [7] for dedicated analysis of IMT, GSM and plaque size. A maximal 10 mm segment with good image quality was chosen for IMT-analysis from the CCA. The programme automatically identifies the borders of the IMT of the far wall and the inner diameter of the vessel and calculates IMT and the diameter from around 100 discrete measurements through the 10 mm long segment. This automated analysis could be manually corrected if not found appropriate at visual inspection. The given value for carotid artery IMT is the mean value from both sides.

A ROI was placed manually around the intima–media segment that was evaluated for IMT and the programme calculates the intima–media GSM (IM-GSM) from analysis of the individual pixels within the ROI on a scale from 0 (black) to 256 (white). The blood was used as the reference for black and the adventitia was the reference for white. The GSM-value given is the mean value from both sides.

The mean length of the evaluated intima–media segments was 9.0 (S.D. 2.1) mm when subjects with a segment recording less than 5 mm were excluded, leaving 946 subjects with valid recordings.

The measurements of IMT were repeated in 30 random subjects giving a coefficient of variation of carotid artery IMT of 7.2 and 7.5% for IM-GSM.

A ROI was also placed manually around plaques for measurement of plaque area and GSM.

Plaque size was graded into four groups according to a previously used classification [8]. A small plaque was considered to present if the IMT was locally thickened more than 50% compared to the surrounding IMT. A moderate plaque was present if the plaque area was more than 10 mm². A flow-limiting plaque was present if the velocity was increased distally of the plaque. Also occluded carotid arteries were noted.

GSM of the plaques were evaluated with the same software as used for IM-GSM. This measurement was repeated in 25 random subjects giving a coefficient of variation of 8.3% for GSM in the plaques.

The carotid plaques were visually inspected and graded by three observers to reach a consensus according to the Gray-Weale classification [9]. According to that classification, the plaques were divided into four groups, echolucent, mainly echolucent, mainly echogenic and echogenic. Since echolucent plaques seems to be more dangerous [2,8], the worst case scenario was applied so the subject was classified according to the most echolucent plaque in any of the carotid arteries, with the exception that subjects with one mainly echogenic plaque and one echogenic plaque were denoted echogenic in order to achieve a certain number of such subjects.

Relationships between continuous variables were evaluated by Pearson’s correlation coefficient and multiple regression analysis. Two-tailed significance values were given with p < 0.05 regarded as significant.

3. Results

Mean value for IMT in CCA was 0.89 (S.D. 0.16) mm, for IM-GSM in CCA 79 (24) and for GSM in the plaque 74 (32).

When all subjects with a plaque were evaluated, IM-GSM in CCA was correlated to GSM in the plaque (n = 582, r = 0.60, p < 0.0001, Fig. 1). When only subjects with a plaque

![Fig. 1. Relationship between the grey scale median in the intima–media complex in the common carotid artery (IM-GSM in CCA) and grey scale median (GSM) in the plaque in subjects with a carotid plaque (n = 582, r = 0.60, p < 0.0001).](attachment:fig1.png)
>10 mm² were evaluated, this relationship was very similar (n = 448, r = 0.55, \( p < 0.0001 \)). Also when only subjects with an IMT in CCA < 0.80 mm were evaluated the correlation was in the same order (n = 160, r = 0.71, \( p < 0.0001 \)).

Since IM-GSM in CCA was related to IMT in CCA (r = −0.16, \( p < 0.0001 \)), we used IMT in CCA as a confounder regarding the relationship between IM-GSM in CCA and GSM in the plaque in multiple regression analysis. This approach did not however influence the correlation between IM-GSM in CCA and GSM in the plaque (r = 0.60, \( p < 0.0001 \)). Neither did the inclusion of plaque size as confounder in the model influence the correlation between IM-GSM in CCA and GSM in the plaque (r = 0.58, \( p < 0.0001 \)).

IM-GSM in CCA was also related to the echogenicity of the plaque when evaluated by the visual Grey-Weal classification (\( p < 0.0001 \) for trend, Fig. 2).

### 4. Discussion

The present study show that the grey scale median in the intima–media complex in the common carotid artery is closely related to the echogenicity in overt plaques, regardless if evaluated by the a computerized method or when evaluated visually according to the Grey-Weal classification.

To exclude the possibility that this relationship was due to a close similarity in IM-GSM in the CCA and GSM in the small plaques that mainly represents a slightly thickened intima–media complex, we excluded plaques with an area <10 mm². This approach did not have any major influence on the relationship between IM-GSM in the CCA and GSM in the plaques.

In order to exclude the possibility that a part of the plaque was included in the ROI that was used for the IM-GSM measurement in the CCA, we only included subjects with a normal IMT (<0.80 mm) in a separate analysis. Neither this procedure had any major influence on the relationship between IM-GSM in the CCA and GSM in the plaques. Finally, to further exclude the potential impact of plaque size and IMT, these two characteristics were included as confounders in multiple regression analysis, but the relationship between IM-GSM in the CCA and GSM in the plaques remained intact. Thus, the relationship between IM-GSM in the CCA and GSM in the plaques is clearly independent of the size of the plaque and IMT.

While IMT is an established measure of the vascular wall [3], IM-GSM is less commonly used. GSM analysis has previously mainly been performed on plaques and then found to be related to histological features of the plaque, such as the elastin and calcium content, as well as to the size of the lipid-rich necrotic core [10]. However, the histological correlate to variations in the IM-GSM has to be evaluated and the prognostic impact of this new variable has to be investigated.

In the PIVUS study, only 3.7% report a history of stroke and only 2.5% showed plaques that obstructed blood flow. Thus, although carotid artery plaques are common in this population-based cohort, large plaques are rare. Although we find a close relationship between IM-GSM and plaque GSM being independent of plaque size in this population with rather small plaques, it has to be evaluated if the same relationship exists in patients with large and highly stenotic plaques.

In summary, IM-GSM of CCA is closely related to the echogenicity in overt carotid plaques, regardless if evaluated by the same computerized method or evaluated visually according to the Grey-Weal classification. This finding suggests that IM-GSM of CCA could be an important and easily measurable characteristic of the carotid artery wall that could be obtained in almost all subjects, not only those with an overt plaque.

### References


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