PROCEEDINGS OF SPIE

SPIEDigitalLibrary.org/conference-proceedings-of-spie

Analysis of experimental surgical lighting parameters in organs in vivo

Mamoshin, Andrian, Seryogina, Evgeniya, Krasova, Anastasiia, Potapova, Elena, Shupletsov, Valery, et al.

Andrian Mamoshin, Evgeniya Seryogina, Anastasiia Krasova, Elena Potapova, Valery Shupletsov, Andrey Dunaev, Anton Chernyakov, Andrey Aladov, Yuri Ivanov, Dmitry Panchenkov, "Analysis of experimental surgical lighting parameters in organs in vivo," Proc. SPIE 11457, Saratov Fall Meeting 2019: Optical and Nano-Technologies for Biology and Medicine, 114570U (9 April 2020); doi: 10.1117/12.2564391

SPIE.

Event: Saratov Fall Meeting 2019: VII International Symposium on Optics and Biophotonics, 2019, Saratov, Russian Federation

Analysis of experimental surgical lighting parameters in organs *in vivo*

Andrian Mamoshin[a,b], Evgeniya Seryogina[a*], Anastasiia Krasova[a], Elena Potapova[a], Valery Shupletsov[a], Andrey Dunaev[a], Anton Chernyakov[c], Andrey Aladov[c], Yuri Ivanov[d,e], Dmitry Panchenkov[f]

[a]Research and Development Center of Biomedical Photonics, Orel State University, Orel, Russia

[b]Orel Regional Clinical Hospital, Orel, Russia

[c]Submicron Heterostructures for Microelectronics, Research & Engineering Center, RAS, Saint-Petersburg, Russia

[d]Federal Scientific and Clinical Center for Specialized Medical Service and Medical Technologies, Moscow, Russia

[e]Central Research Institute of Tuberculosis, Moscow, Russia

[f]A.I. Yevdokimov Moscow State University of Medicine and Dentistry, Moscow, Russia

ABSTRACT

To determine optimal lighting conditions for contrast imaging of surgical objects, optical characteristics of biological tissues and spectral characteristics of smart light "LED light" source based on RGBW LED are compared. The spectral characteristics of tissues and organs have been investigated. Optimal lighting conditions for contrast imaging of biological tissues during surgery were studied. The optimal colour of light for working with individual organs against the background of the whole organism is selected. Perspective of light fixture application with the possibility of dynamic colour control is shown.

Keywords: light emitting diode (LED), multi-colour LED, RGB-mixing, dynamic control, surgical light, contrast visualization of biological tissues

1. INTRODUCTION

The human eye is not always able to distinguish small objects with similar colours. It is also known that any colour can be obtained by mixing three colours: red, green and blue (RGB)[1]. In this way, it is possible to influence the perception of colours by the human eye during operations by changing the colour-dynamic parameters of the surgical light. It is especially important to take into account the individual characteristics of a surgeon when performing cavity operations. Surgical lighting is an indispensable part of any surgical intervention[2,3]. The optimal light source is necessary for any doctor's manipulation, including examination of the patient, dressings, and surgical interventions. It is important for a surgeon to clearly distinguish anatomical structures, to identify vessels and nerve formations for a successful and rapid operation.

A number of parameters are requirements for the modern surgical lights, such as adjustment to reduce glare and shadows, brightness adjustment, uniform light, central illumination. However, currently used lamps have a number of disadvantages that prevents an accurate assessment of tissue parameters: low contrast of tissues, insufficient colour reproduction, lack of volumetric vision, insufficient depth of illumination, the fusion of neighboring structures. In addition, improperly chosen lighting causes rapid fatigue of the operating team, increases stress level and causes emotional stress.

The LED surgical lights provide white light with high CRI close to natural light, which is comfortable for operating[4-6]. Using the special LED light source based on RGB system allows you to raise the contrast rendering of objects against the background of adjacent objects by colour parameters changing. Colour accents help to identify the boundaries of the area of interest, consider the structure of organs and tissues, to determine the pathological changes or new growths borders.

