Treatment Dose Verification in Liver SBRT using a Deformable Respiratory Motion Model and Treatment Beam’s-Eye-View Fluoroscopy with Tumor Tracking

James D. Christensen, PhD, Olivier Gayou, PhD and Alexander V. Kirichenko, MD, PhD
Department of Radiation Oncology, Allegheny General Hospital, Pittsburgh, PA

Objectives

- Breathing variability in SBRT causes deviation of delivered dose distribution from the planned dose.
- The goal was to calculate the actual dose delivered to a moving tumor using measurements of implanted fiducial marker position obtained using beam’s-eye-view MV fluoroscopy (MVF).

Methods

- A patient with hepatocellular carcinoma was treated with SBRT 40Gy/4fx. Gold fiducial markers were implanted to mark the tumor location.
- 4D-CT was used for ITV definition/planning and modeling of deformable motion between respiratory phases.
- In the TPS, beams were applied to each phase’s 3DCT. Each resulting dose distribution was spatially transformed via the motion model onto a common anatomical space (planning CT).
- MVF with fiducial tracking yielded tumor motion during radiation delivery. Motion analysis determined the duty cycle for each respiratory phase. A duty cycle weighted average of the deformed dose distributions yielded the composite delivered dose distribution.

A motion model was derived via deformable registration between 4DCT respiratory phases. Dose was recomputed for each phase then transformed via the motion model to a common anatomical space yielding the composite dose.

4DCT-derived DRRs provided baseline fiducial position vs respiratory phase. Treatment MVF was used for tracking fiducial position during the treatment beam.

Fiducial position during the treatment beam was used to compute the duty-cycle of each respiratory phase during treatment.

Results

Qualitative analysis shows that the phase-weighted deformed dose, which more accurately models the actual delivered dose, is spread out over a larger volume compared to the planned dose distribution.

DVH analysis shows that tumor motion during treatment negatively impact target coverage, especially in terms of minimum dose to the GTV. In this particular case, the surrounding organs at risk were affected differently depending on location.

Conclusions

- MVF enables intra-fractional fiducial/tumor motion tracking with no added radiation to normal tissue.
- Incorporation of motion during treatment yields the actual dose delivered to a moving tumor.
- Better assessment of prescribed treatment objectives should benefit adaptive RT.