Artículo de investigación

Optical device for determining the viability of biological tissue

Оптическое устройство определения жизнеспособности биоткани

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Written by:
Alexey Vladimirovich Berdnikov[85]
ORCID: 0000-0001-6252-6356
Spin code: 9377-2826
Niyaz Azatovich Yunusov[86]
ORCID: 0000-0003-1139-7552
Dmitriy Ivanovich Vorosnin[87]
ORCID: 0000-0003-0721-1807
Spin code: 1297-7166
Dzgalil Khalilovich Misiev[88]
ORCID: 0000-0002-2797-7749
Spin code: 4037-3659

Abstract

The article solves the problem of increasing the objectivity of visual analysis of internal organs during surgery. The authors found that the spectral characteristics in the visible reflection spectrum allow the practicing surgeon to determine the presence of pathologies of the internal organs, as well as the location of their borders. The paper considers the existing methods for assessing the viability of biological tissues, the most promising one is selected. A description of the proposed device that implements the proposed method and a description of the program executed in the LabView environment is given. The work also presents a methodology for determining the optical parameters of the studied biological tissue of a group of conditionally healthy people, conducted statistical processing of data obtained experimentally and determined normal values.

Key words: Optical diagnostic methods, organ viability, lesion zones, necrosis borders, digital usb video camera, rgb and hsv encodings, normal indicator

Аннотация

В статье решается проблема повышения объективности визуального анализа внутренних органов во время операции. В результате исследования авторы установили, что спектральные характеристики в видимом спектре отражения позволяют практикующему хирургу определить наличие патологий внутренних органов, а также расположение их границ. В работе рассмотрены существующие методы оценки жизнеспособности биотканей, выбран наиболее перспективный. Приведено описание предлагаемого устройства, реализующего предложенный метод и описание программы, выполненной в среде LabView. В работе также представлена методика определения оптических параметров исследуемой биоткани группы условно здоровых испытуемых, проведена статистическаяобработка данных, полученных экспериментальным путем и определены показатели нормы.

Ключевые слова: оптические методы диагностики, жизнеспособность органа, зоны поражения, границы некроза, цифровая usb видеокамера, кодировки rgb и hsv, показатель нормы

[85] Associate Professor, Candidate of Technical Sciences, Associate Professor Kazan National Research Technical University named after A.N. Tupolev K. Marks St., 15, Kazan
[86] Bachelor, master degree program Kazan National Research Technical University named after A.N. Tupolev K. Marks St., 15, Kazan
[87] Postgraduate Kazan National Research Technical University named after A.N. Tupolev K. Marks St., 15, Kazan
[88] Postgraduate Kazan State Medical Academy of Postgraduate Education

Introduction

Necrosis is a common phenomenon, the causes of which can be a violation of venous or arterial circulation, infection by microbes. In the list of causes, there are also diseases of the central nervous system. A decrease in intestinal patency, for example, involves a deterioration in the state of intestinal function, a decrease in immunity, and metabolic disturbance. This is a favorable factor for the development of necrotic processes and its spread to the tissues of other organs of the digestive tract (Zlygostev and Pogorelov, 2012). Preservation of a necrotic intestinal loop or insufficient resection may turn out to be fatal, and unreasonable or excessive resection delays and aggravates the surgical intervention, may be incompatible with the patient's life (Hai, 1998). This is confirmed by studies conducted by M. Yu. Rosengarten (1972). The author showed that out of 83 patients (adults) who had an erroneous assessment of intestinal viability, 72 people died. It was concluded that the viability of the affected intestine was preserved in 32 patients on the basis of visual examination during surgery (Hai, 1998). Therefore, the task of accurately determining the boundaries of necrosis during amputation of dead sections of the intestine is relevant.

Errors in operational diagnostics indicate that it is not always possible to judge the viability of an organ by such visible signs as coloration, peristalsis, and luster of the serous cover. Determining the viability of a particular area of biological tissue creates significant difficulties and is the cause of diagnostic artifacts, often with serious or dangerous consequences. Therefore, it is necessary to accurately determine the boundaries of the affected areas during surgery. There are methods for determining the boundaries of necrosis by the introduction of contrast agents, but they can only be used when opening the organ.

There are methods for assessing the state of intestinal tissues by assessing blood circulation in the vessels of the test site. There are also methods for assessing the bioelectromagnetic reactivity index, evaluating the reflectivity of a microwave tissue signal, techniques based on changes in the polarization coefficient of the tissue, etc.

In addition, there is a method by which visually, i.e. subjectively, the boundaries between healthy and affected intestinal tissue are revealed by the color of the serous membrane, the frequency of intestinal motility and pulsation of its blood vessels.