* e.s.seryogina@gmail.com; phone 7 4862 419876; bmecenter.ru/en

Saratov Fall Meeting 2019: Optical and Nano-Technologies for Biology and Medicine, edited by Valery V. Tuchin, Elina A. Genina, Proc. of SPIE Vol. 11457, 114570U · © 2020 SPIE
CCC code: 1605-7422/20/$21 · doi: 10.1117/12.2564391

The latest research is aimed at studying the operating parameters of a single organ in vitro[7,8], not taking into account the fact, that it is an essential anatomical and functional part of the whole body. The spectral characteristics of tissues depend on their functional state. Abnormal appearance of atypical chromophores altering cell structure and hemoglobin derivatives percentage affects the optical properties of tissues[9,10]. Visually, the tissue acquires pathologic changes that can be distinguished by using amplification or attenuation of certain colour parameter.

Investigation of characteristics of the light produced by mixing different combinations of colours (spectral distribution) is directed to development of the colour intensity library of illumination for individual organs, taking into account their anatomical position in relation to other organs and systems.

On the basis of accumulated data in the course of experimental studies, comparing the results with a view to identifying common characteristics of colour lighting body for optimal visual perception of the surgeon adjusted for individual variability of each individual have been conducted. The aim of this work is the identification of patterns using spectral data analysis and organoleptic correction to create a library of colour lighting combinations.

2. MATERIALS AND METHODS

In the biomedical laboratory, on the basis of Orel State University named after I.S. Turgenev (OSU) (Orel, Russia), tests researches on animals using "smart light" LED light source based on RGBW LED Phlatlinght CBM-360 Luminus Inc. were carried out[6].

Experimental studies were performed on clinically healthy male rats (n=5) of the Wistar line (age 6-7 months) (according to GOST 33647-2015). The work was approved by the Orel State University Ethics Committee (protocol No. 10 of 16.10.2017). Animals were kept in quarantine conditions for 2 weeks. The rats were kept in separate rooms for keeping laboratory animals under controlled environmental conditions (20-26°C at a relative humidity of 30-70%). The temperature and humidity in the room were monitored daily using automatic electronic thermometers and psychrometers throughout the day. The animal rooms maintained a 12-hour lighting cycle and a 10-fold change in the room's air volume per hour.The animals were fed using balanced granulated feed for rodents in accordance with daily physiological needs. Distilled deionized water was given ad libitum. During the study, rats were anaesthetized with Zoletil 100 (Vibrac, France) at standard dosages. Animals were placed on a special fixing platform. Experiments were carried out on the following areas: skin, muscle layer of the anterior abdominal wall, kidneys, liver and pancreas. In addition, the parameters of pancreatic tissues during the simulation of acute destructive pancreatitis and myxofibrosarcoma were evaluated in a single case.

In order to obtain spectral characteristics of tissues, the OL 770-LED High-speed LED Test and Measurement system were used[11].

A thin cut of the 1 mm thick tissue being studied (obtained with a scalpel) was placed on a 77 × 26 × 1 mm slide. Glasses with objects were installed in the OL770-71 set-top box for measurement of reflection spectra. The sample was fixed with a second thin cover glass A thin cut of the 1 mm thick tissue being studied (obtained with a scalpel) was placed on a 77 × 26 × 1 mm slide. Glasses with objects were installed in the OL770-71 set-top box for measurement of reflection spectra.

The second stage was the selection of a combination of colours for comfortable work and visualization of certain organs tissue. The scheme of the experiment is shown in Figure 1.

