Original Article

Association Between Atherosclerosis in Carotid Artery and Elastic Modulus of Brachial Artery

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Abstract

Background: *Common carotid arterial stiffness can be assessed during carotid arterial ultrasonography, but its association with brachial stiffness, a well-defined cardiovascular risk factor, has not been clarified. The aim of this study was to examine the relationship between common carotid artery and brachial artery stiffness.*

Methods: *The static pressure-strain elastic modulus of the common carotid and brachial arteries were evaluated in 40 men with 15 healthy carotids, 15 mild carotid stenoses, and 10 severe carotid stenoses, by B-mode and Doppler ultrasonography. The local elastic modulus was estimated by the measurement of the arterial strain; the static pressure was also measured based on the peak-systolic and end-diastolic velocity in each artery.*

Results: *The elastic modulus of the right common carotid artery (RCCA) and right brachial artery (RBA) increased linearly with the growth of atherosclerosis from 1772±566 Pa and 26391096± Pa for the normal subjects to 6168±1026 Pa and 55871592± Pa for the severe stenosis group, respectively. In the three groups; healthy, mild stenosis, and severe stenosis; there was a significant difference in the elastic modulus of the right common carotid artery between the groups and also for the right brachial artery, separately (p-value<0.05). The Pearson correlation analysis showed a significant correlation between the elastic modulus of the right common carotid artery and the elastic modulus of the right brachial artery.*

Conclusion: *The brachial artery elastic modulus is associated with the common carotid elastic modulus. This study showed that atherosclerosis was a generalized process that might involve the entire vasculature. An evaluation of the elastic modulus of the RBA, however, showed that there were fundamental differences in the dynamic behavior of the brachial artery when compared to elastic arteries, such as the common carotid artery.*

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Introduction

In recent years, the noninvasive determination of artery wall properties has become increasingly important, not only

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in clinical studies, but also in patient management.[1] Despite the recently introduced ultrasound methods for a noninvasive assessment of the local change in the artery diameter and wall thickness, the estimation of the elastic properties of arteries can still be considered a good predictor of atherosclerosis.[2] A great many studies have shown an increase in structural stiffness (an inverse of compliance) with the development of atherosclerosis.[2-5]

A noninvasive, early detection of atherosclerotic damage would be of great significance with regard to risk stratification and presymptomatic treatment of patients with atherosclerotic disease, such as coronary artery disease (CAD). Atherosclerosis seems to be a generalized process that may involve the entire vasculature. In another study, we evaluated the elastic modulus both at the site of stenosis in the right common carotid artery and at the other site in the left common carotid artery. However, there are precious few data on the fundamental differences in the dynamic behavior of the brachial artery when compared to elastic arteries, such as the common carotid artery.

Carotid artery stiffness may provide indications of early arterial changes that may foretell the severity of major vascular disease.[6-8] Since the carotid artery is easy to study on account of its superficial position and its relative thickness, this study sought to evaluate the elasticity of the right common carotid artery and brachial artery and investigate the relationship between them.

Methods

In a cross-sectional design, an examination was performed on 40 men at a mean age of 66±10 years through random sampling: 15 were normal with no history of cardiovascular disease, cerebrovascular disease, hypertension, and diabetes; 15 had mild stenosis; and 10 had severe stenosis in the right common carotid artery.

All the subjects underwent color Doppler ultrasonography (Aloka SSD-1700, High Technology Inc., MA, USA) with a 7.5 MHz linear array transducer.[7-9] The patients were divided into three groups according to the presence of diameter narrowing in the right common carotid artery before the bifurcation region as follows: 1) Normal: no diameter narrowing, 2) Mild stenosis: diameter narrowing of less than 40% (21±9% of stenosis), and 3) Severe stenosis: diameter narrowing of more than 40% (62±14% of stenosis).

A data acquisition system consisting of a personal computer and video-blaster board (Video-blaster Snazzi*1, VCD Master HQ, Singapore) was used to monitor and grab the changes of the blood flow velocities and cross-section of all the examined arteries throughout two cardiac cycles. The peak- systolic and end-diastolic velocities of blood in the two arteries were determined. Also, the systolic and diastolic diameters of each artery were determined. Finally, systolic and diastolic diameter changes were estimated.

