Application of the Integral Quality Monitor (IQM) Transmission Detector for Optimization of Dosimetric Leaf Gap and Multi-Leaf Collimator Transmission Factor

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INTRODUCTION

Intensity modulation with photon beams has been achieved in radiation therapy by application of multi-leaf collimators (MLC). In treatment planning dose calculation, MLC model parameters are introduced to account for the interaction of the MLC with the beam. The transmission factor (TF) influences the dose in regions shielded by leaves during irradiation; and the dosimetric leaf gap (DLG) accounts for the transmission through the leaf edges of a pair of opposed leaves. Prior investigations have focused on optimizing these MLC parameters with spatial array detectors to improve quality assurance (QA) results. The integral quality monitor system (IQM) is a transmission detector developed for real-time monitoring of patient treatments. The system employs a large area ionization chamber which can be used to detect errors in MLC position with greater accuracy.

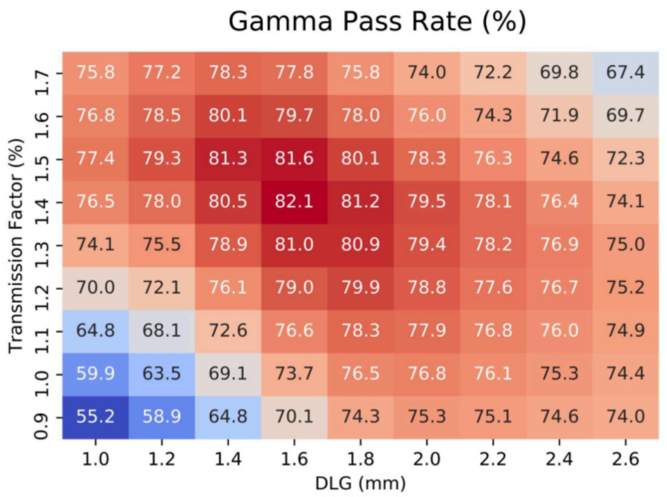
AIM

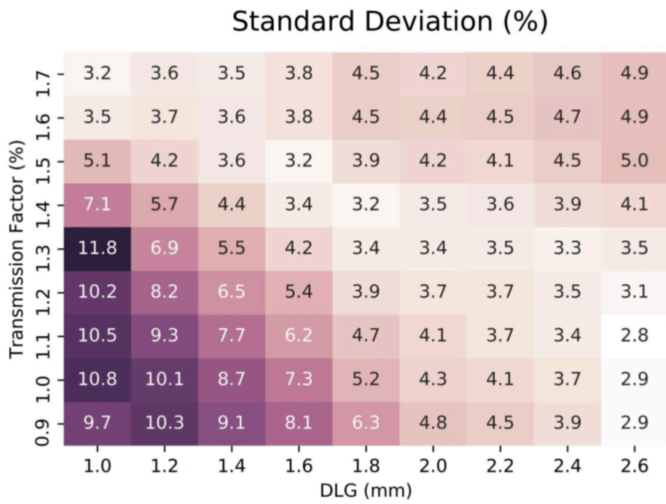
To compare the capability of the Integral Quality Monitor (IQM) for optimizing multi-leaf collimator (MLC) model specific parameters: dosimetric leaf gap (DLG) and transmission factor (TF) to a spatial array (MatriXX).

METHOD

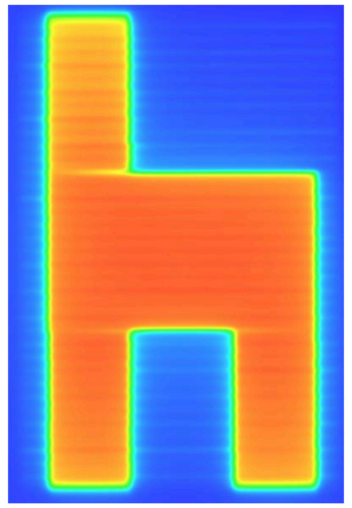
The standard dynamic chair static IMRT pattern was generated and a basis fluence was calculated for commissioned values of DLG and TF. Dose was calculated for a spectrum of values for TF and DLG, while holding constant the dynamic MLC pattern, optimal fluence, and monitor units. The optimum values of the model parameters were evaluated against beam delivery on a 2-D ion chamber array (MatriXX). Gamma analysis, a common metric for patient-specific quality assurance, was used to evaluate optimum parameter settings. Parameters of gamma evaluation (2%/2 mm, 95% threshold, local) were chosen to have a high sensitivity to small parameter changes. The standard chair pattern was measured with the IQM system (n=5) utilizing the MU Merge rule value of 10.0 specific to v1.8.12-beta and found to have very low variation (0.058%) between measurements. The DLG and TF setting in the IQMCalc calculation model were altered across the same range as used previously with MatriXX to evaluate optimum parameter settings as the minimum error percentage between calculated and measured signal. Local minimum (1.49 mm) was determined for DLG, however, there was not a local minimum in the TF in the range selected.

