

Introduction to Molecular Imaging

Radiation treatment requires definition of a target volume to enable targeting of radiation dose. Conventional imaging (CT, MR) is primarily anatomical in nature and shows the location of a tumor and its proximity to other anatomical structures. Anatomical imaging does not reveal the physiologic, metabolic, or biologic character of a tumor. These characteristics may be very important determinants of radiation response. For instance, cell hypoxia may indicate regions refractory to radiation treatment, and proliferation may indicate regions of high tumor growth. In general, clinicians observe the “anatomic” imaging characteristics of different kinds of tumors and correlate a diagnosis (through imaging and biopsy) with known biological and clinical behaviors to plan an effective treatment. Laboratory data, such as PSA, are included for oncologic assessment but are not used in image form. *In vivo* imaging of biological or molecular tumor characteristics (ie, “laboratory data”) is called Molecular Imaging. This growing, new area of research will substantially change the practice of radiation oncology by advancing diagnosis, enabling biologically-directed treatment, and aiding treatment evaluation.

Molecular imaging is the field whereby tissues or cells of a particular state or function, or other biological species such as specific proteins, molecules, or ligands, can be imaged or used to image biological or molecular structure, function, or processes. The resolution scale of molecular imaging procedures covers at least 4 orders of magnitude, from positron emission tomography/nuclear medicine imaging (1 cm resolution) to the use of fluorescent proteins at the sub-cellular level (1 micron resolution). Three general imaging modalities are being used: 1) radioisotopes, 2) magnetic resonance, and 3) optical approaches. The uses of molecular imaging at the cellular and sub-cellular levels are reviewed in three presentations by experts in the field. Applications and potential uses of molecular imaging in radiation treatment will be discussed, with relevance to new radiation treatment approaches such as intensity modulated radiation treatment (IMRT).

Educational Objectives

1. Define and contrast anatomical and molecular imaging.
2. Understand the physical (size) and numerical (quantity) scales of molecular and biological processes and species.
3. Discuss three modalities used in molecular imaging and their physical and biological bases.
4. Discuss applications of molecular imaging for diagnosis of disease, radiation treatment, and treatment evaluation.