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Photoacoustic spectral analysis of biological tissue for plaque diagnosis

プラーク性状診断のための生体組織の光音響スペクトル解析

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1. Introduction

Arteriosclerosis often leads to a stroke or a heart attack, so it is important problem to prevent arteriosclerosis in medical care. Arteriosclerotic mechanism is that plaques build up in the intima of arterial walls, followed fibrosis, calcification. This study is aimed for the detection of the plaques using photoacoustic imaging. Photoacoustic images were mixed ultrasound imaging which obtain anatomical features deeply and optical imaging which obtain functional features noninvasively. At the principle, by laser irradiation tissues causes a heat elasticity expansion and produce the photoacoustic signal.[1)] This study conducts photoacoustic spectral analysis of biological tissue for plaque diagnosis using photoacoustic imaging.

2. Method

The experimental setup is shown in **Fig.1**. Generally, the irradiation intensity of pulse laser changes with a wavelength and a pulse, and the reflectance of beam sampler alse vary with wavelength. So, the intensity of laser irradiation to sample and of reflectance are measured by changing the wavelength. Experiment condition is that water temperature is 39 ℃, frequency of the laser irradiation is 10 Hz, sampling rate is 50 MHz, a beam diameter is 5 mm, respectively.

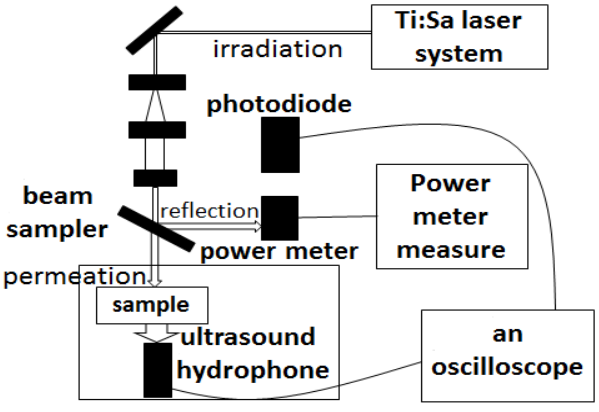

Fig.1 a schematic of the experimental setup

the cuvette width (thickness of the sample) is 1mm. Wavelength ranges from 710 to 980 nm by increments of 5 nm. Firstly, using the experimental setup, we confirmed whether the photoacoustic signal generates from porcine fatty tissues by laser irradiation. Secondly, we obtained the photoacoustic spectrum by correcting amplitude level of the laser output for each wavelength from 710 to 980 nm. Then, we confirmed whether the spectrum is correlated with the absorption coefficient of fat.[2)] Finally, in order to examine the photoacoustic properties of other components of arterial tissues, we also obtained photoacoustic spectra of porcine muscle tissue and of aortic wall by changing wavelengh of pulse laser from 710 to 980 nm.

3. Experimental results

The signals were detected from fatty tissues as shown in **Fig. 2**.

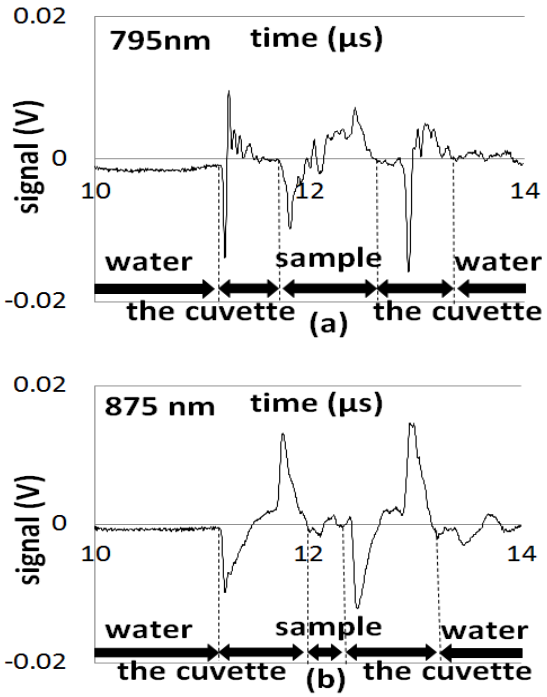

Fig. 2 the signal of fatty meet

Photoacoustic signals generated at tissue sample, and the cuvette were identified by calculation of

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travel time as shown in **Fig. 2(a)**. The photoacoustic signal of the fatty tissue was located from 12 to 12.66 μs for the wavelength of laser from 710 to 980 nm except for around 870 nm. However, the cuvette absorbs the light largely for the range of wavelength from 870 to 880 nm, consequently, photoacoustic signals genereted from the cuvette prohibite the correct measurement of the signals for sample, as shown in **Fig. 2(b)**

