Photoacoustic imaging: An emerging method for visualizing endocrine physiology.

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Introduction

Endocrine problems require the use of imaging in study, diagnosis, and treatment. In endocrinology, ultrasonography, nuclear medicine techniques, MRI, CT, and optical approaches are already in use. Optoacoustic imaging, also known as photoacoustic imaging, is a technique for studying endocrine function and disease at many scales of detail, including microscopic, mesoscopic, and macroscopic. Endogenous light absorbers, such as oxygenated and deoxygenated haemoglobin, lipids, and water, as well as exogenous contrast ants, provide optoacoustic contrast, which displays tissue vasculature, perfusion, oxygenation, metabolic activity, and inflammation. The development of high-performance optoacoustic scanners for human use has sparked a slew of clinical studies to complement the technology's application in preclinical research. We examine key advances in optoacoustic imaging technology as they relate to endocrinology applications, such as visualising thyroid morphology and function, as well as the microvasculature in diabetes mellitus and adipose tissue metabolism, with a focus on multispectral optoacoustic tomography and raster-scan optoacoustic mesoscopic. We discuss the advantages of optoacoustic microscopy and concentrate on mid-infrared optoacoustic microscopy, which allows for label-free imaging of metabolites in cells and tissues. We will present recent optoacoustic applications in endocrinology and explore how these technologies can help researchers and clinicians [1].

Early diagnosis, characterisation, and monitoring of tumours are critical in the field of cancer medicine. The non-invasive investigation of essential biological characteristics in animal models is a well-established method for transferring favourable results from biomedical research to the clinic. Imaging tools help to improve oncology diagnosis by allowing researchers to analyse angiogenesis and measure molecular variables involved in cancer progression and treatment response. During the last decade, photoacoustic imaging (PAI) has been extensively studied in vivo in preclinical investigations, particularly on oncological models, allowing for a reduction in the number of animals sacrificed at numerous time periods. PAI using various wavelengths (spectroscopic imaging) can identify alterations in tissue component concentrations that are markers of cancer [2].

Imaging depths of up to a centimetre and submillimetric resolution, high contrast-to-noise ratios and spectroscopic imaging, real-time acquisition, lack of ionising radiation, and integration with ultrasound (US) scanners, as well as noninvasive imaging for longitudinal studies, cancer progression monitoring, and drug delivery, are some of PAI's main benefits. As a result, the biomedical world is very interested in applying this paradigm to clinical practise. The major types of PAI systems available can be briefly classified as microscopy (PAM), endoscopy (PAE), and computed tomography (CT) depending on the biomedical requirement (PACT, focused in this review). PAM and PAE scanners, which have superior spatial resolution but limited imaging depth compared to PACT systems, have mostly been employed in mice models of human diseases to study superficial areas, vascular and visceral tissues, respectively [3]. However, PACT platforms may give PAI of living biological structures in cross-section and/or three dimensions. As a result, the PACT technology appears to be the most promising for PAI clinical use. PAI apparatus is currently only commercially available for preclinical studies, with just a few clinical applications being investigated in patient-based oncology trials. The basic underpinnings of PAI in biomedicine, as well as the primary technology implementations, have been summarised in depth in a recent publication, and hence are beyond our scope. The general principles, present preclinical uses, and prospective clinical translation of cancer PAI will all be discussed in this study.

PAI Principles and initial clinical applications

PAI is a hybrid technology based on the photoacoustic effect, which is a physical phenomenon in which electromagnetic radiation is absorbed and converted to acoustic waves. To illuminate biological tissues, a brief pulsed (10 ns) laser with different wavelengths is utilised, producing ultrasonic waves from several tissue constituents [4].

A typical PA system consists of a brief pulsed laser source, a signal detecting US array transducer, a signal amplification and digitalization component, a system for B mode US and PA coregistration, data acquisition, and image representation. The laser pulse repetition rate and the time necessary for multiwavelength data gathering usually limit the imaging frame rate of the system. Furthermore, the possibility for tissue damage limits the use of repeated wide field illumination. The commercially available US-PA scanners currently operate at a repetition rate of 5 to 20 Hz.

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The following steps can be used to explain the PA signal generation process: A short pulsed laser illuminates a target tissue; photons propagate unidirectional into tissues and are absorbed by endogenous or exogenous molecules with optical properties; the absorbed optical energy is partially or completely converted into heat, resulting in a transient local temperature rise; tissue thermal expansion changes over time induce local pressure rise, which generates pressure acoustic waves; the heating induces thermoelastic tissue expansion; tissue thermal expansion changes over time induce local pressure rise, which generates pressure [5].

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