JULY 12–16 2020 VIRTUAL JOINT AAPM | COMP MEETING
EASTERN TIME [GMT-4]

Assessing the Dosimetric Links Between Organ-At-Risk Delineation Variability and Treatment Planning Variability

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INTRODUCTION

Delineation variability (DV) is an unavoidable source of uncertainty in radiation therapy (RT) wherein inter-observer [1], intra-observer [2], and methodological variabilities [3] lead to differing delineations given identical input information [4]. It has been demonstrated that DV can lead to dosimetrically suboptimal plans and inaccurate plan quality metrics (PQMs)[3,5].

Setup variability (SV), which results from day-to-day variability in the patient setup, also affects the patient dose received from a treatment plan [6]. It has been shown to "wash-out" the dosimetric impact of DV wherein the effect of DV is apparently reduced when SV is incorporated in the analysis.

Plan variability (PV) arises when planning is performed by different observers [7], at different institutions [8], or for different delivery techniques [9]. Although prior studies have assessed the dosimetric impact of inter-observer DV, to our knowledge, all have assumed a consistent planning methodology.

Just as SV affects the impact of DV, we hypothesize that inter-observer plan variability (PV) may also impact the apparent effect of DV. Furthermore, inherent differences between planning and/or delivery techniques may result in systematic differences in the sensitivity to DV.

AIM

1) Determine the incremental dosimetric impact of DV when inter-observer and inter-technique planning variability is also considered.
2) Identify the relative dose sensitivity of PV and DV.

RESULTS

The primary source of dose variability was PV, which was expected due to inter-observer planning abilities and preferences during the optimization planning process, even when all participants utilized the same constraints.

The parotid had the most significant interquartile range (IQR) on the PV scenario.

Conversely, adding SV, DV, and TV each reduced the IQR, showing a washing out effect on the DVCM.

Figure 1 shows examples of those variabilities.

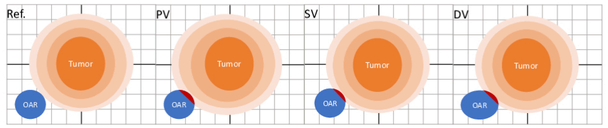

Figure 1. Three different variabilities (PV: plan variability, SV: setup variability, and DV: delineation variability) in RT, Orange: discretized dose distribution, Blue: OAR, and Red: overdosed region in OAR.

Dosimetric uncertainties caused by the variabilities were obtained using DVCM for each OAR, as shown in Figure 2.

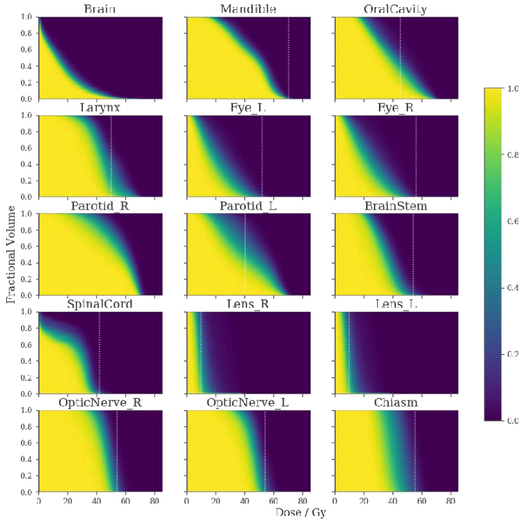

Figure 2. The DVCMs of OARs in HNC.