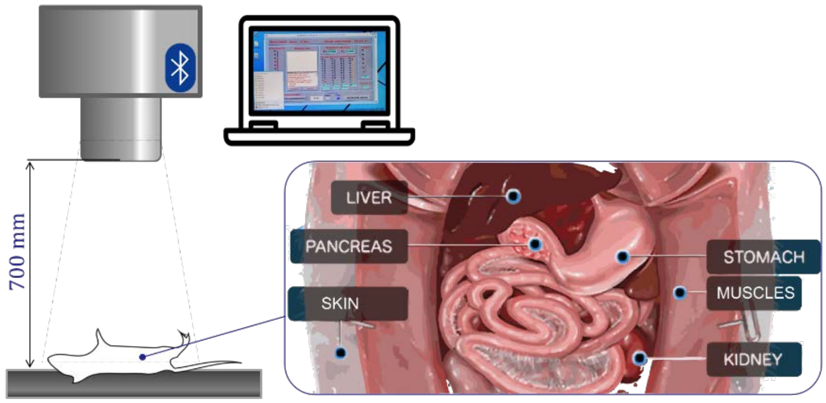

Figure 1. The experimental setup

The LED surgical light source was installed above a special operating table for small laboratory animals at a distance of 70 cm and provided a uniform light field of at least 20 × 20 cm (Figure 1). During the research, with the help of the software, spectral parameters of LED matrix were changed. The LED RGBW (RGBWLED) matrix included four crystals of the large area, different colour radiation: R - red, G - green, B - blue, as well as W-crystals with phosphor coating as white light sources with correlated colour temperature (6500 K). The light parameters of the lamp were controlled from a remote PC. On the basis of subjective visual assessment of surgical operating team, optimal illumination of operational field for tissues and organs was selected. The spectral composition of the emitted light was monitored by a portable MK350 spectrometer.

Selection of optimal illumination of operational field for each type of biological tissue was carried out using subjective visual evaluation of operational team. The criteria for selecting contrast rendering were as follows:

- Brightness and colour contrast compared to surrounding tissues;

- Clear distinction of anatomical structure of tissue and small details (absence of fusion).

In addition, the following were taken into account:

- Comfortable visual perception;

- Absence of highlights and shadows.

3. EXPERIMENTAL RESULTS

The resulting reflection spectra from different biological tissues on which their difference can be seen are shown in Figure 2.

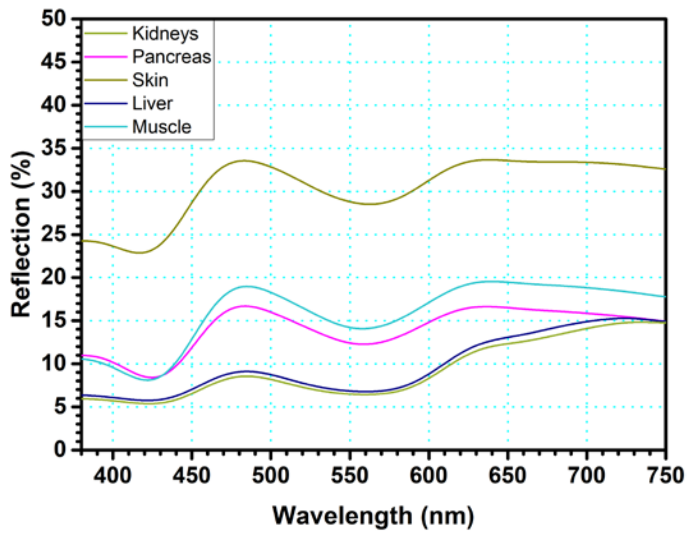

Figure 2. The reflection spectra of normal tissues

Based on the spectrophotometric studies optimal parameters of colour mixing for each organ and tissue were selected. The corrections during experimental studies *in vivo* were performed according to the recommendations of the operating team. The percentage of colour surgical source components contribution, as well as light and colour coordinates, is presented in Table 1 and 2.

Table 1. Power as a % of each colour's total optical power .

Area of study	**Red (630 nm)**	**Green (525 nm)**	**Blue (460 nm)**	**White (6500 K)**
Skin	24	22	4	50
Muscle layer	19	29	4	48
Myxofibrosarcoma	14	4	10	72
Kidney	30	16	8	46
Liver	25	25	8	42
Pancreas	27	24	4	45
Ischemic pancreas	14	11	9	66

Table 2. Experimental lighting parameters.

Area of study	**Characteristics of lighting**		
	Ev, lx	**x**	**y**
Skin	5900	0,355	0,414
Muscle layer	8210	0,354	0,344
Myxofibrosarcoma	180	0,34	0,332
Kidney	50	0,505	0,507

Area of study	Characteristics of lighting		
	Ev, lx	**x**	**y**
Liver	5590	0,325	0,369
Pancreas	760	0,324	0,37
Ischemic pancreas	500	0,344	0,366

Analysis of the experimental data showed that depending on the light, subjective features of the surgical team and individual characteristics of the biological object being studied are necessary to adjust the parameters of illumination of the surgical field. Overall power ratios of each colour (red green blue) for organs such as kidneys and liver have been identified (see table 1). Pancreatic ischemia significantly altered the distribution of power in the direction of decreasing red colour components, presumably caused by the cessation of blood flow compared to the normal body. When studying a mixofibrosarcoma located in the posterior limb, it was found that the optimal range for tumor imaging is close to muscle tissue, but it contains a marked decrease in green light source contribution.