The elasticity of each vessel was estimated from the pulsatile diameter changes and blood pressures. The arterial strain, or the relative diameter change, was defined as:

$$Strain = \frac{D_s - D_d}{D_d} \quad (1)$$

Where D_s and D_d were the arterial peak-systolic and end-diastolic diameters.

We also calculated the static pressure change (ΔP_s), defined according to Mokhtari et al.[7] as:

$$\Delta P_s = \tfrac{1}{2}\rho\,(v_s^2 - v_d^2) \quad (2)$$

The static pressure change was used in lieu of the blood static pressure, and v_s and v_d were the peak- systolic velocity (PSV) and end-diastolic velocity (EDV), respectively. Blood density[10] was 1060 kg/m^3. The static pressure-strain elastic modulus(E_{ps})was estimated by using the static pressure change (ΔP_s) and strain, which was defined as:

$$E_{ps} = \frac{\Delta P_s}{\Delta D / D_d} \quad (3)$$

All the observations were made by the same investigator under the same standard conditions. The Kolmogorov-Smirnov test was

applied to check the normality of the variables. Differences between the means of the data were analyzed using the one-way ANOVA. All the data are reported as the mean±1standard deviation (SD). The statistical correlation was assessed using the Pearson test. The correlation coefficient between the growth of the right common carotid artery (RCCA) stenosis and right brachial artery (RBA) was estimated. A multiple linear regression analysis was performed. The dependent variable was the static pressure-strain elastic modulus of the brachial artery, and the independent variable was the static pressure-strain elastic modulus of the right common carotid artery. P-values less than 0.05 were considered statistically significant. All the statistical analyses were performed using the statistical package for social sciences (SPSS, version 9.0).

Results

In this study, the mean stenosis of the RCCA increased from 21 percent in the mild stenosis group to 62 percent in the severe stenosis group. Figure 1 shows a significant increase in the static pressure-strain elastic modulus of the RCCA relation to the progression of atherosclerosis (p-value<0.05).

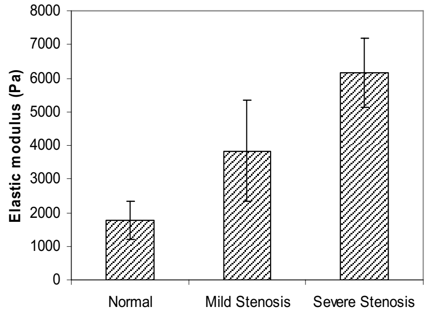

Figure 1. Elastic modulus (Pa) in right common carotid artery in each group

The static pressure-strain elastic modulus of the RCCA increased from 1772±566 Pa in the normal subjects to 3829±1501 Pa in the mild stenosis group and 6168±1026 Pa in the severe stenosis group. The static pressure changes of the RCCA increased from 193±84 Pa in the normal subjects to 227±110 Pa in the mild stenosis group and 291±110 Pa in the severe stenosis group (figure 2).

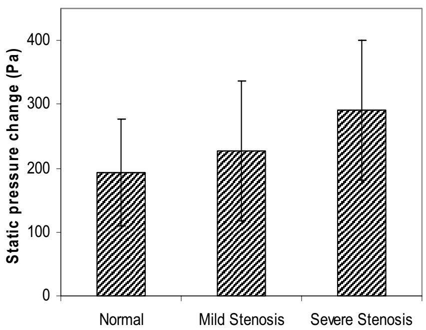

Figure 2. Static pressure changes (Pa) in right common carotid artery in each group

The estimated values of strain are presented in figure 3. The strain of the RCCA decreased from 11.1±3.7 in the normal subjects to 6.4±2.1 in the mild stenosis group and 4.7±1.7 in the severe stenosis group. It shows that strain in the RCCA significantly decreased with the progression of atherosclerosis (p-value<0.05).

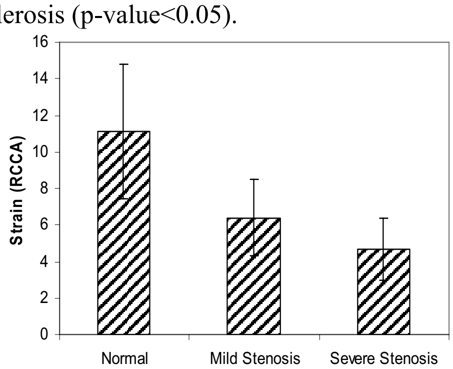

Figure 3. Strain in right common carotid artery (RCCA) in each group

The static pressure-strain elastic modulus of the RBA increased from 2640±1096 Pa in the normal subjects to 3169±1083 Pa in the mild stenosis group and 5587±1593 Pa in the severe stenosis group (figure 4).