Detected photoacoustic spectrum for fatty tissue was campared with the optical absorption spectrum of fat (lard).[2] for the range of wavelength from 710 to 980 nm. As a result, they are correlated very well as shown in **Fig. 3.** Here, the graph was normalized by the peak because the way to obtain the spectra is different between reference and this study. (see **Fig.3**)

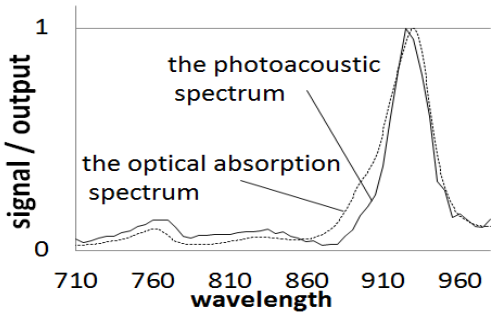

Fig. 3 photoacoustic spectrum and the optical absorption spectrum

Finally, we measured the photoacoustic signal for porcine muscle tissue and of aortic wall by changing wavelengh of pulse laser from 710 to 980 nm. The spectra for each tissue are shown in **Fig.4.**

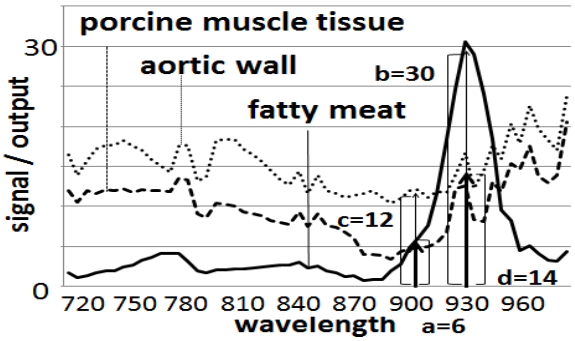

Fig. 4 photoacoustic spectra of some tissues

4. Discussion

It can be concluded from **Fig 3** that if an optical absorption coefficient is known, the photoacoustic spectrum will be approximately estimated. The reasons that two spectra are slightly different in **Fig. 3** are the differrence of component between porcine fatty tissue and lard, and the incomplete correction of the reflectance.

Fig. 4 indicates that photoacoustic spectrum of fatty tissue is much different from those of muscle tissue and aortic wall. Therefore, accessment of the present of plaque is expected by laser irradiation with different wavelength. For example, the relative level of photoacoutic signals for fatty tissue at 900 nm and at 930 nm are set to a and b, respectively. Based on **Fig. 4**, a=6 and b=30.

$$\eta(r) = \frac{b\cdot r+(1-r)d}{a\cdot r+(1-r)c} \qquad (1)$$

$$\theta(r) = \eta(r)/\eta_v = \frac{b\cdot r+(1-r)d}{a\cdot r+(1-r)c}\frac{c}{d} \qquad (2)$$

Similarly, the relative level of photoacoutic signals for aortic wall are set to c and d. Based on **Fig.4**, c=12 and d=14.

We introduce a parameter η which indicates the gradient of spectrum defined as $\eta_f = b/a$ for fatty tissue and $\eta_v = d/c$. Then, $\eta_f = 5$ and $\eta_v = 1.17$. Next, ratio of η_f to η_v is $\eta_f / \eta_v = 5/1.17 = 4.3$, which shows the possibility of detection of fat- rich tissue such as vulnerable plaque.

The feature value eq. (1) will be obtained in the situation that the volume ratio of fat and the artery wall organization in the sample volume is r : 1-r
A ratio of fat is estimated to substitute the above number to eq. (2). The result shows **Fig. 5**.

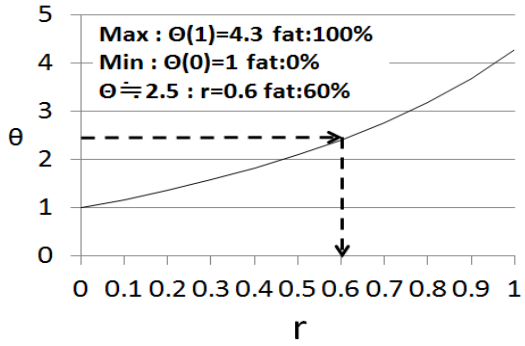

Fig. 5 the grapf of θ

5. Conclusion

This study shows that the photoacoustic spectrum is nearly equal to the optical absorption spectrum. Moreover, accessment of the present of plaque is expected by laser irradiation with different wavelength. In the future, it is necessary to consider the possibility to identify constituents in tissue.

Reference

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