Diagnosing pathological conditions using laser polarimetry methods in forensic medical practice

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Abstract

The article presents the current status of questions concerning the diagnosis of pathological conditions for forensic practitioners. Particular attention is paid to biophysical research methods, which have evidential accuracy, objectivity, reproducibility and fast results. In our opinion, a promising direction in the study of bodily fluids, including the vitreous body, are laser polarimetry techniques. They can help identify and introduce the newest optical criteria for diagnosing time of death.

Keywords: laser polarimetry, time of death, formation of hematomas, myocardial ischemia, vitreous body

Diagnostika patologických stavov pomocou lejzrovej polarimetrie v súdnolekárskej praxi

Abstrakt

Práca prezentuje súčasný stav problematiky týkajúcej sa diagnostiky patologických stavov pre súdnych lekárov. Osobitná pozornosť sa venuje metódam biofyzikálneho výskumu, ktoré majú preukázateľnú presnosť, objektívnosť, reprodukovateľnosť a rýchle výsledky. Podľa nášho názoru sľubným smerom v štúdiu telesných tekutín, vrátane očného sklovca, sú techniky lejzrovej polarimetrie. Tieto techniky môžu pomôcť identifikovať a zaviesť najnovšie optické kritériá na stanovenie času úmrtia.

Kľúčové slová: lejzrová polarimetria, čas smrti, vývoj hematómu, ischémia myokardu, sklovec

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Introduction

In recent years we have seen a tendency of newly developed modern diagnostic methods of studying biological tissues (BT) and bodily fluids (BF). In particular, forensic medical practice is faced with a number of issues that cannot be solved without the development of new approaches to the diagnosis of pathological conditions.

Recent advances in science, technology and development of new diagnostic methods in medicine allow us to find new approaches to solving urgent problems of forensic practice. Currently, forensic medical practice requires a significant supplementation in the spectrum of methods of diagnosis, since most of them depend on the time that has elapsed since the aggravation of the disease to the time of death, qualification level of personnel, correct procedure of sampling BT and BF and evaluation of the results. One of the most powerful methods for studying the structure and properties of BT and BF is polarization microscopy (PM).

Its use may be based on the fact that all tissues of the human body can be represented as a set of optically uniaxial protein fibrils that are birefringent and form a unique structural and functional organization [7,8].

In recent years, PM through integration in all branches of medicine, optical physics and analytical mathematics has transformed into laser polarimetry. In general, the use of lasers in medical research is based on the use of a wide range of phenomena associated with the different effects of light interaction with biological objects. In particular, the use of lasers in the optics of light scattering led to the development of another area of research related to the study of two-dimensional distribution of optical parameters in images of biological objects [4]. Therefore, the development of new approaches and tools to analyze distribution of polarization states and phases of light waves in pictures of BT and BF in different spectral ranges can be effective to solve

tasks and keep track of their changes. The basis of this approach is a set of methods of laser spectrophotopolarimetry that combine traditional methods of single-wave ellipsometry with the development of new methods of spectral and polarization phaseometry of laser images of BT and BF. On the other hand, the tissue can be a source of electromagnetic radiation in the visible spectrum after absorption of energy that is capable of autofluorescence. Therefore, apart from polarization correlation methods, alternative spectral methods based on the diagnostic use of fluorescence effects of molecules and their complexes are being developed.

The staff of the Department of Forensic Medicine and Medical Law of Bukovinian State Medical University and Department of Optics and Spectroscopy of Yuriy Fedkovych Chernivtsi National University decided to implement this technique in forensic medical diagnosis and to develop a new approach to solve complex problems in the practice of forensic experts. This technique provides powerful diagnostic value combined with objectivity, reproducibility and speed of obtaining results [6, 10, 11].

Researchers have developed new laser polarimetric objective criteria for the diagnosis of lifetime and postmortem changes of BT and BF to solve complex problems of forensic practice, including establishing time of death and its various forms, hematoma formation time, injury formation while still alive, diagnosis of acute myocardial ischemia.

Going by the results we obtained from multivariate polarization microscopy and autofluorescence microscopy, their statistical, fractal, correlational, parametric and wavelet analysis, we can note that the methods that most accurately and objectively characterize changes combine the strengths of both autofluorescence microscopy and multivariate polarization microscopy. Thus, the use of these techniques significantly complements the traditional methods of diagnosis of pathological states.

High accuracy and reproducibility of laser polarimetric techniques gives us the opportunity to further improve the results. These methods are currently testing in research of biological fluids, including cerebrospinal fluid and they show positive results. In our view, a promising direction is the evaluation of time of death by laser polyarimetry analysis of vitreous body (VB) of the human eye. It is a suitable object of study as it has a stable chemical composition, is sterile, surrounded by a dense layer, has a delayed onset of putrefaction, and is easily accessible for study [3].

VB is a transparent gel with a volume of about 4 ml, consisting of liquid fractions and film-like structures. The gel consists of collagenous fibrillar stroma and its associated viscous hyaluronic acid solution [1, 5]. According to modern concepts VB contains funnel complexes of visible membranel (thin fibrous plates that reflect light) - vitreal paths. This structure gives the VB optical-uniaxial properties of liquid crystals, which allows us to study it with laser polarimetric methods [9].

From an optical point of view, VB is a multicomponent liquid, which consists of two main factions: optically isotropic – optically homogeneous complex of hyaluronic acid and protein; optically anisotropic – liquid crystal phase consisting of a combination of different types of liquid crystals, fibrin filaments and collagen fibers [9].

Based on the proposed model structure of VB, it can be assumed that in the process of probing it with laser radiation, optically isotropic component images will be formed simultaneously that are responsible for coordinate isotropic distribution of components of VB, and polarization uniform components of the image due to the influence of liquid crystal optically anisotropic structural elements [2, 9].

This means we can study the main optical postmortem changes of VB at different stages of death that are associated with the transformation of its optical-anisotropic structure.

Conclusions

1. Given the rapid scientific and technological progress, we believe that modern laser polarimetric diagnostic methods should be properly studied, developed and implemented in forensic medical practice, as they are the most promising, informative, relatively simple and inexpensive for using in the practice of forensic bureau and investigating authorities among other research methods available today.
2. For forensic medical diagnosis of the time of death, laser polarimetric methods feature high sensitivity and reliability, which together with the vitreous body proves the promise of their further study.

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