Clinical Implementation of a Comprehensive EPID-based 3D/4D Patient Dose Reconstruction Framework for Complex Treatment Validations

Mu-Han Lin, Jinheng Li, C-M Charlie Ma
Fox Chase Cancer Center, Philadelphia, USA

Objective
Intensity modulated radiotherapy (IMRT) and volumetric modulated arc therapy (VMAT) have been widely employed in both conventional fractional and hypo fractionated radiotherapy. To ensure treatment quality as well as patient safety, it is favorable to have an adaptive treatment strategy in which the fractional doses can be monitored and the treatment plan can be modified during the treatment course if the difference between the patient-received dose and the planned dose exceeds a certain level. A method was developed and clinically implemented to reconstruct 3D/4D patient dose distributions utilizing on-line measured EPID transmission images to enable DVH-based dose validation for VMAT and IMRT.

Framework for 4D dose Reconstruction

For patients with fiducial markers, both the MLC and the tumor movements were tracked by continuously acquiring EPID images during treatment. The time-dependent geometry was considered to accumulate the incident fluence at each time point with the tumor motion pattern detected by the EPID. The entrance fluence distributions were sorted into their corresponding phases and accumulated as the incident fluence map for each phase. Together with the patient’s in-room 4D-CT, it was then used for dose calculation of each phase. Deformable registration was performed for patient geometry of each phase and the phase doses were summed up accordingly for treatment assessment.

Fluence and Dose Validations

1. 2D Fluence/Dose Validation

For case A, the tumor is nearly steady during patient breathing and no significant difference was observed. In contrast, Figure 7b shows significant differences on the planned and the reconstructed isodose distributions for case B, which displays large tumor motion during patient breathing. Cold spots were seen in the PTV for the reconstructed dose distribution. As a consequence, the DVHs show significant underdose for the ITV and the PTV (dotted line). However, the DVH of the GTV shows no obvious difference because the motions have been taken care by the treatment margins.

Conclusions
On-line measured EPID transit cine-images together with the delivered MUs can be used for the entrance fluence reconstruction and subsequent fractional dose calculation for both small and large lesions treated with VMAT and IMRT. This method could be utilized routinely for complex treatment validations.

Framework for 3D dose Reconstruction

The proposed method is valid under the assumption that MLC apertures can be reconstructed accurately using the EPID transit images with the patient in place. As shown in Figure 1, the in-house program reconstructs the entrance intensity map using the MLC apertures continuously measured by the EPID during the treatment and the corresponding monitor unit (MU) fractions recorded in the DynaLog file. The patient dose is calculated based on the reconstructed entrance intensity map and the patient’s CT images, using a Monte Carlo dose calculation engine and realistic linac beam data. Isodose- and DVH-based dose comparisons can then be performed after the DICOM dose and structure files are imported from the treatment planning system.

Figure 2. 1D Fluence/Dose Validation

Figure 3. 2D Fluence/Dose Validation

Figure 4. 3D and 4D Validation

Figure 5. Patient Case Demonstration

Figure 6. Clinical Implementation of a Comprehensive EPID-based 3D/4D Patient Dose Reconstruction Framework for Complex Treatment Validations