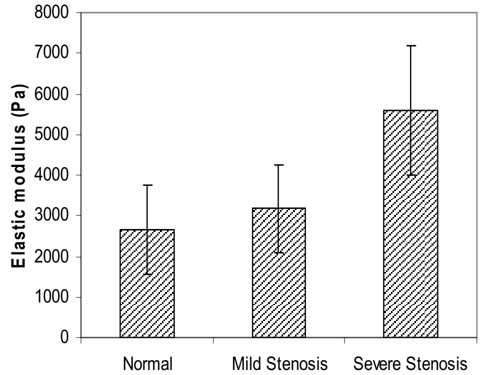

Figure 4. Elastic modulus (Pa) in right brachial artery in each group

The static pressure changes of the RBA increased from 275±148 Pa in the normal subjects to 248±84 Pa in the mild stenosis group and 442±156 Pa in the severe stenosis group (Figure 5).

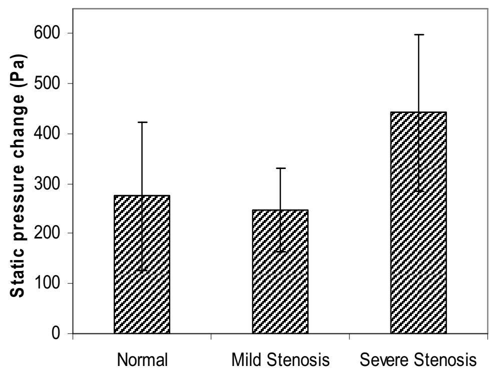

Figure 5. Static pressure changes (Pa) in right brachial artery in each group

The strain of the RBA decreased from 10.5±3.3 in the normal subjects to 8.6±3.0 in the mild stenosis group and 8.4±2.2 in the severe stenosis (figure 6). There were significant differences in the static pressure-strain elastic modulus and static pressure changes between the three groups (p-value<0.05). Nonetheless, no significant difference was shown in the RBA strain between the groups.

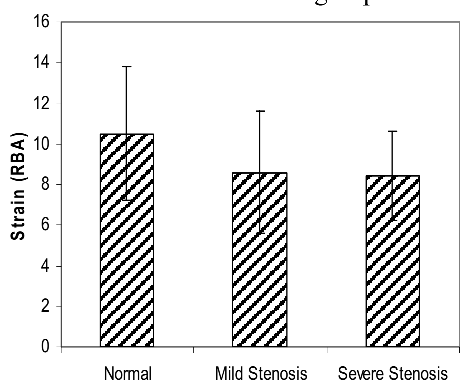

Figure 6. Strain in right brachial artery (RBA) in each group

The statistical correlation between the elastic modulus of the RCCA and RBA was estimated. There was a significant correlation between atherosclerotic changes in the RCCA and RBA, with a slight increase in the elastic modulus of the RBA with the growth of atherosclerosis in the RCCA (R=0.56, P<<0.01). The linear regression function was predicted via a multiple linear regression analysis (Figure 7).

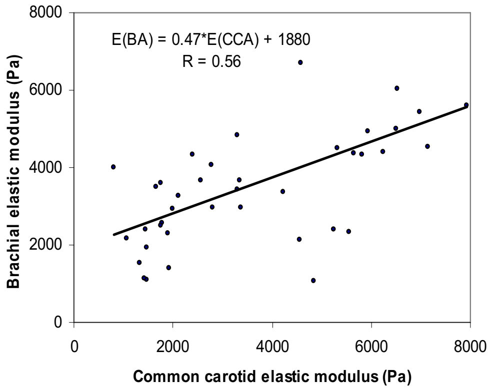

Figure 7. Scatter plot between elastic modulus of right common carotid and brachial artery
CCA, Common carotid artery; BA, Brachial artery; E, elastic modulus; R, correlation coefficient