RESULTS

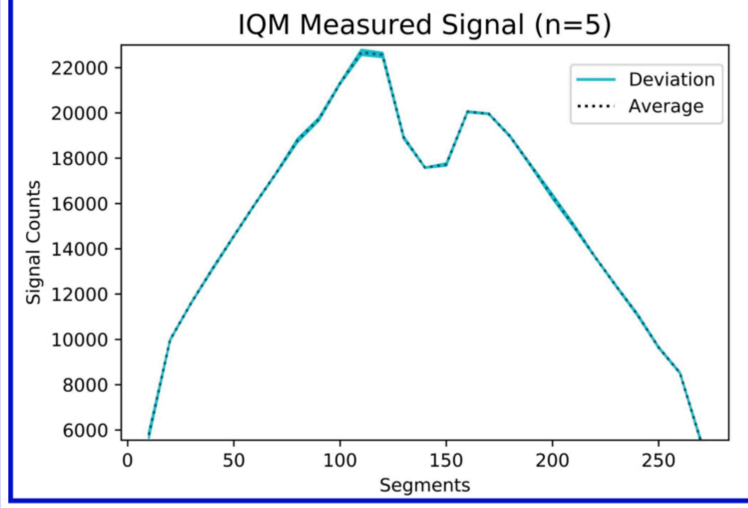


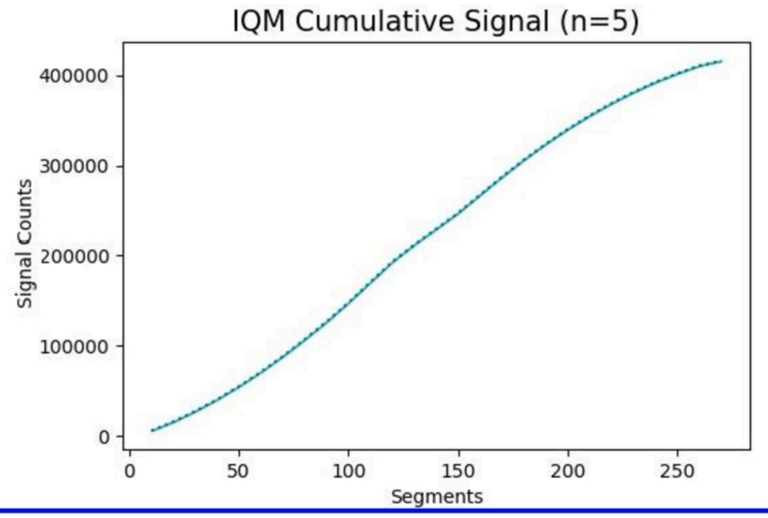


Assessment of optimum trend for a series of measurements using the MatriXX across a spectrum of DLG and TF settings. A) Gamma pass rate (2%, 2mm, 95% threshold, local) trends for model parameters. B) Standard deviation for measurements (n=3).

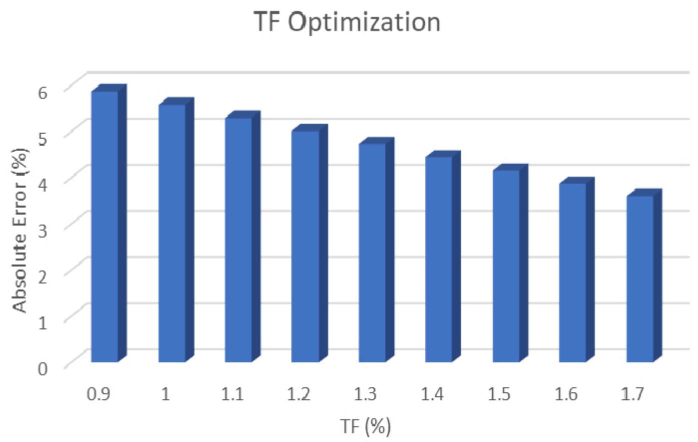


Standard chair fluence pattern used for optimization of DLG parameter.



