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Clinical photoacoustic imaging

Photoacoustic imaging (also referred to as optoacoustic imaging) has had a long history of technology development from pioneering ideas to clinical applications [1]. In the last decade of the 20th century the first clinically relevant *in vivo* diagnostic and imaging applications were envisaged using short-pulse laser excitation. In this century, major technological developments have taken place and several *in vivo* studies have been conducted mostly to demonstrate technical feasibility or as the first exploratory studies. In the last few years, studies have begun to demonstrate suitability in specific clinical roles. Since photoacoustic imaging can provide high resolution and high contrast images of blood present in vasculature, the clinical applications are predominantly in performing detection, diagnosis or therapy monitoring in those pathologies in which there are changes in the vasculature, such as in cancer and in inflammation. With spectroscopic photoacoustic imaging, in addition to making exquisite images of blood-vessels, the estimation of blood oxygen saturation is also possible. This parameter can provide information regarding metabolism of embedding tissues which can serve to provide more information to help make a robust diagnosis.

This Special Issue on Clinical Photoacoustic Imaging is the first ever collection of articles dedicated to clinical works in photoacoustics. There are 8 articles, with 3 reviews and 5 original articles. Three of the 8 articles are in breast imaging, an application that originally motivated development of the method, 2 in imaging in rheumatoid arthritis, 1 intended for use in systemic sclerosis, and 1 intended for use in carotid artery disease.

The issue opens with a general review of the progress in clinical work using photoacoustic imaging by Steinberg et al. [2]. The authors survey the applications in imaging of the brain, of breast cancer, of psoriasis and skin lesions, identification of sentinel lymph nodes, guidance of biopsy, of surgery, and of tumor therapies. They discuss the hurdles and challenges still faced by the method for clinical translation, and discuss future directions and prospects for photoacoustics to make an impact in the clinic. Manohar & Dantuma [3] review present and future trends in photoacoustic imaging in the breast cancer care paradigm. They point out that true to the flexibility of the photoacoustic method, even within the single application of breast imaging, imagers have taken on various measurement geometries, with different choices for ultrasound detector characteristics, for illumination schemes, and for image reconstruction. They present descriptions of the various breast imaging systems and show highlights of patient studies, and close with a discussion on several aspects crucial for future clinical translation. In an original article, Yamaga et al. [4] present a study using a three-dimensional full-breast imaging system based on a hemispherical detection aperture. They identify characteristics of the vascular network in the superficial subcutaneous layer of the breast and analyze differences between breasts with cancer and contralateral unaffected breasts using vessel branching points (VBPs) in patients. Their results indicate that a higher number of VBPs might be a biomarker for primary breast cancer. In their original article, Oraevsky et al. [5] describe technical details and examples of patient breast images obtained with a clinical optoacoustic ultrasound system based on a hand-held probe utilizing a linear-array of ultrawide band ultrasonic transducers. Clinical images obtained using the ultrasound/optoacoustoc system in a multicenter clinical trial demonstrate vascular patterns, microvascular density and relative values of the total hemoglobin and blood oxygen saturation in tumors. This additional functional information enables increased accuracy of radiologist assessment of malignancies compared with sole use of ultrasound.

Jo et al. [6] review the technologies and the studies focused on musculoskeletal imaging and inflammation detection in humans. The authors conclude that the patient results suggest that diagnostic information available from photoacoustics could be similar or better compared to the current imaging technologies. The important advantages of the method are its non-invasive and non-ionizing features, excellent soft tissue contrast, high sensitivity to blood volume and blood oxygen saturation, and its small footprint lending itself to use as a point-of-care device. Van den Berg et al. [7] present an original article where they evaluate a portable ultrasound/photoacoustic imaging system for the feasibility of assessment of clinically evident synovitis in rheumatoid arthritis. The interphalangeal joints of 10 patients and 7 healthy volunteers were scanned using the system. The authors found a 4–10 fold increase in photoacoustic response between inflamed and non-inflamed joints which is a first step toward the application of photoacoustics for diagnosis and monitoring of inflammation in peripheral joints. The original article from Aguirre et al. [8] also deals with photoacoustic imaging of fingers, this time under the nail-folds where three-dimensional images of the deeper arterioles and venules are obtained. They describe the use an ultra-wideband raster-scan optoacoustic mesoscopy (UWB-RSOM) system which is able to quantify capillary density and capillary diameter as diagnostic features that can relate to systemic sclerosis.

Merčep et al. [9] present in their original article, a hybrid approach using a hand-held multi-segment detector array that enables multimodal spectroscopic optoacoustic, pulse-echo ultrasound and color Doppler imaging. In a healthy volunteer, the authors demonstrated oxygenation status of structures located at depths of at least 1–2 cm, such as the carotid artery, the sternocleidomastoid muscles, the thyroid lobe and the jugular vein. Such an integrated approach could contribute to a more reliable assessment of the severity of carotid artery disease.

All papers in this special issue have undergone a rigorous peer review process, and we are grateful to the reviewers for their efforts in ensuring that the Photoacoustics' high standards for quality and integrity were met. We are grateful to Prof. Dr. Vasilis Ntziachristos (Former Editor-in-Chief) for initiating this Special Issue. Further we

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thank the publication staff at Elsevier, for helping us through the process eliciting manuscripts, of reviewing them and finally publishing the articles. We are proud and happy with this issue, and we trust you will find knowledge and inspiration in its collection of articles.

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