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EVALUATION OF CAROTID PLAQUE USING ULTRASOUND IMAGING

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Department of Cardiology, Dong-A University College of Medicine, Busan, Korea

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the evaluation of carotid plaque is only focused on its presence or absence, it is not possible to determine the difference in risk between the two patients.

To address this issue, many studies have quantified the carotid plaque to more accurately estimate cardiovascular risk (Table 1). Maximum carotid plaque thickness is associated with increased risk of vascular outcomes in a multiethnic cohort. A study by Störk et al. looked at the relationship between the total number of carotid plaques and prognosis. They evaluated carotid burden using carotid plaque score (1 point = 1–2 plaques; 2 points = 3–4 plaques; 3 points = 5–6 plaques; and 4 points = 7–12 plaques). As compared to patients with no plaque, the risk of mortality increased 2.9-fold when one to two plaques were present and 4.9-fold when greater than four plaques were present. These findings demonstrated a graded relationship between the number of carotid plaques and mortality. Carotid plaque area, determined by the sum cross-sectional area of all carotid plaques, has also been identified as an independent predictor of future cardiovascular risk. Echolucent plaques are lipid-rich, whereas echogenic plaques are rich of fibrous tissue and calcification. Plaque echogenicity can be graded from 1 to 4 based on visual analysis with gradient progressing, from echolucent (defined as a plaque appearing black) to predominant echolucent, predominant echogenic, and, finally, echogenic (defined as a plaque appearing white or almost white). Honda et al. defined an echolucent plaque as less than -13.4 dB by using integrated backscatter (IBS) analysis. They demonstrated that echolucent carotid plaque with low IBS value was a significant and independent predictor of future coronary events in patients with stable angina. Echolucent plaque was defined by use of the grey-scale median (GSM), a computerized measurement of plaque echogenicity. el-Barghouty et al. have contended that a GSM of less than 32 corresponds to a high risk plaque. Additional studies have further confirmed echolucent plaques as predictor of cerebrovascular events.

![Carotid ultrasound showed carotid plaques in two patients, one patient has an asymptomatic single plaque with low cardiovascular risk (A), and the other patient has multiple complex plaques with recent stroke (B). The image (A) shows a small amount of smooth homogenous plaque (arrow) located on the far wall of the proximal CCA. In contrast, the image (B) demonstrates moderate to large amount of heterogeneous multiple plaques (arrows) with focal calcification and irregular surface, in mid CCA. CCA: common carotid artery.](image)

**Table 1. Quantification of carotid plaque for cardiovascular risk**

| Parameters               | Quantification                                                                 | End points                                      | RR (95% CI)         | Ref. # |
|--------------------------|-------------------------------------------------------------------------------|------------------------------------------------|---------------------|--------|
| Thickness                | Maximum carotid plaque thickness ≥ 1.9 mm vs. no plaque (reference)          | Combines vascular events                        | HR 2.8 (2.04–3.84)  | 12     |
| Number                   | 1–2 plaques and > 4 plaque vs. no plaque (reference)                         | All-cause mortality                             | HR 2.9 (0.96–8.69)  | 13     |
| Area                     | 0.12–0.45, 0.46–1.18, and 1.19–6.73 cm³ vs. 0.00–0.11 cm³ (reference)        | The combined 5-year risk of stroke, MI, and vascular death | RR 1.9 (1.1–3.3), 2.5 (1.4–4.4), and 3.5 (1.8–6.7) | 14     |
| Echogenicity             | Echogenic and echolucent plaque with carotid stenosis vs. no stenosis (reference) | Cerebrovascular events                          | RR 1.84 (0.30–11.23) and 4.56 (1.10–18.93) | 19     |
| Texture                  | Hyperechogenic vs. hypoechogetic plaque by DPTA                              | Microembolism during endarterectomy             | OR 0.32 (0.12–0.89) | 22     |
| Volume                   | Plaque volume < 0.09 mL vs. thickness < 1.35 mm                              | Absence of CAD                                  | NPV (%): 93.3 vs. 75.0 | 27     |

MCPT: maximum carotid plaque thickness, MI: myocardial infarction, DPTA: detailed plaque texture analysis, CAD: coronary artery disease, NPV: negative predictive value, CI: confidence interval, HR: hazard ratio, OR: odds ratio, RR: relative risk.
nosis and plaque morphology; (degree of stenosis = 0 if lumen obstruction < 40%, = 1 if 40%), (echogenicity = 1 for low echogenicity or echolucent plaque, = 2 for intermediate, and = 3 for hyper-echogenicity), (texture = 0 if homogeneous, and = 1 if heterogeneous), and (surface characteristics = 0 if smooth, = 1 if irregular). A total plaque risk score was calculated from each subject examined, which ranged from 1 to 6. The most powerful predictor of cardiovascular events during their follow-up was total plaque risk score > 4.

