What Life Scientists Should Know About Molecular Imaging

Nuclear Imaging: Physical Principles and Instrumentation

SPECT and PET Based Hybrid Imaging Systems

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Learning Objectives:

- To become acquainted with a range of hybrid imaging methods, their rationale and principles.
- To develop an appreciation of the applications of clinical and preclinical hybrid imaging.
- To gain an understanding of technical challenges facing designers of hybrid imaging systems, and recent technological innovations.
- To be familiar with potential sources of artifacts in hybrid imaging and how they may be counteracted.

Nuclear medicine imaging methods that use radionuclides, such as positron emission tomography (PET) and single photon emission computed tomography (SPECT), offer highly sensitive and quantitative tools for detection and localization of the biochemical and functional abnormalities associated with various diseases. In addition, molecular imaging techniques based on radionuclide imaging are the most sensitive methods that are readily translatable to clinical use. However, the major drawbacks of stand-alone PET and SPECT systems are their relatively poor spatial resolutions and low signal-to-noise ratios. The absence of background anatomical information in stand-alone PET and SPECT images of highly target-specific radiotracers sometimes make it difficult to interpret the distributions of these tracers. The introduction of dual-modality PET/CT and SPECT/CT systems in the late 1990s, in which PET and SPECT are combined with X-ray CT in a clinical setting, is regarded as a revolutionary advance in modern diagnostic imaging. In these systems, the PET or SPECT images are acquired sequentially with the CT images using a single device and without moving the patient from the bed, eliminating differences in patient positioning and minimizing the misalignments caused by internal organ motion. The anatomical information provided by the CT images enhances the user's confidence in the PET and SPECT findings. Additionally, the attenuation map derived from the X-ray CT for the gamma-rays emitted from the radionuclides offers useful ways to correct for the attenuation and scatter artifacts in PET and SPECT with minimal addition to the scan time and the image noise. The concept of simultaneous acquisition of PET and MR images was also suggested in the early days of dual-modality systems development, and the development of PET/MR scanners started in the 1990s. However, progress in the development process was relatively slow and the realization of clinical PET/MR scanners was greatly delayed because of technical difficulties when operating PET and MR scanners in close proximity combined with a lack of industrial interest and concern over the high cost of the combined device. The great success of nuclear medicine imaging modalities when combined with CT has, however, revived interest in the combination of PET and MR scanners. The technical advances made over the long development period to minimize the mutual interference between the PET and MR data acquisition processes have led to combined clinical PET/MR scanners with sequential and simultaneous imaging strategies in recent years. The major advantages of PET/MRI include a smaller radiation burden than PET/CT, better soft tissue contrast when using MRI rather than CT, and possible simultaneous

acquisition of images. In this lecture, the basic principles, fields of application, and recent advances will be reviewed for each hybrid imaging device.

Relevant Publications:

1. Townsend DW, et al. Multimodality imaging of structure and function. Phys Med Biol. 53:R1-R39, 2008

References:

1. Seo Y, Mari C, Hasegawa BH. Technological development and advances in single-photon emission computed tomography/computed tomography. Semin Nucl Med 2008;38(3):177-198
2. Zaidi H, Alavi A. Current trends in PET and combined (PET/CT and PET/MR) systems design. PET Clinics 2007;2(2):109-123
3. Cherry SR. Multimodality imaging: beyond PET/CT and SPECT/CT. Semin Nucl Med 2009;39(5):348-353
4. Rahmim A, Zaidi H. PET versus SPECT: strengths, limitations and challenges. Nucl Med Commun 2008;29(3):193-207
5. Lee JS, Kim JH. Recent advances in hybrid molecular imaging systems. Semin Musculoskel R. 2014;18:103–122