Methodology

Despite the availability of technical solutions, to date, most clinics use routine simple methods that are based on assessing the appearance of the affected area of the intestine (color, luster), peristalsis, and pulsation of the mesenteric vessels. However, these signs allow subjectivity in the diagnosis and, therefore, do not exclude the possibility of errors in determining the viability of the body.

Optical methods for the diagnosis of biological tissues are becoming more common and are widely used in biology and medicine. Using optical radiation, it is possible to obtain information about the structure, composition and properties of biological tissues, to study the processes that occur in them without exerting a negative effect on biological tissues (Dunaev, 2016). Biological tissues have a complex structure, which is a complex of various substances, fibers and interstitial fluid, which are optically heterogeneous media. Violation of reflectivity, thinning of the mucous membrane of the upper layers of the tissues of the affected organs can be considered an informative factor and used to determine the functional state of the organs.

The paper considers an optoelectronic system that allows to objectify the assessment of the condition of internal organs.

Almost every description of the processes of necrosis in each source is accompanied by an indication of the main changes that occur in the tissue. The color change of the investigated area is one of the main parameters. The healthy area is pink, has a shine; the area susceptible to pathogenic influences darkens, black spots appear, the luster disappears (Hai, 1998).

Undoubtedly, this factor is very significant, however, many researchers note the subjectivity of determining the boundaries of necrosis, when making decisions based on color. In many respects, the surgeon's experience plays a decisive role.

At the same time, all of the listed signs admit subjectivity in the diagnosis and, therefore, do not exclude the possibility of error in determining the viability of an organ. It is also important to note that determining the boundaries of the affected area of the internal organs of a person can be a serious problem for a young specialist in the field of surgery, who does not have sufficient experience to independently assess the viability of the site.

This is one of the main goals of the study: the creation of a device that allows to quantitatively objectively determine the color of the area of the affected organ, which will help the young specialist decide on the volume of resection during surgery (Berdnikov, Nazmutdinova and Yunusov, 2018).

The proposed solution relates to medicine and can be used to obtain information about the functional state of the studied section of the internal organ.

The device for determining color consists of a digital camera and a processing program for the resulting image. To conduct the study, it is possible to illuminate the studied area of the biological tissue with an operational white light source, while the reflected optical radiation is recorded by a digital USB video camera. The signal through the USB port is transmitted to the PC, where it is processed. To process the video signal, a virtual device created in the LabView environment (Vizilter, Zheltov and Prince, 2008) is proposed; color information is presented in wavelengths convenient for the operator to perceive in the range from 360 nm to 700 nm. The block diagram of the developed virtual device is shown in Figure 1.

Modification of the device for use in minimally invasive operations is possible. In this case, the digital camera through a special mounting device is attached to the eyepiece of the laparoscope, lighting can also be carried out by means of an operational white light source.

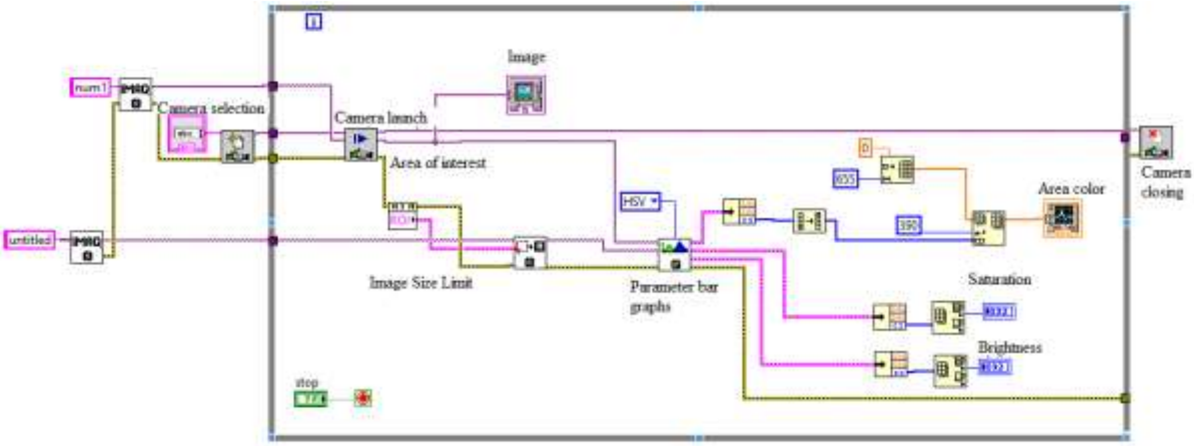

Figure 1. A block diagram of a virtual tissue color instrument developed in LabView

Information about the characteristic of the recorded waves in the visible range is recorded by a digital camera, which converts the received signal to digital form in RGB encoding.