Recently, several new ultrasound technologies have been developed for the evaluation of carotid plaques. A study by Lal et al. analyzed plaque texture by pixel distribution analysis and histology. Madycki et al. found that pixel distribution analysis predicted the risk of perioperative complications more precisely than standard GSM analysis. Another evaluation technique relies on contrast-enhanced ultrasound imaging of the carotid vasa vasorum. Coli et al. demonstrated a strong correlation between histologic density and the degree of contrast-agent enhancement by ultrasound imaging. Contrast enhanced ultrasound may also be used to detect subclinical atherosclerosis in the carotid arteries, serving as an additional method for the detection of carotid plaque ulceration.

The final technique quantifies carotid plaque using a three-dimensional (3D) measurement of plaque volume. 3D measurement demonstrated a higher negative predictive value and sensitivity for coronary artery disease (CAD) than two-dimensional (2D) measurement. In particular, total 3D plaque volumes less than 0.09 mL could predict the absence of CAD. 3D plaque volume is significantly more sensitive to changes with therapy than measurements of cIMT or total plaque area. Sillesen et al. found that carotid plaque volume was more closely correlated with coronary atherosclerosis than cIMT, abdominal aortic diameter, or ankle-brachial index in a large number of patients (n = 6101).

CAROTID PLAQUE AS A PREDICTOR OF SUBCLINICAL ATHEROSCLEROSIS

Traditional cardiovascular disease risk factors such as old age, gender, smoking, cholesterol levels, blood pressure, and diabetes have long been used to predict cardiovascular risk, but this method has its limitations. Imaging modalities such as carotid ultrasound are superior means of predicting cardiovascular risk. Measurement of cIMT has been widely used to predict cardiovascular risk, but it may not be useful for risk stratification in the general population. A meta-analysis by Den Ruijter et al. demonstrated that, for the general population, the added predictive value of including common cIMT measurement to the Framingham Risk Score was small and not significant. However, in individuals of intermediate risk, the added value was 3.2% in men and 3.9% in women.

Despite such limited evidence of cardiovascular risk prediction, recent guidelines recommend measuring cIMT in asymptomatic patients of intermediate cardiovascular risk. The ASE consensus statement recommends that common cIMT measurement should always be supplemented by thorough scanning of extracranial carotid arteries for carotid plaques for higher diagnostic accuracy of subclinical vascular diseases. Although cIMT is a well-known surrogate marker for subclinical atherosclerosis, thickening of cIMT does not necessarily represent subclinical atherosclerosis. cIMT is primarily a result of the hypertensive thickening of smooth muscles in the arterial media layer, rather than the substantial changes which are indicative of atherosclerosis. Compared with cIMT, presence of carotid plaque may be more representative for atherosclerosis. Atherosclerosis Risk In Communities (ARIC) trial showed that the addition of plaque to cIMT resulted in a net reclassification improvement of 9.9% in the overall population and 21.7% in the intermediate risk group. Carotid plaque, compared with cIMT, was shown to predict CAD events more accurately in a meta-analysis. Ultrasound assessment of carotid plaque was found to have a higher diagnostic accuracy than cIMT for the prediction of future myocardial infarction. In addition, the absence of carotid plaque provided greater assurance, with low event rate (4.0%) of 10-year myocardial infarction. The ABIC trial, which evaluated the presence or absence of carotid plaque without quantification, demonstrated that including plaque with cIMT significantly improved risk prediction of coronary heart disease.

Subsequent studies used quantified methods to measure plaques and evaluated risk prediction using quantified plaques. In earlier studies, plaque quantification included the thickness, number, surface, area, and texture of plaques which were detailed by 2D ultrasound. These studies showed significantly improved risk prediction compared to cIMT and traditional risk factors. Studies investigating the evaluation of coronary heart disease based on carotid plaque score also demonstrated its efficacy as a significant predictor for CAD.

Recent developments in new technologies for evaluating carotid plaques show promise in improving our ability to predict the risk of cardiovascular disease. 3D ultrasound shows particular prognostic promise. 3D measurement of carotid plaque volume is more sensitive to the presence of carotid plaque because it creates simultaneous visualization of carotid plaque using all 3 planes, decreasing the odds of missing any plaques present. It also allows for a more accurate assessment of total plaque volume and enhances the ability to observe changes in plaque burden compared to 2D techniques. Further research is required to confirm this, but present evidence suggests that 3D plaque volume measurement will be a stronger predictor of cardiovascular events in patients.

Ultrasound is used for initial evaluation of carotid plaque. The advantage of ultrasound is its low cost and that it is relatively safe as an imaging modality. The presence of carotid plaque on ultrasound is a better predictor of future cardiovascular events compared to cIMT. The disadvantage of ultrasound is that it is dependent on the operator’s skill and image
quality. The limitation of using carotid plaque in clinical prac-
tice is that plaque quantification, such as morphology and vol-
ume, has not been well studied yet.

CONCLUSION
Quantification of carotid plaques is an important step in as-
sessing subclinical atherosclerosis for the prediction of future
Coronary heart disease. While some studies suggest a plaque
scoring method for improved assessment, there is no consen-
sus classification system for carotid plaque severity. In the fu-
ture, 3D ultrasound is expected to be a more reliable means of
evaluating plaque burden and predicting cardiovascular risk.

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