4. CONCLUSION

Carried out studies of biological tissues spectral characteristics showed marked differentiation: the difference of biological tissues by reflection spectra and expediency of selection of optimal spectral-colour parameters of illumination for their contrast imaging. The analysis revealed that in order to optimize the visualization of each organ in the overall system lighting options should be individual. For better visualization of organs with high blood supply, it was necessary to strengthen the red wavelength region among other parameters. In contrast, if it is necessary to differentiate connective tissue structures from liver parenchymal tissue, an increase of green and yellow wavelength regions intensity of light sources is more preferred. In vivo studies allowed setting the colour balance for visualization of the relationship of each body with the surrounding systems and organs.

The proposed combination of lighting in this area can affect the decision-making process of a surgical team during surgical interventions in the liver, biliary tract and gastrointestinal tract. In the future, we plan to expand and improve the library of organs illumination settings in vivo in healthy and pathological tissue, which will form the basis for the development of lighting modes to improve and optimize the visualization of lesions and reduce the visual and emotional stress of operational teams.

It should also be noted that the carried out studies confirm that the surgical lamp should have a common lighting system combining high-quality white light and a dynamically controlled colour lighting system providing contrast imaging of biological tissues.

ACKNOWLEDGMENTS

The measurements were carried out at the Center of Multi-User Facilities “Element Base of Microwave Photonics and Nanoelectronics: Technology, Diagnostics, Metrology”

REFERENCES

[1] Iatridis, P. G., “Best and Taylor’s Physiological Basis of Medical Practice,” JAMA **266**(1), 130 (1991).
[2] Dumbleton, T., Clift, L., Bayer, S. H., Elton, E., Howarth, P. A. and Maguire, M., “Buyers’ guide: operating theatre lighting” (2010).

[3] Dianat, I., Sedghi, A., Bagherzade, J., Jafarabadi, M. A. and Stedmon, A. W., “Objective and subjective assessments of lighting in a hospital setting: Implications for health, safety and performance,” Ergonomics **56**(10), 1535–1545 (2013).
[4] Knulst, A. J., Stassen, L. P. S., Grimbergen, C. A. and Dankelman, J., “Choosing surgical lighting in the LED Era,” Surg. Innov. **16**(4), 37–49 (2009).
[5] Mamoshin, A., Alyanov, A., Seryogina, E., Potapova, E., Dunaev, A., Ivanov, A. and Aladov, A., “Possibilities of using dynamically controlled semiconductor light sources during surgical operations,” Proc. 2018 IEEE Int. Conf. Electr. Eng. Photonics, EExPolytech 2018, 288–291 (2018).
[6] Aladov, A. V., Biryuchinsky, S. B., Dubina, M. V., Zakgeim, A. L. and Mizerov, M. N., “Colour-dynamically controlled operational luminaire with full-colour light emitting diode,” Light Eng. **20**(3), 5–12 (2012).
[7] Kurabuchi, Y., Murai, K., Nakano, K., Ohnishi, T., Nakaguchi, T., Hauta-Kasari, M. and Haneishi, H., “Optimal design of illuminant for improving intraoperative color appearance of organs,” Artif. Life Robot. **24**(1), 55–58 (2019).
[8] Shen, J., Wang, H., Wu, Y., Li, A., Chen, C. and Zheng, Z., “Surgical lighting with contrast enhancement based on spectral reflectance comparison and entropy analysis.,” J. Biomed. Opt. **20**(10), 105012 (2015).
[9] Wang, H.-C. and Chen, Y.-T., “Optimal lighting of RGB LEDs for oral cavity detection,” Opt. Express **20**(9), 10186–10199 (2012).
[10] Tuchin, V. V., [Tissue optics: Light scattering methods and instruments for medical diagnosis: Third edition] (2015).