# 論文 / 著書情報
# Article / Book Information

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論文要約

Arteriosclerotic diseases have been increasing in recent years, and as progress, they are more likely to cause myocardial infarction and cerebral infarction. Although several diagnostic methods have been studied for relatively large blood vessels, hardening also occurs in small blood vessels. Photoacoustic imaging is considered useful for evaluating the effects of treatment because it has a good resolution to capture minute vascular lesions and changes in the progression of atherosclerosis, which is difficult to be detected with conventional imaging methods. Previous studies focused on the characterization of the geometrical structure of a thin tube and the acoustic resonances in liquid-filled thin tubes embedded in a soft phantom through photoacoustic excitation were investigated. Based on those studies, it has been shown that photoacoustic signals generated from thin tubes do not have a uniform frequency response, but rather resonate within the tube, resulting in a signal with a mode and resonant frequency. In this study, we utilized the resonance phenomenon of photoacoustic signals generated from a tube to compare the characteristics of photoacoustic signals from blood vessels in a healthy state and those with atherosclerotic features using a biological phantom. Based on the experimental studies, an evaluation platform for the arteriosclerosis in thin blood vessel was proposed, and then a simpler, painless and cheaper method was expected to detect the arteriosclerosis in human body.

First, the principle of photoacoustic excitation and the acoustic modes in the tube were described. An ideal stiff-boundary cylindrical structure was used to simulate this specific situation. The acoustic field and corresponding resonance mode were studied and theoretically derived from the fundamental wave equation and the stiff boundary condition. Then we present numerical and experimental studies on the effects of tube hardness on the directivity of the generated photoacoustic signal. A thin glass capillary and silicone tube of 1 mm in diameter were tested using a pulsed light of 637 nm wavelength. Black ink was confined in the glass capillary and silicone tube as a photoacoustic sample material. In the glass capillary, acoustic resonance modes in the glass capillary were efficiently excited, and clear

directivity was observed in the generated photoacoustic signals. On the other hand, little resonance was stimulated in the silicon tube because of the acoustic impedance matching between the sample and surrounding media, which resulted in the weak confinement of acoustic waves.

Second, we prepared a thin silicone tube filled with a mixture of red ink and olive oil as a model that mimics arteriosclerosis. The tube was embedded in a soft phantom. Photoacoustic measurements were performed using 405 nm and 520 nm laser diodes. As a result, the 405 nm laser produced a higher photoacoustic signal as the oil concentration in the mixture increased, whereas the 520 nm laser produced lower photoacoustic signals as the oil concentration increased. By focusing on the difference in the optical absorption at different wavelengths between the red ink and oil, it was shown that there was a possibility of estimation of the oil concentration from the ratio of photoacoustic signals between different wavelengths.

Third, a platform was designed for quantitative evaluation of the degree of vascular occlusion using a low power pulsed semiconductor laser and a MHz-range ultrasonic transducer to satisfy the demand of realistic evaluation. To replicate clogged blood vessels, we partially filled a silicone tube with commercially available beef fat. After creating five samples with varying degrees of occlusion, we experimentally investigated the photoacoustic characteristics of each sample. In addition to differences in the amplitude of the photoacoustic signals, we focused on the acoustic impedance differences between the beef fat and the silicone tube. We evaluated the degree of occlusion in the tubes based on the resonance frequency and the strength of the resonance for each sample.

Finally, instead of using a biological phantom, we investigated the photoacoustic signals generated from the thin blood vessels in the author's finger. The photoacoustic signals generated from the actual blood vessels were similarly not very strong in resonance, akin to the silicone tubes in the biological phantom. However, unlike the single-layer structure of the silicone tube, the actual blood vessels have a multi-layer structure, which allowed us to observe multiple resonance peak frequency characteristics compared to the silicone tubes.