AbstractID: 9746 Title: Optoacoustic Tomography is Coming of Age

In 1880 Alexander G. Bell heard “a pure musical tone” in a closed gas volume that had absorbed a modulated sunlight beam. However, it would be a century before interest in the photoacoustic effect stimulated physicists to employ this discovery in novel medical instruments. In the beginning of the 21st century, opto-acoustic tomography (OAT) emerged as a sensitive modality for visualization and quantitative characterization of malignant tumors and blood vessels. OAT combines the most compelling features of light and sound to provide maps of absorbed optical energy in optically scattering and opaque media including biological tissues. The new hybrid modality improves spatial resolution of the optical imaging and contrast of the ultrasound imaging.

The basic principles behind the optoacoustic imaging system are that (1) laser pulses may be effectively used to produce acoustic sources in tissues with enhanced optical absorption, and (2) ultrasonic waves propagate in biological tissues as expanding spheres with minimal wavefront distortion and deliver temporarily resolved information to the surface of tissue where it may be detected. The application of transducer arrays permits reconstruction of two-dimensional and three-dimensional images. One of the main endogenous chromophores of tissue in the near-infrared spectral range is the hemoglobin of blood. Therefore, blood vessels possess high optoacoustic contrast. Malignant solid tumors develop an enhanced network of microvessels to supply nutrition and oxygen to aggressively growing cancer cells. Therefore, optical contrast between normal and cancerous tissues is substantially greater than the contrast utilized in ultrasound imaging and other imaging modalities. Furthermore, functional information about hemoglobin concentration and its level of oxygen saturation in tumors can serve as a basis for noninvasive diagnostic utility of OAT. The empirical rule of thumb is that optoacoustic resolution equals depth / 100, so that at the depth of 50 mm one can obtain resolution of about 0.5 mm, while typical resolution is about 50 micron at the depth of 5 mm. Experimental schemes of optoacoustic imaging system for two-dimensional and three-dimensional optoacoustic tomography as well as corresponding algorithms of image reconstruction will be discussed.

The niche of the optoacoustic tomography in biomedical imaging is to provide high-resolution 3D maps containing (1) functional information on blood concentration and its oxygen saturation, and (2) molecular content of endogenous or exogenous chromophores. Clinical studies performed in breast cancer patients will be presented to demonstrate that the functional imaging capability of OAT provides additional medically relevant information regarding breast tumors, which results in better sensitivity and specificity of cancer detection. The molecular imaging capability of OAT is enabled by variation of the optical wavelength for selective heating of specific chromophores administered and targeted to the site of interest. A unique opportunity for further substantial enhancement of the optoacoustic detection sensitivity comes from merging OAT with plasmonic nanotechnology. An optoacoustic contrast agent based on gold nanorods selectively delivered to cancer cells in order to substantially increase brightness of cancerous tumors will be described. The same contrast agent can serve potentially as a therapeutic agent for treatment of early cancer.