An intelligent IMRT optimization method based on radiobiological effects oriented by dose prediction

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INTRODUCTION

We consider this work to be innovative because it put forward and validates a new method, which based on equivalent volume reconstruction of physical dose volume in radiobiology, for intelligent IMRT treatment planning optimization, called ***equivalent reconstructed volume minimization method (ReVol)***. Bio-mathematical model provides a holistic description of the volume of ROI to more directly reflect the radiobiological effects of the volume corresponding to a specific dose, which reduced the exposure dose to OAR. And the use of guidance for predicting dose distribution can improve the efficiency and universality of plan design, which is helpful to the improvement of plan quality and will be useful to planner for a better solution.

AIM

To propose a dose prediction oriented equivalent reconstructed volume minimization method by radiobiology optimization for knowledge based treatment planning for intensity modulated radiotherapy.

METHOD

On the basis of our in-house developed IMRT treatment plan 3D dose distribution prediction model, we customized a novel an optimization engine based on the radiobiological equivalent of the conventional dose-volume approach to further reduce the OARs dose. ***It reconstructed the dose-volume (DV) on the biological criterion to obtain the equivalent reconstructed volume (ReVol), which is more clinically relevant than the DV method.***

We used the tolerated dose of OAR as the reference dose and the corresponding volume as the reference volume, then let them be the two input parameters of the proposed biological optimization model for equivalent volume calculation and plan optimization.

We collected ***8 patient cases of head and neck cancer*** which had received radiotherapy to evaluate the developed method. Develop two plans for each case. Firstly, the target area and organs at risk(OAR) were optimized by dose-volume-based objective and constraints to obtain the ***DV plan***. Then with the original objective and constraints unchanged, the equivalent reconstructed volume constraint to the bilateral parotid glands to get ***ReVol plan***. The plan quality was investigated by comparing the DV plan to the ReVol plan in terms of ROI's DVH and statistics.

RESULTS

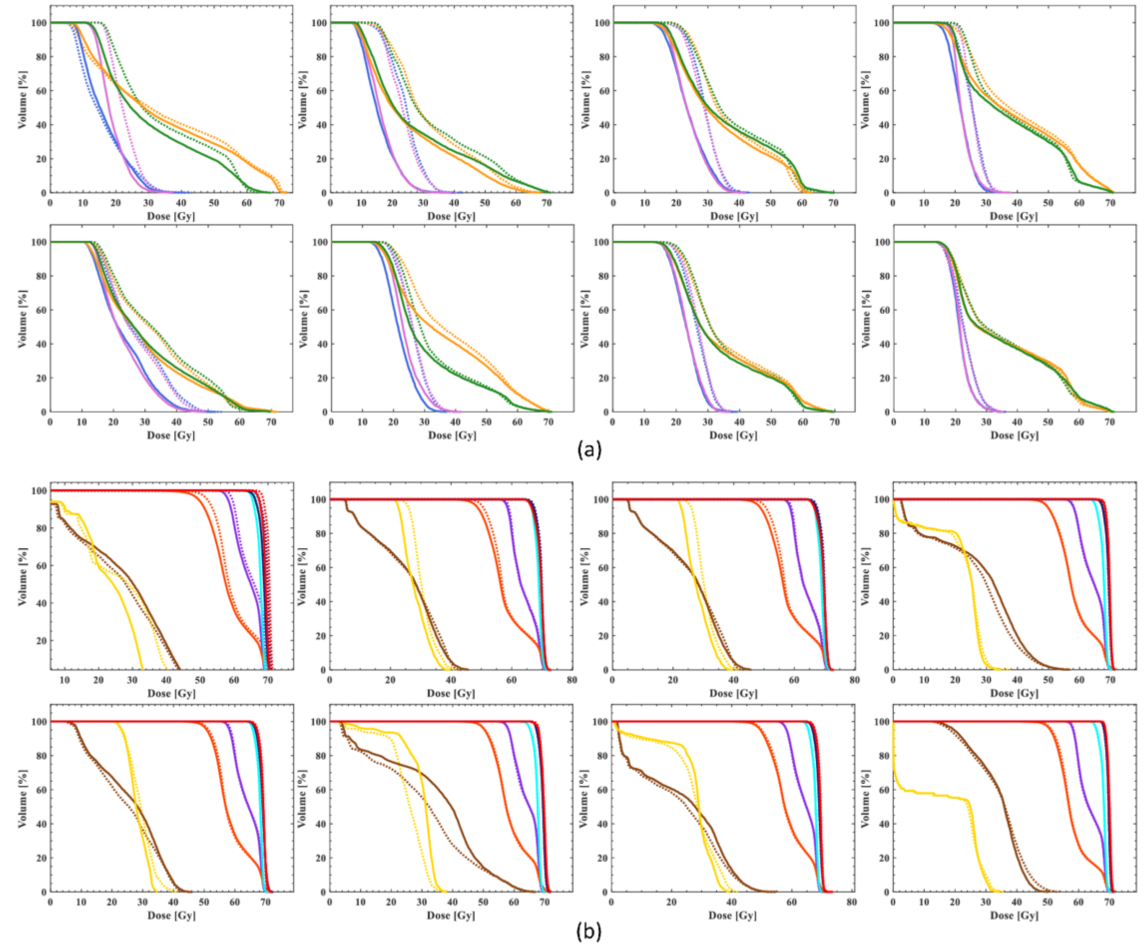

Fig.1. DVH of 8 Head and Neck cases of (a) Bilateral total parotid glands and normal parotid glands (outside the target area). (b) 5 Planning targets (PTVnx, PTVnd_L, PTVnd_R, PTV1, PTV2) and other OARs (Brain stem, Spinal cord). (ReVol plan is indicated by the solid line whereas the DV plan is indicated by the broken line.)

