Methods and tools of forensic medical digital polarization histology of traumatized tissues of the deceased

Roman Besaha[a], Oxana Kinzerska[a], Alexandra Litvinenko[b], Ivan Gordey[a],
Igor Oliynyk[b], Oleg Vanchulyak[b]
[a] Yuriy Fedkovich Chernivtsi National University, Chernivtsi, Ukraine, 58012
[b]Bukovinian State Medical University, Chernivtsi, Ukraine, 58009

ABSTRACT

The experimental methodologies of digital histology are presented, including: azimuthally-invariant polarization mapping of microscopic images of histological tissue sections of human internal organs; mapping of Mueller matrix invariants of linear and circular birefringence in histological tissue sections of human internal organs; polarization reconstruction of maps of linear and circular birefringence in histological tissue sections of human internal organs.

Keywords: polarization histology, biological tissue, forensic medicine, diagnostics.

1. INTRODUCTION

The obtained results of polarization mapping have revealed informative (diagnostic) correlations between the azimuthal polarization maps and the concentration of optically active molecular compounds in biological tissues and organ fluids of humans[1-7]. Similarly, the ellipticity polarization maps have shown correlations with the degree of organization (crystallization) of fibrillar networks in biological samples. However, currently, digital polarization microscopy methods for determining the age of injuries to human internal organs are practically absent in histological research. Moreover, the analysis of microscopic images is often performed semi-qualitatively through observation of the image structure by an expert, followed by subjective conclusions[8-22].

Given these limitations, it is crucial to develop and validate new methodologies for obtaining microscopic images, assessing their diagnostic effectiveness, and ensuring the accuracy of objective statistical analysis of polarization maps in microscopic images of histological sections from different types of injured human internal organs.

2. THE MAPS OF AZIMUTH AND ELLIPTICITY POLARIZATION IN MICROSCOPIC IMAGES OF HISTOLOGICAL SECTIONS OF BIOLOGICAL TISSUES FROM HUMAN INTERNAL ORGANS

A comparative representation of the topographical structure of conventional microscopic images (at 4x and 40x magnification) of a histological brain section from a deceased individual with ischemic heart disease is shown (Fig. 1, fragments (1),(3)). Additionally, corresponding maps of azimuth and ellipticity of polarization of these images are provided (Fig. 1, fragments (2), (4)).

From the obtained data (Fig. 1), it can be observed that in addition to the topographical structural features of the intensity values in conventional microscopic images ((1),(3)), their polarization maps ((2),(4)) also exhibit more pronounced structures in terms of the scattering of azimuth values and their average level. This result indicates the presence of additional information reserves for studying computer polarization maps[13-17] of such images with the aim of obtaining new insights into the changes in the bionic and molecular structure of biological tissue samples from the internal organs of deceased individuals with varying degrees of damage.

Sixteenth International Conference on Correlation Optics, edited by
Oleg V. Angelsky, Claudia Yu. Zenkova, Proc. of SPIE Vol. 12938,
129381P · © 2024 SPIE · 0277-786X · doi: 10.1117/12.3014290

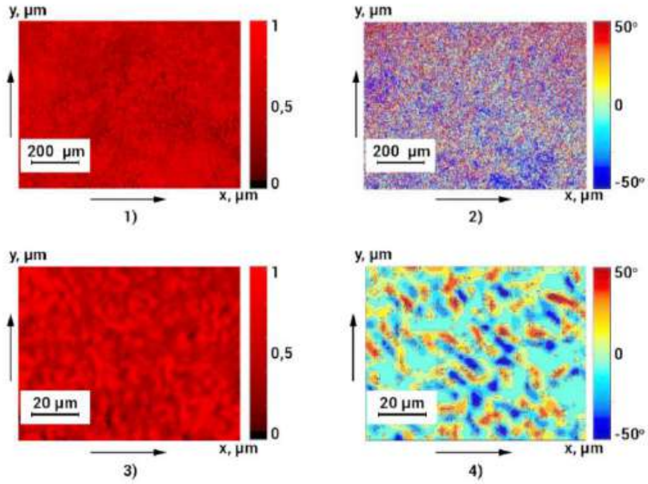

Figure 1. Microscopic images ((1),(3)) and azimuth polarization maps ((2),(4)) of the histological section of the brain from a deceased individual with ischemic heart disease (IHD).

3. THE METHOD OF MUELLER MATRIX MAPPING OF HISTOLOGICAL SECTIONS OF BIOLOGICAL TISSUES OF INTERNAL HUMAN ORGANS

In the series of image fragments in Figure 2, microscopic images ((1),(3)) and Mueller Matrix Invariants[4,7-9,12] (MMI) maps ((2),(4)) of linear birefringence (degree of crystallization) in the liver of a deceased individual from ischemic heart disease (IHD) are presented.

