Microcirculation Imaging with Multicolor LEDs and Mini CCD camera

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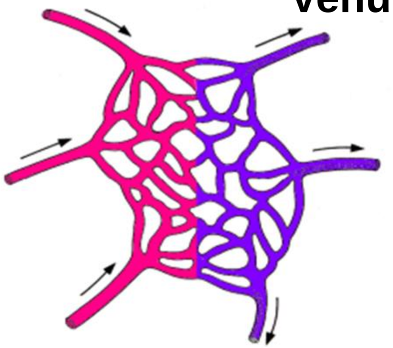
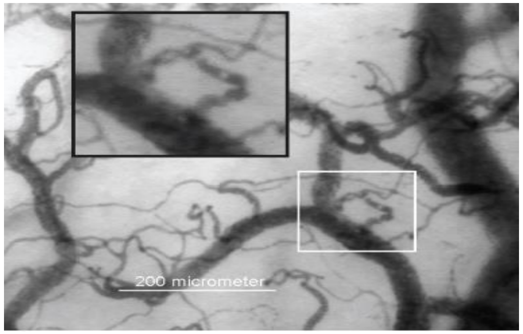
Research Center for Frontier Medical Engineering

Introduction



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 .



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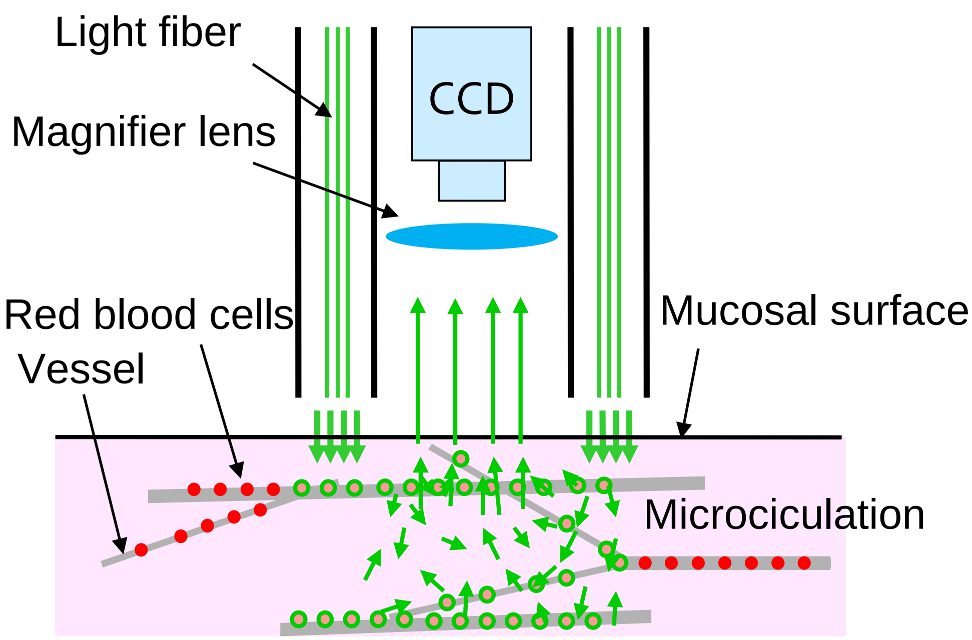
The recent development of new imaging modalities such as sidestream dark field (SDF) imaging has helped to directly investigate microcirculation in clinical and experimental studies

Identify vessel structure and blood flow change in human sublingual microcirculation

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



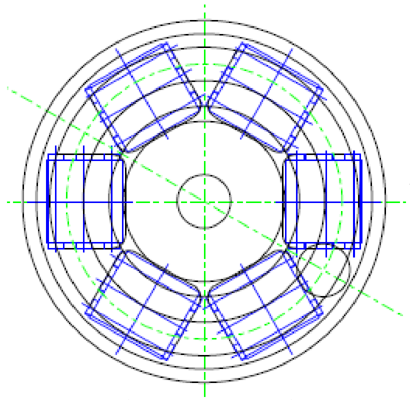
A schematic illustration of the Sidestream Dark-Field (SDF) imaging technique

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.

