What Life Scientists Should Know About Molecular Imaging

Optical Imaging, Ultrasound, Photoacoustics

Physics of Ultrasound Imaging
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Learning Objectives:

- Gain basic understanding of ultrasound 8-mode imaging
- Ability to select correct settings for imaging
- Understand resolution, penetration depth and artifacts
- Realize advantages and drawbacks in comparison to other modalities
- Get an understanding of new development trends in ultrasonic imaging

Owing to the very sensitive detection of microbubble contrast media, ultrasonic imaging has become a modality for molecular imaging. Additionally, the new imaging modality of photoacoustic imaging is also based on ultrasound detection and allows to image dye or nanoparticle contrast media as well as metabolic changes like oxygen saturation. With the availability of high-frequency small animal ultrasound scanners, 8-mode and contrast imaging have become important research tools.

The current talk gives an introduction to the underlying principles of ultrasound imaging used in clinical scanners and laboratory small animal scanners. The physics of mechanical waves in the ultrasound range are discussed first avoiding too much mathematical detail. While the pulse/echo-principle in ultrasound is easy to understand, the scanner proper ties influencing the resolution and contrast of the images are often less well understood. The talk focusses on presenting the basic relationships in image formation that explain image quality differences e.g. between different systems. Typical artifacts – for example the speckle pattern disturbing ultrasound images – are explained and demonstrated.

A major component of the image formation is ultrasound array beamforming: traditionally, the ultrasound system addresses a one-dimensional array of ultrasound transducers in the scan-head with different amplitude and delay to focus the sound beam along one scan-line, which is then moved electronically. This principle will be discussed together with new acquisition schemes needed for real-time three-dimensional imaging with two-dimensional arrays, e.g. in current cardiovascular ultrasound systems.

Application examples for anatomical and molecular imaging with microbubble contrast media will be given and discussed. Additionally, an overview of novel developments coming to the clinical and preclinical ultrasound systems will be given and used to apply what has been learned in the first part of the talk.