Table 1. Overdosed volume affected by different variations (probability > 5%)

	TV	SV+PV	SV+DV	PV+DV	SV	PV	DV	Average
BrainStem	15.0%	11.0%	10.0%	7.0%	3.0%	1.0%	2.0%	7.0%
Chiasm	68.0%	0.0%	65.0%	56.0%	0.0%	0.0%	49.0%	34.0%
Eye_L	7.0%	5.0%	4.0%	1.0%	2.0%	1.0%	1.0%	3.0%
Eye_R	2.0%	1.0%	1.0%	1.0%	0.0%	0.0%	1.0%	0.9%
Lens_L	100.0%	100.0%	100.0%	100.0%	99.0%	100.0%	1.0%	85.7%
Lens_R	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	1.0%	85.9%
Mandible	4.0%	4.0%	0.0%	7.0%	0.0%	8.0%	1.0%	3.4%
OpticNerve_L	51.0%	42.0%	43.0%	36.0%	17.0%	0.0%	34.0%	31.9%
OpticNerve_R	56.0%	38.0%	61.0%	38.0%	20.0%	0.0%	39.0%	36.0%
SpinalCord	13.0%	12.0%	5.0%	5.0%	4.0%	1.0%	2.0%	6.0%
Average	41.6%	31.3%	38.9%	35.1%	24.5%	21.1%	13.1%	29.4%

>95%
>50%
>30%
>20%
> 5%
≤ 5%
= 0%

Table1 shows the fractional volume of the overdosed region in each OAR, when the coverage probability at the maximum-dose constraint was more significant than 5%, and the color codes were applied according to the levels of the affected volume ratio.

Lenses showed about 100% of the volume to be overdosed when SV or PV was applied since they are small organs, and the maximum dose criteria of them is low (10 Gy).

In contrast, Mandible showed a small portion of the volume (average 3.4%) to be overdosed when any variability was applied, and PV was washed out when adding SV onto it (8.0% -> 4.0%).

BrainStem and SpinalCord showed elevations of variabilities when combining SV and PV.

METHOD

409 plans for a single head-and-neck patient from the 2017 Radiation Knowledge plan competition were used.

Plans were created with Eclipse (N=227), Pinnacle (N=49), RayStation (N=25), Monaco (N=75), and TomoTherapy (N=33) with delivery techniques conventional linac IMRT (N=142), volumetric modulated arc therapy (VMAT, N=234), and helical TomoTherapy (N=33).

All plans were optimized using a consistent set of target volumes and a single OAR structure set. Four additional OAR structure sets were contoured by radiation oncologists (N=2) and medical physics residents (N=2) who had completed head-and-neck contouring training.

Probabilistic DVHs, dose-volume coverage maps (DVCM), which shows the probability of achieving a dose metric, were computed for each OAR on the following scenarios:

- SV alone (N=1000)
- SV+PV (N=1000*409)
- SV+DV (N=1000*5)
- SV+PV+DV (total variability [TV], N=1000*409*5)

The following procedure is to generate a DVCM for an OAR.

1) Generate DVHs for various plans, delineations, and setup errors.
2) Accumulate all grid squares lying below or left of each DVH.
3) To obtain the DVCM, divide them by total numbers of DVH.

We then obtained a measure based on the DVCMs to compare the dosimetric impact, which is the fractional volume of the overdosed region.

The probability of the volume coverage at the maximum dose constraint and the corresponding fractional volume are used to estimate the dosimetric consequences.

We used 5th percentile DVH (PDVH) for each OAR, which was obtained by connecting DVCM grid squares containing a probability of 5%.

Therefore, we computed the fractional volume at the maximum-dose constraint of 5th PDVH, which is a ratio of how much of the OAR volume will be overdosed by variabilities.

CONCLUSIONS

This study evaluated the incremental dosimetric impact of PV, SV, and DV.

Assessment of OAR sensitivity to DV will be highly sensitive to the specific planning technique and planner, likely requiring plan-specific assessment of in-tolerance delineation variations.

Incorporation SV and DV variabilities in plan assessments washes out their relative impacts on maximum dose.

CONTACT INFORMATION

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ACKNOWLEDGEMENTS

This work was supported by NIH R01CA222216.

Ahmad Nobah, M.Sc, DABR, for providing the plan competition database. https://radiationknowledge.org/