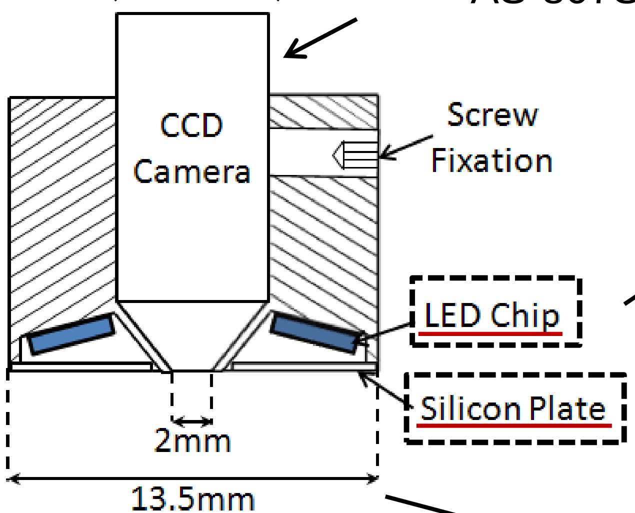
Trial model for SDF imaging



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

(front side)

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



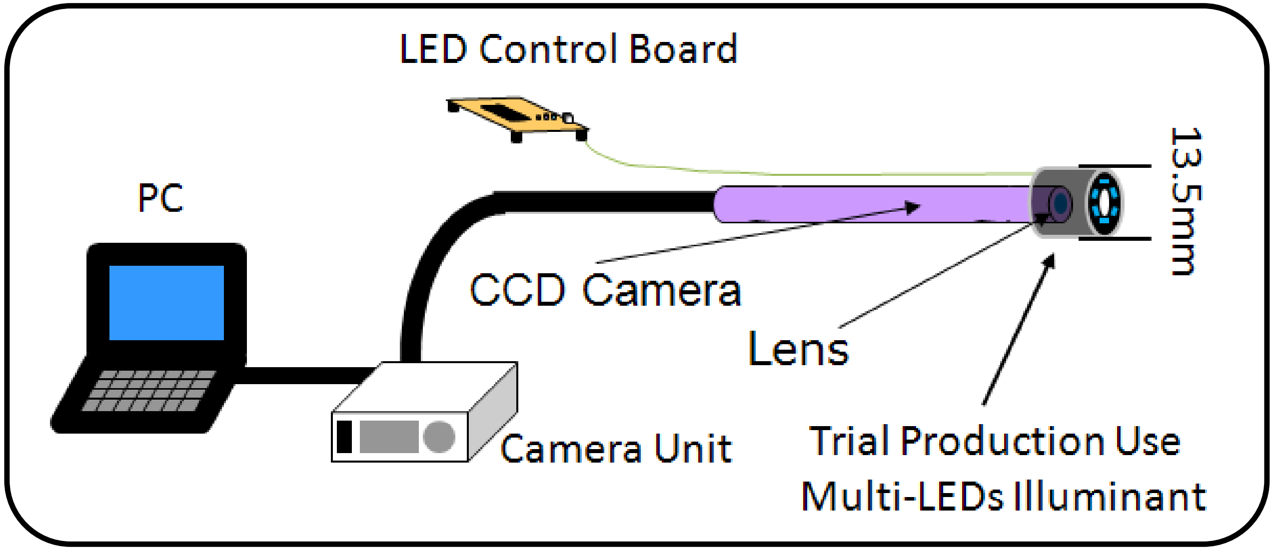
(lateral side)

