Comprehensive Calculation-based IMRT QA Using a Second Treatment Planning Software

**Introduction:** The ASTRO whitepaper “Safety Considerations for IMRT”[1] recommended the need for pretreatment and on-going QA to “guard against catastrophic failures.” On-going QA is not routinely done and pretreatment QA has traditionally been measurement based (Figure 1A). These methods of QA have several weaknesses including high labor and machine time costs and the lack of QA in the patient specific geometry and inhomogeneities. Calculative methods have been presented for IMRT QA but these have lacked the patient geometry and have not included a check of the data transfer to and interpretation by the verify and record (V&R) system.

**Proposed Method:** We propose a calculative based system (Figure 1B) that recomputes the treatment plan in the patient geometry using data from the V&R system delivered by a mock treatment to the QA system. In addition using the same methods each treatment can be recomputed using records from the V&R system combined with data from the delivery unit. A second treatment planning software (TPS) can be used to also verify the original calculation algorithm. Delivery verification relies on the accuracy with which the treatment console records the mechanical and dosimetric performance of the treatment unit. We feel that verification of these aspects can be accomplished via routine QA of the treatment unit. However, the amount and frequency of mechanical QA may need to be increased.

The proposed system has two very important advantages over measurement-based methods:

1. The proposed QA takes place using patient-specific geometry supplied by the same simulation CT dataset used for the original dose calculation. This not only allows the dose calculation to be verified in the entire patient volume, but also verifies the inhomogeneity corrections applied by the TPS. Measurement-based methods are performed using a homogenous phantom by recomputing the dose on a phantom CT dataset. Measurements also only sample small a small portion of the treatment volume (i.e. the active volume of a detector, or a few film planes).

2. The proposed QA does not require any patient specific measurements, making it much less labor intensive than traditional QA. This method has a high potential for automation, and makes it feasible to perform QA for every treatment fraction delivered.

**Gamma Analysis:** To compare each verification dose distribution to the clinical dose distribution, the 2D gamma analysis presented by Low et al. [2] was extended to three spatial dimensions. The dose difference criteria are expressed as a percentage of the maximum dose in the clinical dose distribution. All dose distributions were interpolated to a 1mm X 1mm X 1mm grid spacing. The results of the gamma analysis varied depending on the source of the verification plan (Figure 2). For this reason three separate sets of dose difference and distance criteria were used to compare the dose distributions: 3%-3mm, 2%-2mm, and 1%-1mm. The results show the differences introduced by data transfer errors or treatment delivery uncertainties are only detected when using the strictest gamma criteria (1%-1mm), and the average percentage of voxels passing the gamma analysis of two TPS distributions is greater than 95% for gamma criteria of 3%-3mm and 2%-2mm.
Figure 1. Diagrams of the information flow in (A) measurement-based IMRT QA, (B) the proposed calculation-based IMRT QA, and (C) this study.

Figure 2. Results of the 3D gamma analysis comparisons. Error bars are ±1 standard deviation. Gamma dose criteria are expressed as a percentage of the maximum clinical dose.

References: