AbstractID: 14594 Title: A Physicist Perspective of the Use of MRI and Spectroscopy for In-vivo Verification of Photon and Proton Beam Therapy

The accuracy of radiation delivery has improved significantly with every technological leap. The improved treatment accuracy has lead to highly conformal dose distributions with subsequent reduction in normal tissue exposure and improved therapeutic ratio. However, shrinking PTV margins based on the perceived accuracy of the treatment may lead to geographic misses and subsequent marginal recurrences. For these reasons, in-vivo verification of the delivered dose in patients receiving either X-ray or proton therapy is of critical importance. Post-treatment in-vivo verification may be useful to assess if the treatment has been correctly given. The therapeutic radiation may produce changes within organs that may be used to verify that the target has been adequately treated, with the appropriate visualized imaging modality.

Magnetic Resonance Imaging (MRI) and spectroscopy (MRS) have the potential of measuring X-ray and proton radiation induced changes to tumors in the liver, brain, bone marrow, prostate and other sites. In the case of bone marrow, studies show marrow changes leading to bright signal intensity within vertebral marrow on T1-weighted (short T1 inversion recovery, STIR) and out-of-phase images. The bright marrow signal is thought to represent fatty infiltration after radiation therapy. Histology of radiation effect: two distinct phases of radiation-induced changes in the bone marrow were observed: 1) acute and 2) chronic. In acute phase, radiation caused edema, vascular congestion and capillary injury to the fine structure. In addition, dilatation of the sinusoids and hemorrhage in the irradiated bone marrow could be detected as early as 1-3 days after irradiation. In the chronic phase, hematopoietic cells and blood vessels were depleted and replaced by yellow fat cells. Signal intensity (SI) changes in MR: fatty replacement of irradiated bone marrow was shown to be responsible for SI increase in the T1-weighted image due to the shortened T1 relaxation time of the increased fatty content. Hematopoietic elements of the bone marrow are extremely radiosensitive, resulting in myeloid depletion if a large volume of marrow is irradiated. Recovery is dose-dependent and usually occurs with doses bellow 30Gy. Above 50Gy the effects are irreversible. Within days of irradiation, there is a transient increase in SI on STIR MR images due to acute marrow edema, necrosis and hemorrhage. After this initial period, there is fatty replacement with a consequent increase in signal intensity on T1-weighted images.

In this lecture we will review the physics of MRI and spectroscopy with emphasis on understanding how radiation effects may induce i) local and ii) organ-wide spin changes visible on an MR.

Learning Objectives:
1-Review and discuss MRI and spectroscopy and its benefits to radiation oncology.
2-Present clinical cases where MRI and spectroscopy has been used to visualize and quantify post-radiation therapy dose distributions.
3- Demonstrate the utility of post-treatment MRI and spectroscopy