Geometry of head part the imaging system

- ✓ 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 as13.5mm

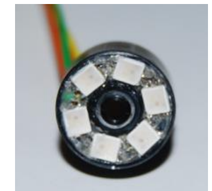
Trial model for SDF imaging

◆ Total set up of the trial model

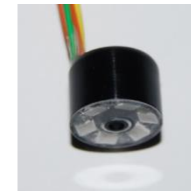


LED external view

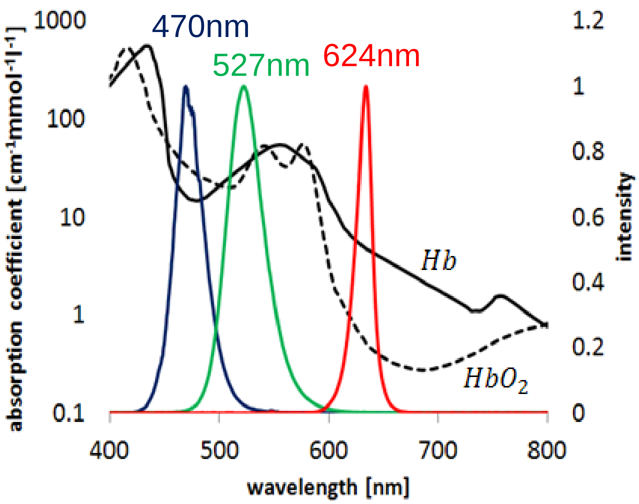
front



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 HbO_2

Blue

Green

Red

stroboscopic mode

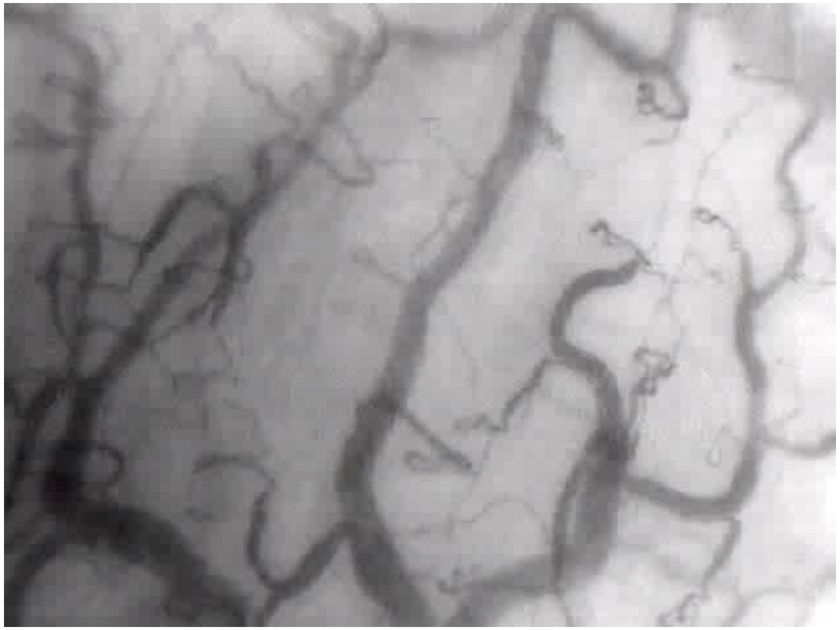
(In order to collect the images of the same area)

