In vivo imaging of cerebral hemodynamics and light scattering parameter in rat brain with a digital red-green-blue camera

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Cerebral hemodynamics and tissue morphology is important for evaluating brain function and tissue viability in neurosurgery as well as in the diagnosis of several neurological disorders. Diffuse reflectance spectroscopy is one of the most promising methods for evaluating the cerebral hemodynamics and regional cerebral oxygen saturation of *in vivo* brain tissue. Diffuse reflectance spectroscopy based on the measurement of CW light can be simply achieved with an incandescent white light source, inexpensive optical components, and a spectrometer. Several imaging methods based on diffuse reflectance obtained from the exposed *in vivo* brain tissue have been used to acquire the spatiotemporal maps of cortical hemodynamics [1-5]. The use of a red-green-blue (RGB) image acquired by a digital RGB camera is promising as a technique of rapid and cost-effective intraoperative imaging.

In the present study, we investigate a method to monitor the spatial distribution of total hemoglobin concentration (C_{HbT}), the regional oxygen saturation (rSO_2), and the scattering power b in the expression of $\mu_s'(\lambda)=a\lambda^{-b}$ in cerebral cortex using a digital red-green-blue camera. In the method, the *RGB*-values are converted into the tristimulus values in CIEXYZ color space which is a device-independent color system and compatible with the common RGB working spaces (NTSC, sRGB, etc). Monte Carlo simulation (MCS) for light transport in tissue is used to specify a relation among the tristimulus *XYZ*-values and the total hemoglobin concentration (C_{HbT}), the regional oxygen saturation (rSO_2), and the scattering power b.

A white-light emitting diode (LED) illuminated the surface of the exposed cortex via a light guide and a ring-shaped illuminator with a polarizer. The light source covered a range from 400 to 780 nm. Diffusely reflected light was received by a 24-bit RGB CCD camera without an IR cut filter via an analyzer and a camera lens to acquire an RGB image of 640×480 pixels. The primary polarization plate (ring-shaped polarizer) and the secondary polarization plate (analyzer) were placed in a crossed Nicols alignment in order to reduce specular reflection from the sample surface. A standard white diffuser was used to regulate the white balance of the camera. The field of view of the system was 9.31×6.98 mm^2 with 1024×768 pixels. The lateral resolution of the images was estimated to be 9.1 μm. The RGB images were then used to estimate the images of C_{HbT}, rSO_2, and scattering power b according to the process described.

As the feasibility study, we performed *in vivo* recordings of RGB images for exposed brain of rats while varying the fraction of inspired oxygen (FiO_2). The values of rSO_2 and b are decreased as FiO_2 decreases. The value of C_{HbT} begins to increase before respiratory arrest (RA) and reaches a maximum amplitude approximately 1 min after RA, which is indicative of an increase in blood flow for compensating hypoxia. Immediately after RA, the values of both rSO_2 and b decreased rapidly, and then, increased gradually. The time courses of C_{HbT} and rSO_2 are consistent with the well-known hemodynamic responses to the change in FiO_2. The time course of b is indicative of morphological changes due to physiological conditions and loss of tissue viability in brain tissue.

References

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