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EASTERN TIME [GMT-4]

Modulation Complexity Score as a Clinical Decision Aid for VMAT-Based Pancreas SBRT Treatment Planning

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INTRODUCTION

Pancreas SBRT planning is not a straightforward task; planners struggle to meet constraints and generally must make compromises among achievable constraints and between constraints and PTV coverage. We demonstrate strong inverse correlation between modulation complexity score (MCS) and VMAT MLC-defined field size. This makes possible plan evaluation and decision making based on an acceptable MCS range as a function of field size. We provide this range for typical field sizes at our institution.

Furthermore, there is evidence to both support[1] and refute[2] a correlation between dosimetric accuracy and plan complexity. We demonstrate weak correlation of measurement-based patient-specific QA gamma passing rates with both MCS and field size. This indicates that other factors are responsible for dosimetric accuracy and, therefore, planning decisions regarding modulation do not require consideration of dosimetric accuracy.

AIM

To investigate the clinical decision making impact of using complexity score for pancreas VMAT-based SBRT plan evaluation.

METHOD

Thirty (30) pancreas VMAT SBRT plans generated in Eclipse at our institution were retrospectively studied. Monitor unit (MU)-weighted modulation complexity scores (MCS) were calculated via an in-house script through ESAPI. The MCS metric varies from 0 for high modulation to 1 for minimum modulation. Linear regression was performed on MCS as a function of mean MLC-based equivalent-square field side (EqSq) per plan. Measurement-based patient-specific QA gamma passing rates with 2%/2 mm (2/2) and 3%/3 mm (3/3) criteria were also examined as a function of MCS, field size, and the combined parameter EqSqMCS, defined as (1 – EqSq/22cm) × MCS.

The modulation complexity score (MCS) for VMAT was defined by Masi et al.[1] as:

$$MCS_{arc} = \sum_{i=1}^{I-1}\left[\frac{AAV_{\mathrm{cp}_i} + AAV_{\mathrm{cp}_{i+1}}}{2} \times \frac{LSV_{\mathrm{cp}_i} + LSV_{\mathrm{cp}_{i+1}}}{2} \times \frac{MU_{\mathrm{cp}_{i,i+1}}}{MU_{arc}}\right],$$

$$AAV_{\mathrm{cp}} = \frac{\sum_{a=1}^{A}\left(\langle pos_a\rangle_{\mathrm{leftbank}} - \langle pos_a\rangle_{\mathrm{rightbank}}\right)}{\sum_{a=1}^{A}\left(\langle \max(pos_a)\rangle_{\mathrm{leftbank}\in\mathrm{arc}} - \langle \max(pos_a)\rangle_{\mathrm{rightbank}\in\mathrm{arc}}\right)},$$

$$LSV_{\mathrm{cp}} = \left[\frac{\sum_{n=1}^{N-1}\left(pos_{\max} - |(pos_n - pos_{n+1})|\right)}{(N-1)\times pos_{\max}}\right]_{\mathrm{leftbank}} \times \left[\frac{\sum_{n=1}^{N-1}\left(pos_{\max} - |(pos_n - pos_{n+1})|\right)}{(N-1)\times pos_{\max}}\right]_{\mathrm{rightbank}},$$

where the involved quantities are defined as:

AAV, LSV	aperture area variability, leaf sequence variability,
cp	control point,
I, A, N	number of control points, leaves in arc, moving leaves inside jaws, and
pos	leaf position coordinate.

RESULTS

MCS and field size were strongly correlated (Pearson r = 0.85, MCS = 0.12 - 0.45, EqSq = 1.4 cm - 5.1 cm). This indicates that modulation, and thus potentially plan quality, could be improved with decreased MLC aperture size. Gamma index was not found to correlate with MCS [r = -0.46 (3/3), -0.37 (2/2); Gamma test passing rates = 91.6% - 100.0% (3/3), 78.5-100.0% (2/2)]. This indicates that decreasing the MLC aperture size in these cases would not affect the agreement between calculation and measurement, and thus the dosimetric accuracy [as evidenced by a correspondingly low EqSq r = -0.41 (3/3), -0.14 (2/2)]. There was also no significant improvement in the correlation with EqSqMCS. The uncertainty effect of plan complexity on dosimetric accuracy is insignificant relative to other factors affecting calculation and delivery.