RGB is an additive color model, as a rule, describing a color coding method for color reproduction using three colors, which are commonly called primary (RGB, 2019). This representation of color allows us to process information about it using 3-dimensional vectors; however, human perception of color information is difficult, since information about color and brightness comes in a mixed form.

Analysis of existing color models allowed us to determine the most preferred, which allow you to get a visual representation of the encoded color. For the tasks to be solved, the HSV color model was chosen - a color model in which the color coordinates are (RGB, 2019):

Hue - color tone, (for example, red, green or blue-blue). It varies between 0-360, but sometimes it is reduced to the range 0-100.

Saturation varies between 0-100. The larger this parameter, the "cleaner" the color, so this parameter is sometimes called color purity. The closer this parameter is to zero, the closer the color is to neutral gray.

Value (color value) or Brightness.

As you can see, only one Hue parameter is responsible for color reproduction in this color model, which allows you to visually represent the color closest in interpretation to the wavelength, which facilitates the perception of information and interpretation of the results.

The encoding of information in a digital format uniquely determines the registered color of the object of interest, which allows depriving the measurement of subjectivity inherent in assessing the state of tissues by a person.

After obtaining the image using the cursor, the area in which the pixel color analysis will be carried out is determined. Next is the distribution of pixels over the histograms, the columns of which correspond to all the values of the Hue color parameter. Thus, we obtain a graph of the frequency distribution of the composition of pixels of various colors, the maximum of which corresponds to the dominant color of the studied area of biological tissue. This value is displayed in the corresponding field, as well as the prevailing value of Saturation and brightness Value.

Results and discussion

Pictures of sections of the human intestine presented below were obtained using a digital camera. Images were obtained during surgical interventions, provided by the City Clinical Hospital No. 7 of the city of Kazan. Images are analyzed using the virtual instrument described above. Figure 2 represents the image of the front panel of the virtual device, on which are located the image received from the camera, on it you can select the area of interest. The numerical values of the color parameters for the HSV color model are on the right. The color parameter value is presented in the form closest to the wavelength. The color distribution of pixels in the selected area is presented below.

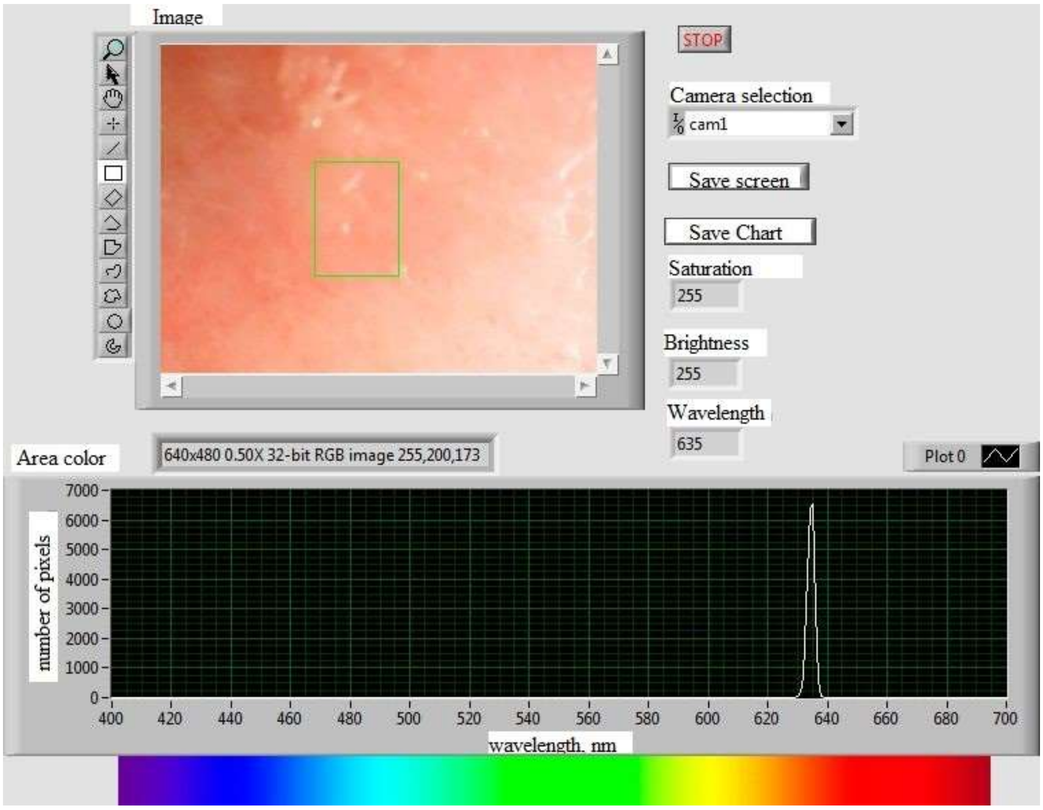

Fig. 2. Image of a healthy section of the intestine on the front panel of the device

As follows from Figure 2, a healthy section of the intestine has a pink color, which is also confirmed by quantitative values (the wavelength reflected by healthy tissue in all cases remained on the order of 640 nm, the saturation and brightness of the area are close to their maximum values).

