Microcirculation Imaging with Multicolor LEDs and Mini CCD camera

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The microcirculation is defined as the smallest vessels where gas and nutrient are exchanged with tissues.

In treatment of critical care, it is desired to monitor microcirculatory dysfunction.

The recent development of new imaging modalities such as sidestream dark field (SDF) imaging has helped to directly investigate microcirculation in clinical and experimental studies.

**PURPOSE**

To acquire clinically useful information from more sophisticated analysis of the SDF images. In order to do so, we made a camera for SDF imaging.
Sidestream Dark Field (SDF) imaging

Illumination is provided by surrounding a central imaging optics.

Optically isolated from the illuminating outer ring thus preventing the microcirculatory image from contamination by tissue surface reflections.

Light from the illuminating outer core of the SDF probe penetrates the tissue and then illuminates the tissue-embedded microcirculation by scattering.

A schematic illustration of the Sidestream Dark-Field (SDF) imaging technique
Trial model for SDF imaging

Six pieces of chip LEDs are placed around the exterior tip of the probe to provide an even illumination (three colors (RGB) chip LEDs)

AS-807SP-3 with 380,000 pixels CCD video camera (Pony Industry CO., Japan)

- Set the slope of LED Chips about 16 degree — provide a strong light intensity
- Set Silicon plate tip of probe — protect LEDs
- Chip LEDs are used — The width can be as small as 13.5mm

Geometry of head part the imaging system

(front side)

(CC
&D Camera)

Screw Fixation

(13.5mm)

(lateral side)

LED Chip

Silicon Plate

2mm

Six pieces of chip LEDs are placed around the exterior tip of the probe to provide an even illumination (three colors (RGB) chip LEDs)
Trial model for SDF imaging

- Total set up of the trial model

Six pieces of chip LEDs are placed around the exterior tip of the probe.

LED external view

- front
- upper

Six pieces of chip LEDs are placed around the exterior tip of the probe.

Spectral intensity of the color LED chips and spectral absorption coefficient of Hb and HbO₂

Stroboscopic mode

(In order to collect the images of the same area)
Human sublingual microcirculation

- SDF probe is placed on human sublingual surfaces
- High contrast images were acquired under Green and Blue LEDs

Identify vessel structure and blood flow change in human sublingual microcirculation
Pig mucosal microcirculation

- SDF probe is placed on mucosal of the small intestine surfaces
- Illuminating by Blue and Green LEDs respectively
- Collect the images of the same area

**Illuminated by Blue LED**

**Illuminated by Green LED**

Identify vessel structure and blood flow change in pig mucosal microcirculation
Spectrophotometric method for determining the degree of oxygen saturation of the hemoglobin in the blood in vivo utilizes the differences between Hb and HbO\textsubscript{2} in spectral absorption.

- 470nm spectral image emphasizing the change of absorption spectra in HbO\textsubscript{2}(⊔)
- 527nm spectral image has an isosbestic point (●) in the absorption spectra of Hb and HbO\textsubscript{2}

Two visible spectral bands among three LED spectral bands can be used to estimate oxygen saturation.
Oxygen concentration

Scattering model of light transmission in tissue.

SDF probe is placed on tissue surfaces

Directly penetrates deep into the tissue illuminating the microcirculation

Scattering light is used to obtain the SDF image directly

Light enters to the tissue from the peripheral region, scatters and illuminates blood vessels as the incident light in the transmission model

Use Lambert–Beer law to estimate the oxygen saturation from the obtained images

Lambert–Beer law

Incident light

Transmitted light

Cross section
Biological phantom

Made a tissue-mimicking vessel phantom

<table>
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<th>0%</th>
<th>100%</th>
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Artery blood sample was obtained from a healthy bovine

obtained blood samples OS(%) 66, 73, 77, 80, 86

mixing with different ratio of artery blood

Artery blood sample was obtained from a healthy bovine

Illustration of the phantom:
- Made of agar
- Vessel imitative bored hole
- Diameter was 0.128mm
- Depth 1mm

OS measurement

Used to measure the OS of blood sample

measured value was used as ground truth

i-STAT 300F portable blood analyzer
The result of Biological phantom

**Spectral images of biological phantom**

- Collect the images of the same area under two color LEDs
- Estimate the oxygen saturation five times for each phantom and calculate each mean value

**Oxygen saturation estimation**

- Five phantoms with different OS, 66%, 73%, 77%, 80%, and 86% were made and the images were captured five times for each phantom
- The estimated values correlate to the true ones in some degree
- Have rather large variation
Conclusions and future works

Conclusions
• Use the multicolor LEDs and Mini CCD camera the flow of RBCs from vascular structure of human and mucosal microcirculation of a pig were visualized.
• We also could get the three band images of the subject and using the difference of the optical absorption coefficient of hemoglobin to show the possibility of the degree of oxidation hemoglobin by imaging.

Future works
• It is expected to obtain the distribution of microvascular oxygen saturation.
• To get a brighter high-contrast spectral image, a stable acquisition method and device development is needed.
• We will also improve the technique regarding the estimation of oxygen saturation.

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