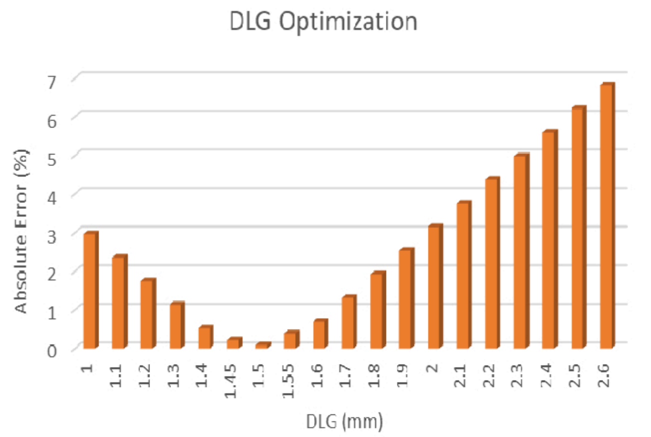


IQM measured signal for standard dynamic chair static IMRT pattern measured on Varian TrueBeam. Signal is plotted against segments from the trajectory file. Presented are both the segment-by-segment (left) plot and the cumulative (right) plot. Dotted line represents the average of n=5 measurements with standard deviation as the blue window.



TF optimization with IQM. TF setting altered in IQMCalc across the range evaluated with MatriXX. The absolute error % was evaluated, but no local minimum was found due to the geometric differences increasing the backscatter of IQM measurements comparted to those made at isocenter.

Optimization of DLG parameter with IQM. Calculation model altered to find best match with measured data with minimum absolute error %. Value of 1.49 mm is close to the initial model parameter of 1.50 mm.



DISCUSSION

Alteration of the MLC model parameters, DLG and TF, are frequently made to increase sensitivity of patient-specific quality assurance measurements. Common tools utilized for optimization (MatriXX, film, EPID, etc.) measure spatial data that is collapsed to a scalar value to facilitate comparisons. MatriXX measurements of the standard dynamic chair plan were evaluated across several DLG and TF settings to establish optimum settings for our set of TrueBeams. High standard deviations in the measurements made the optimized value unreliable. The highly robust integrated signal measurements of IQM were evaluated as a method to increase the resolution of the MLC model parameters. Measurements with the IQM were highly reproducible across a series of measurements. Altering TF resulted in a linear change to signal, however; a minimum value was not resolved in the range. The IQM is attached to internal mount (slot 1) of the TrueBeam and therefore is affected differently by linac head scatter than detectors at isocenter. Most TPS implement TF assuming reference conditions, and therefore the optimized TF from IQM does not correlate with the value as implemented in dose calculations. Future MLC model parameter optimization with IQM will focus solely on the DLG factor. Altering DLG in the IQM calculation model produced a linear change in the predicted signal. The optimum DLG value was determined by the minimum percent absolute error between predicted and measured. The IQM facilitated a higher resolution (0.01 mm) measurement than was possible with MatriXX and resolved an optimum value intermediate (1.49 mm) between commissioned DLG (1.23 mm) and MatriXX DLG (1.6 mm). Forestalling the immediate implementation of this value, however, is the close agreement of this optimum with the original commissioned DLG value of 1.50 mm derived by iRT in association with their research partners, potentiating a bias in analysis. The IQM calculated signal for U monitor units is determined from the equation:

$$C_{IQM} = U * AOF(x,y) * \frac{N_{IQM}}{n*m} * \sum_{i,j}^{n,m} S_{IQM}(i,j) * I(i,j)$$

The affect of the DLG factor in the calculation is implemented in the beam intensity $I(i,j)$, however, precalculated Area Output Factors, $AOF(x,y)$, are a function of the initial commissioned DLG value. Future efforts will focus on disentangling the effect of the DLG factor on calculated signal between the AOF and beam intensity.

REFERENCES

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