AbstractID: 14550 Title: Real-Time Guidance in Radiation Therapy: Present and Future Perspectives

For current radiation delivery techniques (beam types, fields, margins, schedules), performing set-up verification seconds to minutes prior to actual delivery might be adequate. However, refinement of radiation delivery as a local therapy will have to occur in real-time. Any real-time delivery modification should be evaluated for geometric accuracy, dosimetric impact over a treatment course, and ultimately clinical benefit observed in patients.

Presently, for deep-seated organs, real-time (or near-real time) guidance is clinically implemented with implanted fiducials, utilizing either monoscopic X-rays, stereoscopic X-rays, or electromagnetic tracking. Electromagnetic tracking of implanted transponders, currently approved for the set-up of localized prostate cancer patients, provides the closest flavor to true real-time tracking. At MD Anderson Orlando, 51 patients were analyzed (40 fractions, 3 mm posterior planning margins, 5 mm otherwise). Therapists were instructed to re-adjust position if drift persisted >3 mm. If motion was transient, even if >3 mm, instructions were not to intervene. The analysis was performed in 1997 of a total 2040 sessions (98%); an average of 39.2 fractions per patient (range 32-40). Of all fractions, 1273 (64%) had motion ≤3 mm (not requiring correction), 202 (10%) had motion exceeding 3 mm not requiring correction (mostly transient motion), 514 (25%) had motion exceeding 3 mm requiring correction (individual patient range: 10-100%), and only 8 (0.7%) had any motion where the course of action was determined differently by the therapists versus the physician. An important observation is that, given the largely random nature of the motion, and the large inter-patient and intra-patient variability, real-time verification and modification seemed necessary. However, the observed motion had only a minor dosimetric effect on retrospective analyses.

The limitation of fiducial-based guidance is the availability of only one set of coordinates. Volumetric information (deformation) is not documented. Ultimately, real-time delivery verification and modification will require real-time volumetric imaging and image processing. One proposed solution is the acquisition of MRI images during delivery. Another is physics-based bio-mathematical modeling using surrogates to create real-time virtual anatomies coupled with real-time dose calculations. Such real-time dose calculations are necessary to assess the impact of minor geometric variations on dose delivery. A perfect setting to demonstrate the potential use of real-time volumetric guidance is in lung cancer patients. An example of a computational 3D lung model using multi-level multi-resolution optical flow is presented using lung elasticity, overlaid with GPU based dose calculations. The model includes spirometry measurements, 4D CT scans, and elasticity estimates for each voxel. Such a framework would enable real-time monitoring of radiation dose delivery, possible real-time modification, and retrospective sophisticated analyses of dose delivery incorporating real-time tissue motion and deformation. Currently, validation results for 9 subjects show that the method for lung tissues has a mean error rate of 1.45 voxels with a STD of one voxel.

In conclusion, future refinements of radiation delivery will require real-time guidance.

Learning Objectives:
1. Understand current applications of real-time guidance
2. Understand the issues related to evaluating real-time guidance methods
3. Understand possible future avenues of real-time delivery verification and modification