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Comparison of the autoregressive modeling and fast Fourier transformation in demonstrating Doppler spectral waveform changes in the early phase of atherosclerosis

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Abstract

In this study, we have performed fast Fourier transformation (FFT) and autoregressive (AR) signal processing of the Doppler signals at a nonstenotic arterial site in patients with atherosclerosis and healthy volunteers. We have not only utilized Doppler sonograms, but also facilitated the power spectral density distribution graphs using AR modeling and FFT. Our preliminary analysis show that AR modeling has a higher efficacy in demonstrating Doppler spectral waveform changes in the preclinic or silent phase of atherosclerosis. AR has especially revealed an outstanding difference in the calculation for frequency level of maximum power spectral density.

Keywords: Atherosclerosis; Autoregressive modeling; Fast Fourier transformation; Carotid artery

1. Introduction

Hardening of the arteries is basically called as atherosclerosis. The hardening is caused by deposition of fibrofatty tissue (plaques) in the inner lining of the arteries, where these plaques diminish the elasticity and cause occlusion by thickening the arterial walls [1].

The clinical manifestations of the disease depend on the vessels affected and the extent of the sclerotic change. An insidious narrowing of the artery does not become symptomatic until significant

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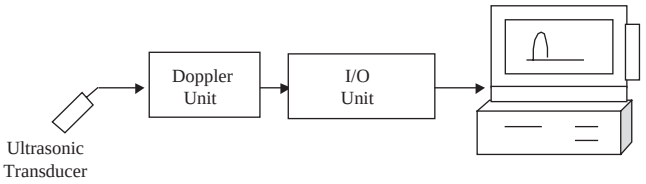

Fig. 1. Block diagram of the system hardware used to acquire Doppler data.

hemodynamic changes occur, i.e., about 70% of the artery's interior is blocked [2]. In case of a sudden occlusion of an artery by superimposed thrombosis or hemorrhage into a plaque, severe symptoms develop [1]. Although any artery may be affected, the disease involves mainly the aorta, the coronary and cerebral system and so myocardial infarction, cerebral infarction and aneurysms are the major consequences of this disease [1,3].

When the symptoms develop, catheter angiography is considered as the gold standard to detect and quantify the stenosis. Since angiography is invasive and has a relatively high cost, Doppler sonography is generally recommended. The rationale in clinical use of Doppler sonography is to detect the major waveform changes in hemodynamically significant stenosis, however, subtle waveform changes in the preclinic phase of atherosclerosis remains undefined. Recently, indirect measurements of the arterial stiffness such as pulse wave velocity and carotid artery intima-media thickness have been advocated as noninvasive screening methods to quantify the early changes in atherosclerosis [4].

In this study, we have performed fast Fourier transformation (FFT) and autoregressive (AR) processing of the Doppler signals at a nonstenotic arterial site in patients with atherosclerosis and healthy volunteers. We have not only utilized Doppler sonograms, but also facilitated the power spectral density distribution graphs using both methods. The aim of the study is to compare the AR modeling and fast Fourier transformation in detecting the spectral waveform differences in the preclinic or silent phase of atherosclerosis.

2. Material and methods

Carotid arterial Doppler ultrasound signals were acquired from left carotid arteries of five patients and five healthy volunteers. The subjects had no clinical and echocardiographic evidence of valvular disease or heart failure. The patient group included two males and three females with an established diagnosis of atherosclerosis through coronary or aortofemoropopliteal (lower extremity) angiographies (mean age, 68 years; range, 53–76 years). Healthy volunteers were young nonsmokers who seem to not bear any risk of atherosclerosis, including three males and two females (mean age, 22 years; range, 20–23 years).

Doppler signal acquisition was conducted by Toshiba PowerVision 6000 Doppler Ultrasound Unit in the Radiology Department of Erciyes University Hospital. The system hardware was composed of Digital Doppler Ultrasound unit that can work in the pulsed mode, linear ultrasound probe, input –output card and a personal computer (Fig. 1). A personal computer (PC) was used for storage, displaying and spectral analysis of the acquired Doppler data.