Human sublingual microcirculation

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

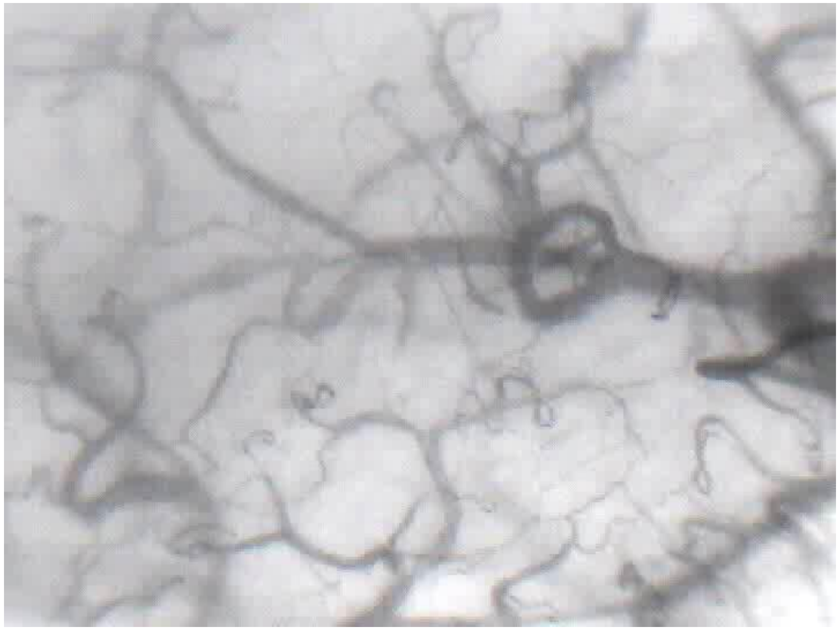
Sublingual microcirculation

Illuminated by Blue LED



1.5mm

Illuminated by Green LED

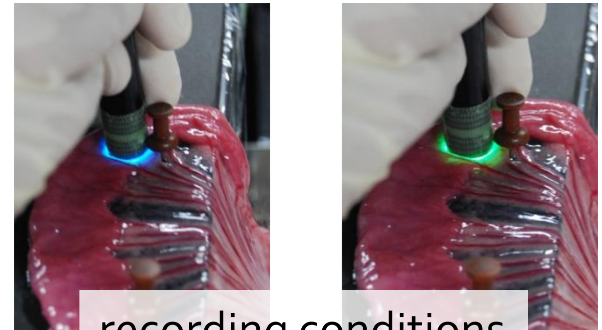


1.5mm

Identify vessel structure and blood flow change in human sublingual microcirculation