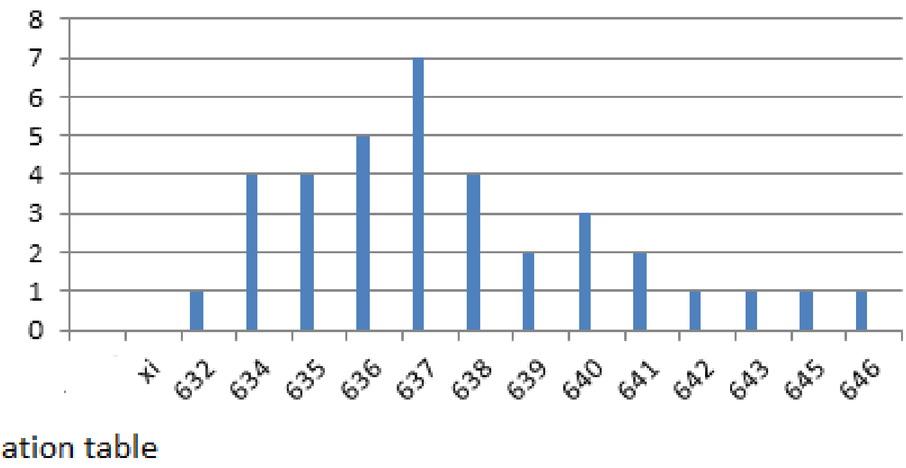

Fig. 3. Histogram of the distribution of frequencies of sample elements

During the experiments, 36 patients were studied for whom images and color values were obtained for healthy sections of the intestine.

Based on the obtained data, a histogram of the frequency distribution of the color parameter was constructed (Fig. 3). Statistical data processing was carried out.

When testing the hypothesis about the law of the distribution of sample values, it was revealed that it was rejected by the Pearson criterion. However, testing the hypothesis of the distribution of X according to the normal law using the 3-sigma rule gives a positive result. Each value of the series differs from the average value of 638 nm by an average of 3.093. The average value is approximately equal to the mode and median, which indicates the normal distribution of the sample. The values of As and Ex differ little from zero. Therefore, we can assume the proximity of this sample to the normal distribution.

Conclusion

Optical methods for the diagnosis of biological tissues are becoming more common and are widely used in biology and medicine. Using optical radiation, it is possible to obtain information about the structure, composition and properties of biological tissues, to study the processes that occur in them without exerting a negative effect on biological tissues.

As a result, the integration of diagnostic methods using the characteristics of reflection in the visible spectrum can significantly increase the information content of the results and, therefore, the objectivity of diagnosis. The color differentiation of parts of organs makes it possible to form a conclusion about the presence of a pathological process by measuring the color of biological tissue. It was found that the distribution of chroma values is close to normal, therefore, data close to the average value of 638 ± 3.1 nm can be considered data of good healthy tissue, thus, the norm indicator for conditionally healthy patients was established.

References

Berdnikov A. V., Nazmutdinova N. M. and Yunusov N. A. (2018). Optical diagnostics of biotissues. Bulletin of scientific conferences, 6-2 (34). Prospects for the development of science and education: based on the materials of the international scientific-practical conference on June 30, 2018. Part 2. 210.

Dunaev A. V. (2016). Optical non-invasive diagnostics in biomedical practice: a laboratory workshop. Orel: Oryol State University named after I.S. Turgenev, 96.

Hai G. A. (1998). Assistance in surgical operations. St. Petersburg: Hippocrates, 382.

RGB (2019). In: Internet-encyclopedia Wikipedia. Available at: https://ru.wikipedia.org/wiki/RGB.

Vizilter Yu. V., Zheltov S. Yu. and Prince V. A. (2008). Processing and analysis of digital images with examples at LabView IMAQ Vision. Moscow: DMK Press, 464.

Zlygostev A. S. and Pogorelov G. P. (2012). Necrosis as a pathological form of cell death: News on anatomy and physiology. In: Fundamentals of pathology. Taganrog. Available at: http://anfiz.ru/ekzamen/item/f00/s00/z0000001/st008.shtml.

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