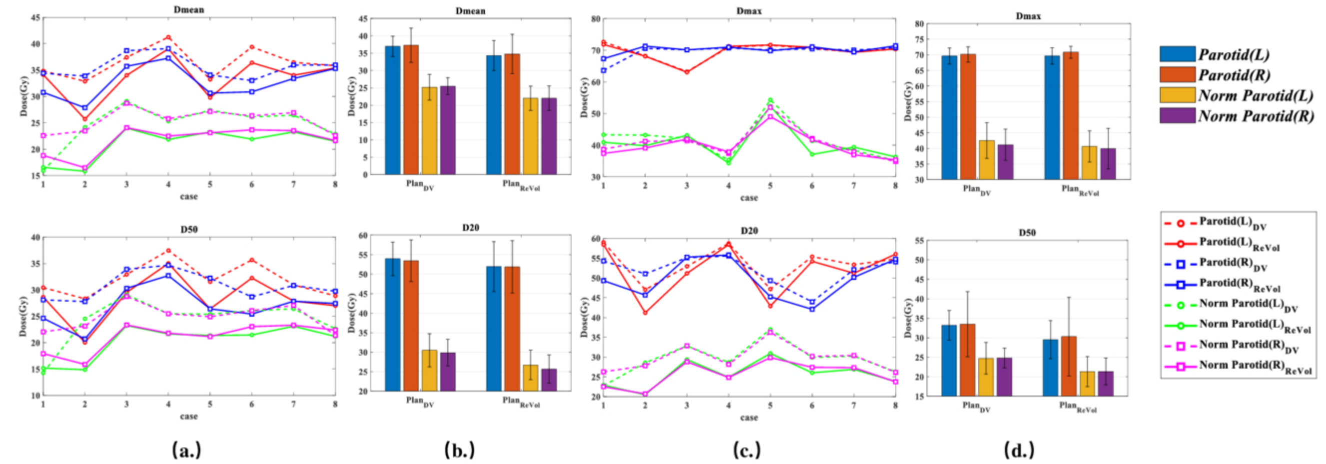

Fig.2. Statistics of parotid glands in 8 Head and Neck cases.
(a., c.) Numerical comparison of Dmean, Dmax, D20 and D50 of the two methods (ReVol plan is indicated by the solid line whereas the DV plan is indicated by the broken line). (b., d.) Boxplot of the mean and standard deviation of the results of the two methods. Each vertical bar represents the mean plus or minus the standard deviation value of samples from the results obtained carried out with two methods of eight Head and Neck cases each.

*Both DVH and statistical results show that our proposed optimized plan **improved the bilateral parotid glands sparing** under the comparable target coverage and other OAR protection with DV plan.*

*It is clearly shows that the DVH curves of bilateral parotid glands with ReVol plan are much better than in DV plan in **Fig.1.(a)**, and the effect of the proposed method in normal parotid glands (outside the target area) are more prominent. The line chart and boxplot were used to show the statistics of parotid glands in **Fig.2.** We can observe that the mean dose and D_{20}, D_{50} of bilateral parotid glands in ReVol plan were significantly lower than that in DV plan, while the maximum dose were comparable.*

*As **Fig.1.(b)** shows that the DVH curves of all five PTVs in DV plan and ReVol plan almost overlop. Furthermore, specific statistics for each target are listed in **Table 1.** For all PTVs, D_{95} and D_{max} remained at a comparable level to the DV plan while HI has no significant difference.*

By using our equivalent reconstructed volume minimization method to optimized the plan, the better protection of OAR was realized and the quality of the plan was successfully improved.

		$Plan_{DV}(x \pm s)$	$Plan_{ReVol}(x \pm s)$	P
PTV_{nx}	D_{mean}	68.06±0.51	67.91±0.4	0.127423694
	D_{max}	70.75±0.52	70.73±0.49	0.457579212
	D_{95}	65.9±0.56	65.69±0.43	0.088785489
	HI	0.15±0.01	0.15±0.01	**0.001019032**
$PTV_{nd}(L)$	D_{mean}	69.39±0.33	69.25±0.41	0.143827478
	D_{max}	71.74±0.61	71.93±0.55	0.064550499
	D_{95}	67.6±0.66	67.33±0.8	0.055903006
	HI	0.13±0.03	0.14±0.03	**0.004235859**
$PTV_{nd}(R)$	D_{mean}	69.54±0.35	69.43±0.28	0.229336466
	D_{max}	71.94±0.65	72.13±0.76	0.049470481
	D_{95}	67.87±0.61	67.6±0.66	0.059438843
	HI	0.12±0.02	0.13±0.03	**0.002553718**
PTV_1	D_{mean}	64.23±0.44	64.1±0.18	0.181900637
	D_{max}	70.75±0.52	70.79±0.43	0.401104846
	D_{95}	58.6±0.46	58.28±0.15	0.029891984
	HI	0.52±0.01	0.54±0.01	**0.000605056**
PTV_2	D_{mean}	58.75±0.65	58.4±0.44	0.03661247
	D_{max}	72.07±0.7	72.34±0.69	0.01696659
	D_{95}	50.77±0.79	49.94±0.72	0.017849299
	HI	1±0.04	1.04±0.06	**0.008055632**

Table.1. Average endpoints comparisons of targets between ReVol plan and DV plan of 8 cases.

CONCLUSIONS

We proposed a novel dose prediction oriented radiobiological equivalent reconstructed volume method for knowledge based treatment planning optimization for intensity modulated radiotherapy, which reducing the dose of OAR exposure while more directly related to clinical and biological significance.

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