In Tables 1 and 2 are given descriptive statistics of and Pearson correlation coefficient between the arc-averaged MLC-defined equivalent-square field side (EqSq) and the MCS of 30 pancreas VMAT SBRT plans generated in Eclipse at our institution (Rx: 25/33 Gy × 17, 25/33/40 Gy × 5, 25 Gy × 5, 40 Gy × 2, 25/40 Gy × 1 in 5 fractions). The corresponding data and fit with 95% confidence interval is plotted in Fig. 1. Strong positive correlation indicates that plan complexity and MLC-defined field size are strongly inversely correlated.

In Figs. 2-4, gamma passing rates of measurement-based patient-specific QA with a Delta4 phantom with 2%/2 mm criteria are provided for all plans as a function of MCS, EqSq, and a combination of the two, respectively. No correlation indicates that QA results are independent of plan complexity.

Table 1: Descriptive statistics and Pearson correlation coefficient for MLC-defined equivalent square field side (EqSq) and modulation complexity score (MCS)[1] of 30 pancreas VMAT SBRT plans at our institution.

	EqSq / cm	MCS
Min	1.39	0.116
Mean	3.29	0.247
Max	5.15	0.447
90% <	4.42	0.339
σ	1.04	0.082
r	**0.85**	

Table 2: Measurement-based patient-specific QA gamma passing rates, percentage of plans with passing rates > 95% and > 90%, and Pearson correlation coefficients with plan parameters in Table 1.

	Γ 3%/3 mm	Γ 2%/2 mm
Min	91.6%	78.5%
Mean	98.6%	93.6%
Max	100.0%	100.0%
Plans > 95%	90.0%	50.0%
Plans > 90%	100.0%	73.3%
r (EqSq)	**-0.41**	**-0.14**
r (MCS)	**-0.46**	**-0.37**

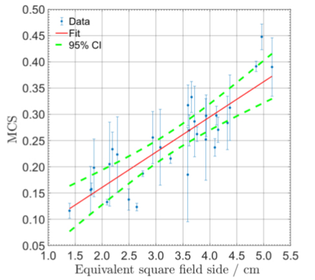

Figure 1: Linear regression of variables in Table 1. Errors bars represent one standard deviation. Confidence lines indicate 95% confidence level.

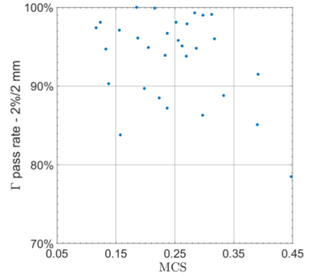

Figure 2: Gamma passing rates for 2%/2 mm criteria, normalized to local measurement, as a function of modulation complexity score (MCS).[1]

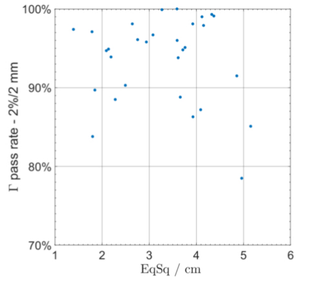

Figure 3: Same as Fig. 2, but as a function of VMAT arc-averaged MLC-defined equivalent square field side (EqSq).

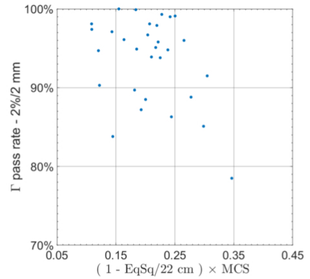

Figure 4: Same as Fig. 2, but as a function of a combination of the plan parameters in Figs. 2 and 3, EqSqMCS = (1 - EqSq/22 cm) × MCS.

CONCLUSIONS

Based on the strong correlation between MCS and pancreas VMAT SBRT MLC aperture equivalent-square field size, we conclude that MCS can be used to score plan complexity for clinical treatment plan decision making. Given a VMAT plan MLC score, a recommendation of modulation improvement/reduction can be made based on the achieved MCS-MLC aperture size regression with uncertainty range. Such recommendation may reduce time consumption as in the trial-and-error planning manner.

The key results above demonstrate that decisions regarding plan complexity can be made (1) based on field-dependent criteria and (2) independent of dosimetric accuracy considerations. This promises to improve planning and verification workflow. Although institution and treatment site-specific, these results could be compared to those of other centers and conclusions made regarding the clinical decision making process.

REFERENCES

[1] L. Masi, R. Doro, V. Favuzza, S. Cipressi, and L. Livi, Impact of plan parameters on the dosimetric accuracy of volumetric modulated arc therapy, Med Phys **40**, 071718 (2013).

[2] M. Glenn et al., Treatment plan complexity does not predict IROC Houston anthropomorphic head and neck phantom performance, Phys Med Biol **63**, 205015 (2018).

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