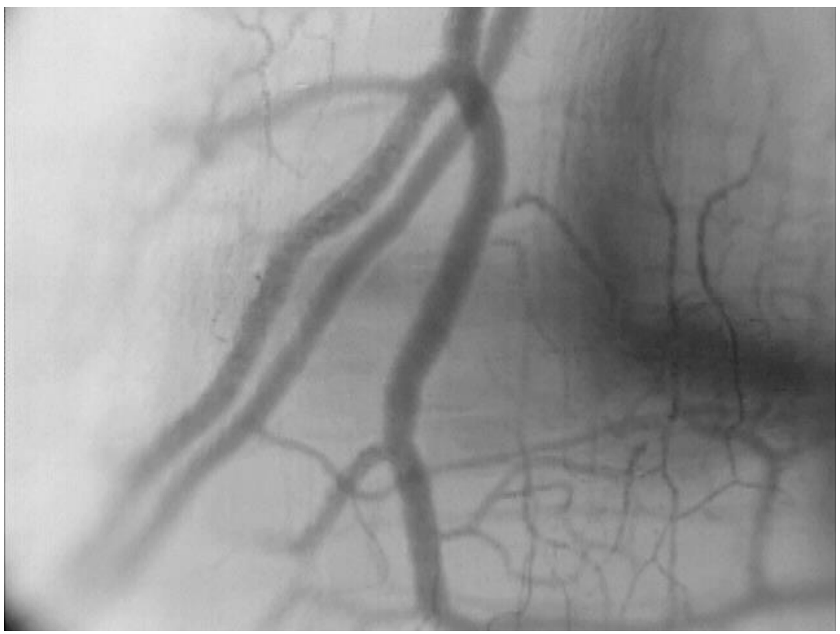
Pig mucosal microcirculation

- 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



recording conditions

Illuminated by Blue LED



1.5mm

Illuminated by Green LED

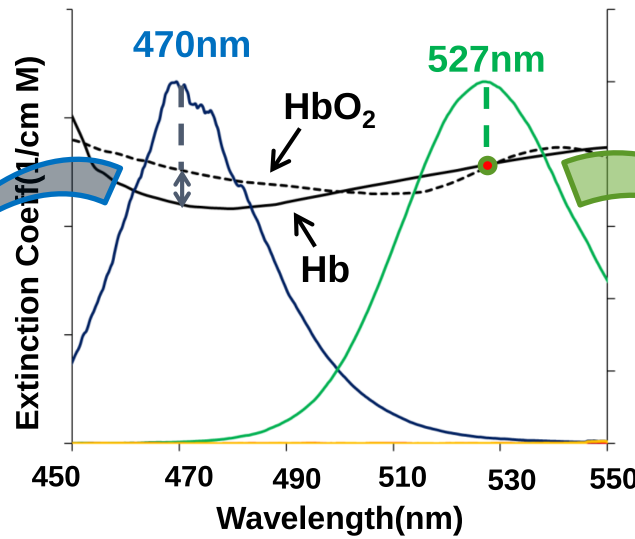
1.5mm

Identify vessel structure and blood flow change in pig mucosal microcirculation

Oxygen concentration

Spectrophotometric method for determining the degree of oxygen saturation of the hemoglobin in the blood in vivo utilizes the differences between Hb and HbO_2 in spectral absorption.

Blue(470nm)



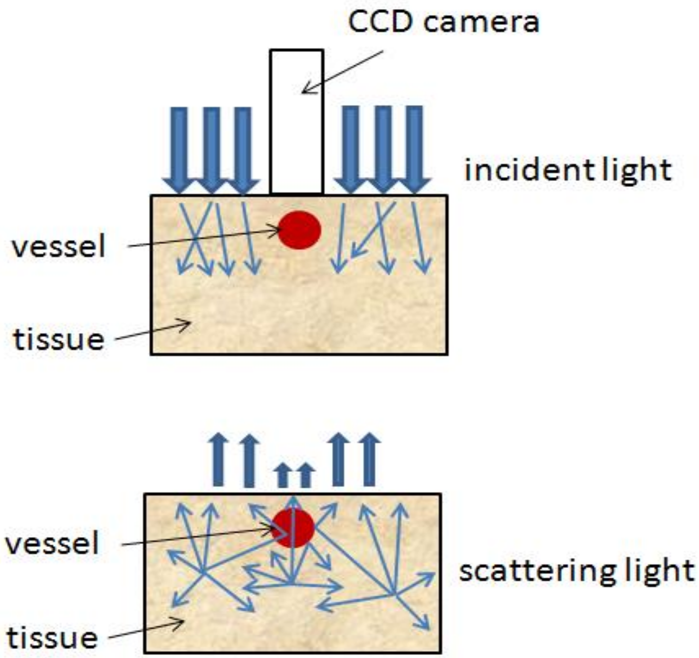
Hb and HbO_2 have different absorption at 470nm and 525nm

Green(527nm)

- 470nm spectral image emphasizing the change of absorption spectra in HbO_2(↕)
- 527nm spectral image has an isosbestic point (●)in the absorption spectra of Hb and HbO_2

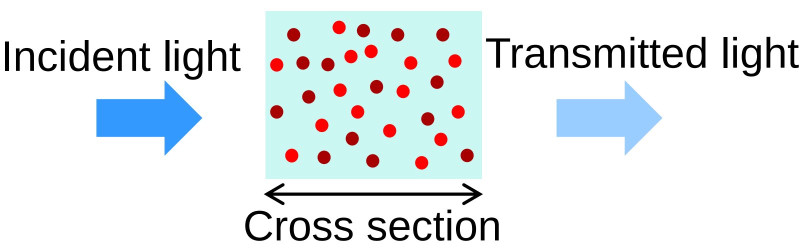
Two visible spectral bands among three LED spectral bands can used to estimate oxygen saturation

Oxygen concentration



Scattering model of light transmission in tissue.

Lambert–Beer law



SDF probe is placed on tissue surfaces

Directly penetrates deep into the tissue illuminating the microcirculation

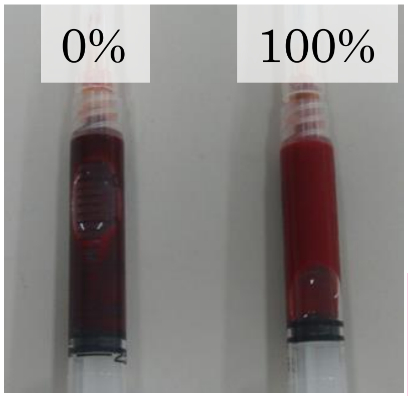
Scattering light is used to obtain the SDF image directly

