Optical coefficient measurements using bulk living tissue with optical fiber puncture

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Abstract: Slicing sample preparation in tissue optical characteristic measurement may make huge error over individual optical differences. We proposed the combination of light intensity measurement through an optical fiber puncturing into a bulk tissue varying detection numerical aperture and ray tracing calculation to avoid slicing degradation of living tissue. To reveal the characteristics of this measurement, optical coefficients of pig myocardium obtained by the IAD method with slicing living tissue sample preparation and proposed measurement method were compared. In the proposed method, a silica fiber installed in an 18G needle was punctured up to the bottom of the myocardial bulk tissue to measure light intensity in the bulk tissue changing depth and numerical aperture. The author found that measured apparent attenuation coefficients tended to strongly depend on numerical aperture. The ray trace calculation explained the same numerical aperture tendency in above mentioned experimental result. Optical characteristics of sliced myocardial samples revealed temporal change due to dehydration.

Keywords: slicing sample preparations, optical fiber puncturing, ray tracing calculation, optical coefficients, numerical aperture

1. Introduction

The author focused on the fact that errors in the method of measuring optical coefficients of tissues tend to occur due to slicing preparations. We proposed the combination of light intensity measurement through an optical fiber puncturing into a bulk tissue varying detection numerical aperture and ray tracing calculation to avoid slicing degradation of living tissue. To reveal the characteristics of this measurement, optical coefficients of pig myocardium induced by the IAD method with slicing living tissue sample preparation and proposed measurement method were compared.

Optical coefficients of myocardium such as absorption coefficient μα, scattering coefficient μs, and anisotropy parameter g are used in the myocardium calculation model. However, these coefficients are needed to be measured because various values have been reported in these coefficients over individual optical differences of living samples [1-3]. Optical coefficients calculated using sliced tissue could be unstable because they are affected by hydration and heterogeneity on the sample surface [4]. Optical coefficient measurement using bulk tissue could eliminate instability comes from slicing. We measured light intensity in bulk tissue of pig myocardium through the punctured optical fiber. The absorption coefficient and reduced scattering coefficient were adjusted to fit the measurement result by the ray tracing calculation using the Monte Carlo method.

2. Material and Method

2-1: Measurement of optical coefficients using bulk tissue

A schematic illustration of this experimental system is shown in Fig.1. A bulk tissue cut out from a fresh pig myocardium was placed on an acrylic board. A red diode laser (663 nm wavelength) was irradiated down to the bulk tissue through a silica fiber. Another silica fiber (core: 200 μm; NA: 0.5) installed in an 18G needle was punctured up to the bottom of the bulk tissue to measure light intensity in the bulk tissue. This needle was moved by an automatic stage. By moving the needle downward by the automatic stage, light intensity was measured at a total of 6 points from 1 mm to 6 mm depth every 1 mm. The detection NA was varied from 0.1 to 0.5 changing detection NA outside of the sample by an aperture. An apparent effective attenuation coefficients of each detection NA of light intensity was calculated by the exponential fitting.

Red laser Wavelength: 663 nm
Myocardial tissue
18G Needle
Automatic stage
Power meter display
Detection fiber NA: 0.5
Aperture
Power meter CP-2 VIS

Fig. 1 Schematic illustration of this experimental system

2-2: Ray tracing simulation

In order to determine appropriate optical constants of the pig myocardium, we performed a ray tracing calculation to fit measured NA dependence of apparent attenuation coefficient adjusting the absorption coefficient and scattering coefficient. In this simulation, we created detection fiber models with NA change from 0.1 to 0.5 to mimic the experimental measurement scheme.

2-3: Measurement of optical coefficients using sliced tissue

In the general measurement method using sliced tissue sample, we measured transmittance and reflectance of the sample tissue with a spectrophotometer with an integrating sphere at the same time. Then, the optical coefficients were calculated by entering the measured values into the program incorporating the Inverse Adding Doubling (IAD) method [5]. In order to evaluate quantitatively the dispersion of the optical coefficients by slicing sample preparation, those of the sample immediately after slicing and 10 minutes after slicing were compared.

Keywords: slicing sample preparations, optical fiber puncturing, ray tracing calculation, optical coefficients, numerical aperture

References

3. Results

3-1: Measurement of optical coefficients using bulk tissue

The results of measured and calculated apparent effective attenuation coefficients of each NA using the bulk tissue are shown in Fig. 2. The absorption coefficient 0.02 mm\(^{-1}\) and scattering coefficient 2.0 mm\(^{-1}\) were used in the ray tracing calculation myocardium model.

![Fig. 2 Measured and calculated apparent effective attenuation coefficient (N=3)](image)

The author found that measured apparent attenuation coefficients tended to strongly depend on NA. The ray trace calculation could explain the same NA tendency.

3-2: Measurement of optical coefficients using sliced tissue

The absorption coefficient and scattering coefficient immediately after slicing and those 10 minutes after slicing are shown in Table 1.

<table>
<thead>
<tr>
<th>Just after slicing</th>
<th>0.051</th>
<th>1.07</th>
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<tr>
<td>10 minutes after slicing</td>
<td>0.072</td>
<td>1.17</td>
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Forty-one % of the absorption coefficient change and 9% of the reduced scattering coefficient change were obtained. The optical change of living tissue due to slicing was confirmed.

4. Conclusion

The author found that measured apparent attenuation coefficients obtained by our proposed method tended to strongly depend on NA. The ray trace calculation explained the same NA tendency. In contrast, we revealed 41% of absorption coefficient change and 9% of the reduced scattering coefficient change with using slicing method in 10 minutes.

Reference