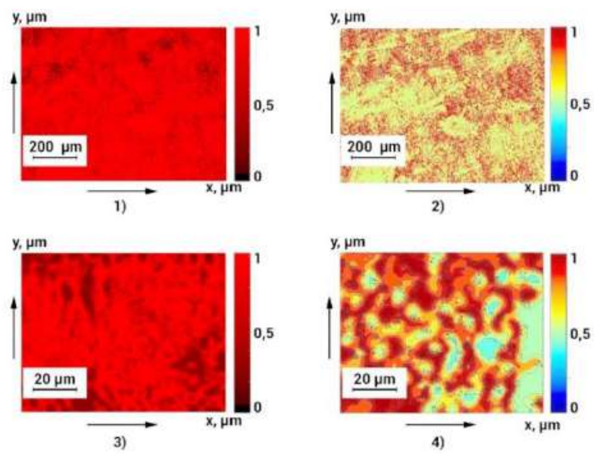

Figure 2. Microscopic images ((1),(3)) and Mueller matrix invariants of linear birefringence ((2),(4)) of the histological section of the liver from a deceased individual with ischemic heart disease (IHD).

The analysis of the determined MMI maps of linear birefringence ((2), (4)) revealed significant structural heterogeneity in the degree of crystallization of the histological liver section compared to the topographic structural pattern of intensity values in traditional microscopic images ((1), (3)). The newly obtained additional information will be utilized to enhance the efficiency of histological detection of morphological changes in samples of human internal organ tissues with varying degrees of damage.

4. THE METHOD OF POLARIZATION RECONSTRUCTION (TOMOGRAPHY) OF THE POLYCRYSTALLINE STRUCTURE OF HISTOLOGICAL SECTIONS OF HUMAN INTERNAL ORGAN TISSUES

The fragments in Figure 3 represent examples of polarization reconstruction of the degree of crystallization of the substance in the histological section of the kidney from a deceased individual with Ischemic Heart Disease (IHD).

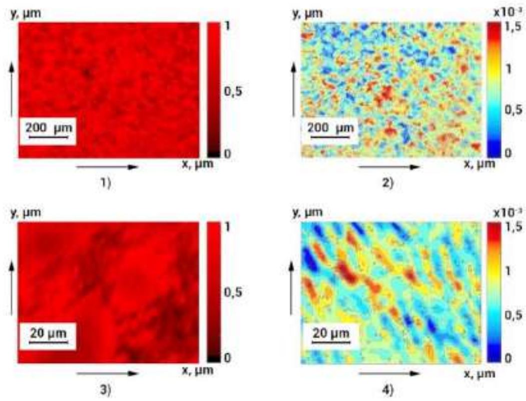

Figure 3. Microscopic images ((1),(3)) and maps of linear birefringence ((2),(4)) in a histological section of the kidney from a deceased individual with ischemic heart disease (IHD).

The comparison of traditional microscopic images Figure 3 ((1), (3)) and tomographically reconstructed maps of linear birefringence of fibrous structures ((2), (4)) in a histological section reveals a significant range of variation and coordinate heterogeneity in the degree of tissue crystallization in the kidney sample. The information obtained in this way allows for the direct detection (not accessible by traditional light microscopy methods) and quantitative assessment of changes in the spatial structure of fibrous networks and morphological composition of tissues from human internal organs due to traumatic injuries of different ages.

5. CONCLUSIONS

A structural-logical diagram and a designed comprehensive digital histological investigation of the antiquity of internal organ injuries in humans using azimuthally-invariant polarization and Mueller matrix mapping methods, as well as polarization reconstruction of polycrystalline component parameters in histological tissue sections of internal organs, have been developed and justified.

The following methodologies have been presented and analyzed:

- Azimuthally-invariant mapping of azimuths and ellipticity of polarization in microscopic images of histological tissue sections of human internal organs.
- Mapping of Mueller matrix invariants of degree of crystallization and optical activity of the polycrystalline component in histological tissue sections of human internal organs.
- Tomographic reconstruction of maps of linear and circular birefringence of the polycrystalline component in histological tissue sections of human internal organs.

6. REFERENCES

[1] Baracat, R., “Exponential versions of the Jones and Mueller-Jones polarization matrices,” J. Opt. Soc. Am., A13 (1996).

[2] Arteaga, O., “On the existence of Jones birefringence and Jones dichroism,” Opt. Lett. 35, 1359-1360 (2010).

[3] Zabolotna, N. I., Pavlov, S. V., et.al, “System of the phase tomography of optically anisotropic polycrystalline films of biological fluids,” Volume 9166, Biosensing and Nanomedicine VII, 916616 (2014).

[4] Ushenko, O. G., Dubolazov, A. V., Balanets'ka, V. O. et.al, “Wavelet analysis for polarization inhomogeneous laser images of blood plasma,” SPIE Proc. 8338, 83381H (2011).

