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Viewpoint

Quantification of tissue optical properties: perspectives for precise optical diagnostics, phototherapy and laser surgery

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This Viewpoint relates to an article by A N Bashkatov *et al* (2005 *J. Phys. D: Appl. Phys.* **38** 2543) and was published as part of a series of Viewpoints celebrating 50 of the most influential papers published in the *Journal of Physics* series, which is celebrating its 50th anniversary.

Recent technological advancements in photonics have encouraged remarkable progress towards the development of innovative methods and systems for clinical functional optical imaging, laser surgery, and phototherapy. The development of the optical biomedical methods and techniques has stimulated a great interest towards the investigation of optical properties of human tissues, which define the efficacy and the impact of tissue optical probing via the possibility to predict precisely the photon propagation trajectories and the fluence rate distribution within irradiated tissues.

Examples of the application of measured tissue optical properties for diagnostics include monitoring of blood oxygenation and tissue metabolism [1, 2], imaging of skin and mucous cancer tissues [3–5], tracking of drug [6, 7], micro-container [8–10] and nanoparticle delivery [11, 12], etc. In therapeutics, the methods of photodynamic therapy (PDT) [5, 13], low-level laser therapy (LLLT) [14–16], photo-thermal therapy (PTT) [17] or plasmonic photo-thermal therapy (PPTT) [18, 19], need a careful dosimetry that is impossible to provide without quantification of the tissue optical properties. The precision of laser tissue ablation [8, 9], coagulation [20] and welding [21, 22] strongly depends on spectral properties of tissues. Therefore, for all these applications, the knowledge of tissue optical properties is of great importance for the explanation and the quantification of the diagnostic data, and for the prediction of light distribution and absorbed energy for therapeutic and surgical use.

For our knowledge, the quantitative study of the optical properties of tissues began in the fifties of the last century. However, the most intensive researches were done from the nineties to the present. A rapid surge in the publication of studies during this period was caused by the development of optical technologies applicable for non-invasive or least-invasive diagnostics, therapy, and surgery of different diseases, as well as the perfection of the techniques for measurements of optical parameters of tissues in a wide wavelength range.

From these studies, several books, book chapters, and reviews summarizing and analyzing data on optical properties can be mentioned [23–30]. The analysis of these references (and literature within them) shows that the optical properties of human and animal skin, subcutaneous adipose tissue, breast tissue, myocardium, muscle, the skull, *dura mater* and other brain/head tissues,maxillary sinuses, the mucous membrane, stomach wall mucosa, the colon, the peritoneum, the uterus, gallbladder tissue, the liver, the aorta, lung tissue, the sclera, the conjunctiva, the retina and other ocular tissues, hairs, bone, cartilage, tooth enamel and dentin, and blood have been investigated in the visible and near-infrared spectral ranges.

Among papers, dealing with skin optics, the paper of Bashkatov *et al* [31] is one of the most cited. The paper has 450 citations in the database 'Scopus', 401 citations in the database the 'Web of Science', 637 citations in Google Scholar, and 422 citations in the Russian Science Citation Index. The citations show a variety of advanced biomedical technologies which are in direct need of knowledge of the optical parameters of tissues.

As the most impressive and most useful examples of tissue quantified data application, we can present the dosimetry of radiation during PDT and PTT [5, 13–17] and laser surgery

[8, 9, 20–22], different imaging technologies [1–5], the development of batteryless solar-powered cardiac pacemakers [32, 33], standardization of tissue-mimicking phantoms [34, 35], assessment of tissue chromophores concentration and distribution [36, 37], and proposition of the adequate optical models of tissues [38–41].

In the nearest future, we are expecting a further increase of the number of publications related to quantification of optical properties not only healthy, but also pathologically modified tissues and intensive use of these data for more precise diagnostics and monitoring of malignant neoplasm, diabetes, cardio-vascular diseases, as well as for light dosimetry at PDT, LLLT, PTT, PPTT, and laser surgery.

More efficient, accurate, and fast computer algorithms and experimental methods which are already available or will appear soon will allow for the measurement of the optical properties of tissues *in vivo* in a real time. This will bring the optical method to a new horizon and will significantly improve the care of people's health. For example, quantification of time varying optical parameters caused by endogenous metabolic processes or the external impact on a tissue via thermal action or due to immersion or compression optical clearing [42, 43] will be possible.

New 'tissue diagnostic/therapeutic windows' in the NIR attracted a lot of attention recently [44, 45]. In addition to visible/NIR 'windows' such as I (625–975 nm), II (1100–1350 nm), III (1600–1870 nm), and IV (2100–2300 nm) [12, 13], a narrow UV 'window' (350–400 nm) can be also used [14]. Due to great interest to UV [46], MIR [47] and terahertz [48] ranges in biophotonics, new studies of the optical properties for different tissues in these prospective wavelength ranges are expected to be done soon.

In addition, we should also expect the growth of the application of optical methods for characterization of tissues for the aims of the food industry to test meat quality and freshness, as this is evident from recent publications [49, 50].

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A number of laser surgery, therapy, and non-invasive diagnostic technologies may have a signicant benet at a reversible scattering reduction.Â The control of skin optical properties was related to the matching of refractive indices of scatterers (kerati-nocyte components in epidermis, collagen, and elastic bers in dermis) and ground matter induced by OCA permeation and/or tissue dehydration due to the osmotic properties of OCA [8â€“18].Â Effects of ethanol/propylene glycol composition on macroscopic bar-rier properties of the skin with respect to aspirin transport were also described [22]. Besides ethanol, a number of chemical agents may serve as enhancers of cell membrane permeation [19,20]. Needless to say, tissues with different optical properties result in variations of these processes, which must be taken into account when designing diagnostic techniques.28 Furthermore, the multilayered nature of tissues like the bladder dramatically changes the passage and properties of light. Many previous studies in the field of autofluorescence spectroscopy have not taken into account the scattering and absorptive effects of different tissue layers.Â The IAD method allows for the determination of tissue absorption and scattering coefficients using the values of the diffuse reflectance and total transmission coefficients. The anisotropy factor (g) was fixed during the calculations. Quantification of tissue optical properties: perspectives for precise optical diagnostics, phototherapy and laser surgery. A. Bashkatov, E. Genina, V. Kochubey, V. Tuchin. Materials Science. 2016. 4. Save. Alert.Â Measurement of tissue optical properties in the context of tissue optical clearing. A. Bashkatov, K. V. Berezin, +14 authors V. Tuchin. Medicine, Engineering. Journal of biomedical optics. 2018. 47. PDF. Keywords: tissue, optical clearing, optical diagnostics, imaging. Paper #1992 received 2014.12.26; revised manuscript received 2015.02.03; accepted for publication 2015.02.05; published online 2015.03.28. References. 1. V. V. Tuchin (Ed.), Handbook of Optical Biomedical Diagnostics, SPIE Press, PM107, Bellingham (2002).Â 55. V. V. Tuchin, "Optical immersion as a new tool for controlling the optical properties of tissues and blood," Laser Phys. 15, 1109-1136 (2005). 56. E. A. Genina, A. N. Bashkatov, A. A. Korobko, E. A. Zubkova, V. V. Tuchin, I. V. Yaroslavsky, and G. B. Altshuler, "Optical clearing of human skin: comparative study of permeability and dehydration of intact and photothermally perforated skin," J. Biomed.