Discussion

It has recently been argued that the ultrasonography of the peripheral vessels, rather than coronary arteriography, is the most accurate measure of atherosclerosis. B-mode ultrasonography allows an accurate visualization of the arterial wall and measurement of the ITM.[11] It has also been shown that atherosclerotic lesions in their earliest stages may progress without a reduction in lumen diameter because of the simultaneous dilation of the arterial wall,[12-14] making recognition of stenosis on arteriography difficult. Functional disturbances of the vascular wall may occur early in the atherosclerotic process, even before the anatomical changes of intima-media thickening become perceptible.[15-17]

Therefore, the study of dynamic arterial wall properties of large arteries such as the carotid and femoral arteries is becoming more common. Since the mechanical and structural properties of the arterial wall may change before the occurrence of clinical symptoms of cardiovascular disease, a noninvasive measurement of arterial wall stiffness could become important in identifying individuals at risk for cardiovascular disease.[18,19] By using Doppler ultrasound techniques, information about the hemodynamics in large and superficial arteries can be obtained noninvasively. The technique has proven to be of great value for the diagnosis of obstructive vessel disease.[1] Since the carotid artery is easy to study, because of its superficial position and its relative thickness, considerable attention has recently been directed at the wall thickness of the carotid arteries as an early marker of atherosclerotic disease and as a means of showing the effectiveness of medical therapies in treating atherosclerosis.[20]

In this study, we investigated the relationship between the RBA elasticity and development of atherosclerosis in the RCCA. A significant correlation between the elastic modulus of the RCCA and RBA was found. Studies have shown that the intima-media thickness of the CCA may be the most sensitive marker for the earliest stages of atherosclerosis.[21]

A clear and significant relationship between wall changes in the thoracic aorta, common carotid IMT, and the angiographic extent of coronary artery stenosis in patients with severe CAD has been found.[22,23] One study has illustrated that the detection of atherosclerosis in the common carotid artery is a simple, noninvasive, and reproducible clinical tool to evaluate atherosclerosis in coronary artery disease.[24] The relationship between peripheral atherosclerosis and coronary atherosclerosis is now well documented.[25] High-resolution ultrasound (13MHz) has shown that the brachial artery wall thickness is associated with coronary artery disease and risk factor. These findings support the use of the BA as a surrogate vessel for coronary circulation, provided it can be measured with the use of ultrasound.[26] There are other studies demonstrating that the thoracic aortic plaque detected on transesophageal echocardiography appears to be a useful marker for coronary artery disease.[27]

We found a modest association between the elastic modulus in the right common carotid and brachial artery. There are fundamental differences in the dynamic behavior of the peripheral arteries such as the femoral artery when compared to elastic arteries, such as the aorta and the common carotid artery.[28] Increased IMT and impaired wall mechanics associated with cardiovascular risk factors and events are the result of changes in the intrinsic structural and functional properties of the artery. Structural aberrations include the thinning and fracturing of elastin fibers, as well as the deposition of more collagen, leading to the thickening of the arterial wall and a decrease in its elasticity and compliance.[29] An experimental study in sheep has shown differences in the mechanical properties between central (abdominal aorta) and more peripheral (common carotid and common femoral) arteries. One noninvasive study in children has demonstrated that the central arteries are more distensible than the peripheral ones.[30]

The relative amount of collagen and elastin in different arterial regions has been previously examined, showing that elastin is predominant in the thoracic aorta, whereas, outside the thorax, the reverse is the case. This could provide the basis of different mechanical behavior in different vascular regions, which can be seen in the young females investigated with a stiffer CCA as compared to the abdominal aorta (AO).[31] A recent study has shown that the distensibility of the muscular common femoral artery is not clearly affected by either aging or gender, in contrast to what has been shown in central elastic arteries. Furthermore, there is a considerable variation in the interindividual values for a given age, which might be due to the muscular nature of the vessel.[28]

In summary, the present study showed that atherosclerosis was a generalized process that might involve the entire vasculature and that there was a modest, significant relationship between the extent of atherosclerotic lesions in the RCCA and the static pressure-strain elastic modulus of the RBA. However, our findings also denoted that there was a fundamental difference in the dynamic behavior of the peripheral arteries, such as the brachial artery, when compared to elastic arteries, such as the common carotid artery.

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