[5] Angelsky, O.V., et.al, “Optical measurements: polarization and coherence of light fields,” INTECH Open Access Publisher (2012).

[6] Ushenko, V. A., Benjamin T. Hogan, Dubolazov, O. V., et.al, “3D Mueller matrix mapping of layered distributions of depolarisation degree for analysis of prostate adenoma and carcinoma diffuse tissues,” *Scientific Reports* 11, 5162 (2021).

[7] Ushenko, V. A., Benjamin T. Hogan, Dubolazov, O. V., et.al, "Embossed topographic depolarisation maps of biological tissues with different morphological structures," *Scientific Reports* 11, 3871 (2021).
[8] Garazdyuk, M. S., Bachinskyi, V. T., Vanchulyak, O. Ya., et.al, "Polarization-phase images of liquor polycrystalline films in determining time of death," Applied Optics 55(12), B67-B71 (2016).
[9] Ushenko, A., Sdobnov, A., Dubolazov A., et.al, "Stokes-correlometry analysis of biological tissues with polycrystalline structure," IEEE Journal of Selected Topics in Quantum Electronics 25(1), 1-12 (2018).
[10] Ushenko, V. A., Sdobnov, A. Y., Mishalov, W. D., et.al, "Biomedical applications of Jones-matrix tomography to polycrystalline films of biological fluids," Journal of Innovative Optical Health Sciences 12 (06), 1950017 (2019).
[11] Angelsky, O. V. and Maksimyak, P. P., "Polarization-interference measurement of phase-inhomogeneous objects," Appl. Opt. 31, 4417-4419 (1992).
[12] Angelsky, O. V. et al, "Experimental demonstration of singular-optical colouring of regularly scattered white light," Journal of the European Optical Society - Rapid publications, Europe 3 (2008).
[13] Angelsky, O. V., Maksymyak, P. P., Zenkova, C. Y., Maksymyak, A. P., Hanson, S. G., and Ivanskyi, D. D., "Peculiarities of control of erythrocytes moving in an evanescent field," Journal of Biomedical Optics 24(5), 055002 (2019).
[14] Ushenko, V. A., Dubolazov, A. V., Pidkamin, L. Y., et.al, "Mapping of polycrystalline films of biological fluids utilizing the Jones-matrix formalism," Laser Physics 28 (2), 025602 (2018).
[15] Sun Fayou, Hea Choon Ngo, Yong Wee Sek, "Combining Multi-Feature Regions for Fine-Grained Image Recognition," International Journal of Image, Graphics and Signal Processing (IJIGSP) 14(1), 15-25 (2022).
[16] Vo Hoai Viet, Huynh Nhat Duy, "Object Tracking: An Experimental and Comprehensive Study on Vehicle Object in Video," International Journal of Image, Graphics and Signal Processing (IJIGSP), 14(1), pp. 64-81 (2022).
[17] Zhengbing Hu, Tereikovskyi, I., Chernyshev, D., Tereikovska, L., Tereikovskyi, O., Dong Wang, "Procedure for Processing Biometric Parameters Based on Wavelet Transformations," International Journal of Modern Education and Computer Science(IJMECS) 13(2), 11-22 (2021).
[18] Thiago Nascimento Rodrigues, "A Fast Topological Parallel Algorithm for Traversing Large Datasets", International Journal of Information Technology and Computer Science (IJITCS), 15(1), 1-8 (2023).
[19] Alovsat Garaja Aliyev, "Technologies Ensuring the Sustainability of Information Security of the Formation of the Digital Economy and their Perspective Development Directions," International Journal of Information Engineering and Electronic Business(IJIEEB) 14 (5), 1-14 (2022).
[20] Destra Andika Pratama, Masayu Anisah, Andi Setiyadi, "Modeling and Analysis of Disturbance on Three Phase Induction Motor at CFPP Tanjung Enim 3x10 MW Using Matlab/Simulink," International Journal of Information Engineering and Electronic Business(IJIEEB) 14(5), 24-31 (2022).
[21] Adelia Juli Kardika, Aulia Khoirunnita, Salman, Saharuddin, Indah Muliana, "Development Web-GIS of Commodity Information System for Agriculture, Establishment and Forestry in Marangkayu District," International Journal of Education and Management Engineering (IJEME) 12(5), 1-8 (2022).
[22] Atam Kumar, Hafiz Karim Bux Indher, Ali Gul, Rab Nawaz, "Analysis of Risk Factors for Work-related Musculoskeletal Disorders: A Survey Research," International Journal of Engineering and Manufacturing (IJEM) 12(6), 1-13 (2022).

ACKNOWLEDGMENT

This work received funding from: National Research Foundation of Ukraine, Project 2022.01/0034; Scholarship of the Verkhovna Rada of Ukraine for Young Scientists-Doctors of Science 2023; Scholarship of the Cabinet of Ministers of Ukraine for Young Scientists 2023.