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

Biological phantom

Made a tissue-mimicking vessel phantom



mixing with different ratio of artery blood

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

Artery blood sample was obtained from a healthy bovine

Filling

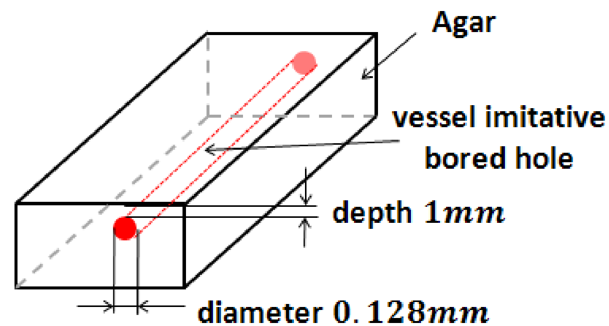


Illustration of the phantom

- Made of agar
- Vessel imitative bored hole
- Diameter was 0.128mm
- Depth 1mm

OS measurement

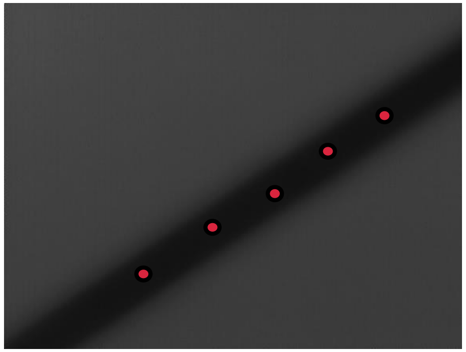
i-STAT 300F portable blood analyzer

- Used to measure the OS of blood sample

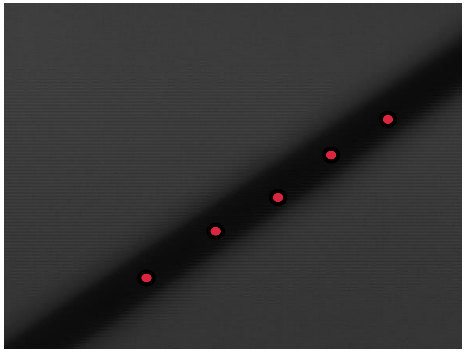
measured value was used as ground truth

The result of Biological phantom

Spectral images of biological phantom



470nm

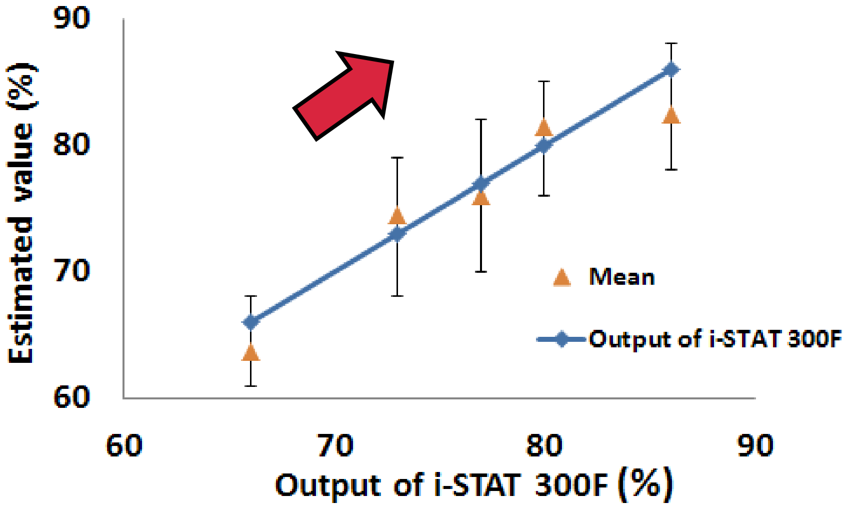


527nm

- Collect the images of the same area under two color LEDs

- Estimate the oxygen saturation five times for each phantom and calculate each mean valve

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.

Acknowledgement

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