Relation of Daily Dosimetric Variations to the Accumulated Dose Distribution in Online MR-Linac Guided Prostate SBRT

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INTRODUCTION

MRI, with its unrivalled soft tissue delineation and functional imaging capabilities will redefine the adaptive radiotherapy paradigm with the availability of a fully integrated MR-Linac (MRL). The MRL enables daily online replanning to account for anatomical variations to reduce dose to the organs-at-risk (OARs) and maintain target coverage or escalate dose.

AIM

Determine the clinical and cumulative impact of daily dosimetric excursions from our ideal tolerance bands in an online adaptive radiotherapy workflow.

METHODS

7 prostate SBRT patients were treated to 40Gy in 5 fractions on the MRL using an online adaptive strategy accounting for daily anatomical changes:

- T2-weighted MRs acquired on the treatment unit at each fraction were used to generate new treatment plans, which required physician re-contouring.
- CTV = Prostate + proximal 1cm of seminal vesicles
- PTV = CTV + 4mm
- Treatment plans generated for each fraction were evaluated based on 3 dosimetric criteria levels to permit some flexibility in online re-planning as follows: Ideal (from reported clinical SBRT outcomes), Acceptable, or Out of Tolerance (derived from institutional experience).

Tolerance levels achieved tabulated: 33 fractions, 7 patients:

- Fractional values binned according to the tolerance level [165 OAR parameters (33 fractions x 5 constraints) and 66 target dose constraints (33x2)].
- Final cumulative dose to OARs and targets also binned according to tolerance level. Deformable image registration used to warp daily MRI and dose distribution from each given fraction to determine cumulative dose.

RESULTS

		Ideal	Acceptable	Out of Tolerance
Rectum	Dmax	< 4060cGy	≤ 4200cGy	> 4200cGy
Rectum	V3800cGy	< 1cc	≤ 1.5cc	> 1.5 cc
Rectum	V3500cGy	< 2cc	≤ 5cc	> 5 cc
Bladder	V3950cGy	< 2cc	≤ 3cc	> 3 cc
Bladder	V3800cGy	< 6cc	≤ 8cc	> 8 cc
CTV	V4000cGy	> 99%	≥ 95%	< 95%
PTV	V3625cGy	> 99%	≥ 90%	< 90%

Table 1. Dosimetric Criteria Levels

For the 33 fractions in 7 patients reviewed (Figure 1-left):

- OAR criteria: 89.7% (148/165) were Ideal, 10.3% (17/165) were Acceptable, none Out of tolerance.
- Target coverage criteria: 54.5% (36/66) were Ideal and 45.5% (30/66) were Acceptable, none Out of tolerance.

For cumulative doses reviewed (Figure 1-right):

- OAR criteria: 97.1% were Ideal, 2.9% were Acceptable, none Out of tolerance.
- Target coverage criteria: 21.4% were Ideal and 78.6% were Acceptable, none Out of tolerance.

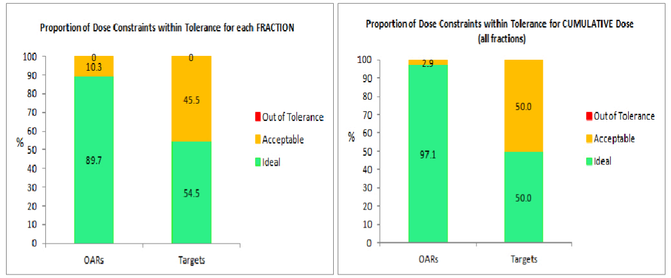

Figure 1. *Proportion of OAR and Target constraints within and outside tolerance bands. Tolerance bands for fractional doses are shown on the left and tolerance bands for cumulative doses is shown on the right.*

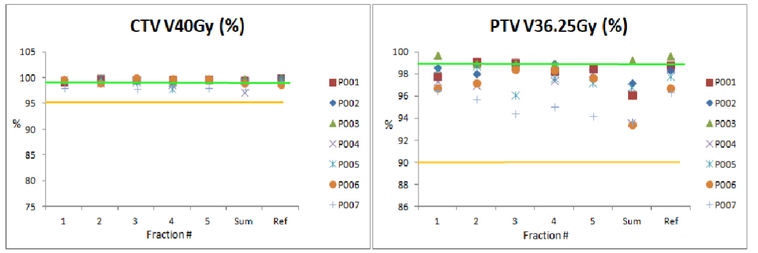

Figure 2. *Fractional and Cumulative (Sum) Target Doses for each Patient. The CT-based reference plan metrics for each patient are also reported. The green and orange lines reflect the ideal and acceptable tolerance bands as shown in Table 1.*

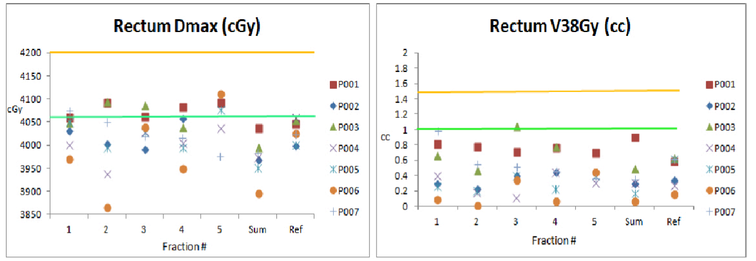

Figure 3. *Fractional and Cumulative (Sum) Rectal Doses (selected) for each Patient. The CT-based reference plan metrics for each patient are also reported. The green and orange lines reflect the ideal and acceptable tolerance bands as shown in Table 1.*

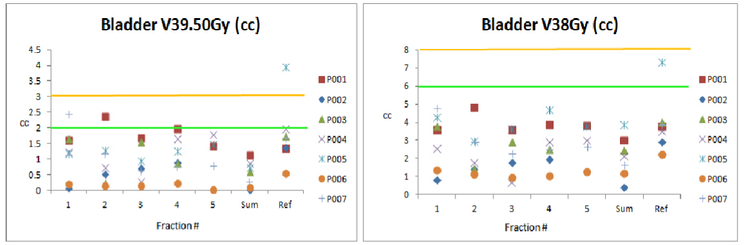

Figure 4. *Fractional and Cumulative (Sum) Bladder Doses (selected) for each Patient. The CT-based reference plan metrics for each patient are also reported. The green and orange lines reflect the ideal and acceptable tolerance bands as shown in Table 1.*

CONCLUSIONS

Minor variability in dosimetric criteria across treatment fractions suggests that hot spots or areas of under-coverage wash out in the accumulated dose (majority of dosimetric criteria fell within Ideal and Acceptable bands).

The online workflow is robust despite the allowance in fractional variability in dosimetric criteria. Efficiency may be gained by further expanding fractional dose tolerance bands, given the limited impact singular dosimetric excursions on cumulative dose.

Future work involves re-assessing the tolerance bands to optimize the tradeoff between online planning flexibility with clinically acceptable cumulative doses.

REFERENCES

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