Biologically Equivalent Dose Summation Considering Organ-specific Radiosensitivity for Reirradiation of Thoracic Cancer Patients treated with Stereotactic Body Radiation Therapy

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PURPOSE

Dose-volume constraints for organs at risk (OARs) in stereotactic body radiation therapy (SBRT) for thoracic cancer patients have been well established through multiple prospective clinical trials. However, during equivalent dose in 2 Gy fractions (EQD2) summation for reirradiation, inconsistencies between physical dose and EQD2-based constraints have been observed for certain OARs when a nominal α/β =3 Gy is used in linear–quadratic (LQ) model–based calculations. We developed an EQD2 summation workflow in MIM that incorporates organ-specific α/β ratios.

MATERIAL & METHODS

Organ-specific α/β ratios were derived from published dose–volume constraint data used in thoracic treatment planning. A workflow was developed in MIM to deformably map prior physical doses onto retreatment CTs , convert physical doses to EQD2 using the LQ model with organ-specific α/β ratios, and accumulate them to generate a composite dose for plan evaluation . Each dose voxel was assigned an α/β value based on the OAR contour in which it resided. To address resolution mismatches between the dose and contour grids — particularly at structure boundaries where a single dose voxel may intersect multiple contours—a custom Java extension was implemented in MIM to resample the dose grid to the contour resolution using trilinear interpolation, ensuring a one-to-one correspondence between dose and contour voxels. The workflow was evaluated in seven patients undergoing EQD2 summation involving SBRT for thoracic cancer.

RESULTS

Organ-specific α/β ratios were successfully obtained for thoracic OARs and ranged from 2.1-28.1 Gy. The developed MIM workflow eliminated α/β misassignment caused by voxel sharing across adjacent contours. Compared with EQD2 calculations using α/β =3 Gy for all OARs, the proposed workflow produced more consistent and clinically interpretable EQD2 results across all fractionations evaluated.

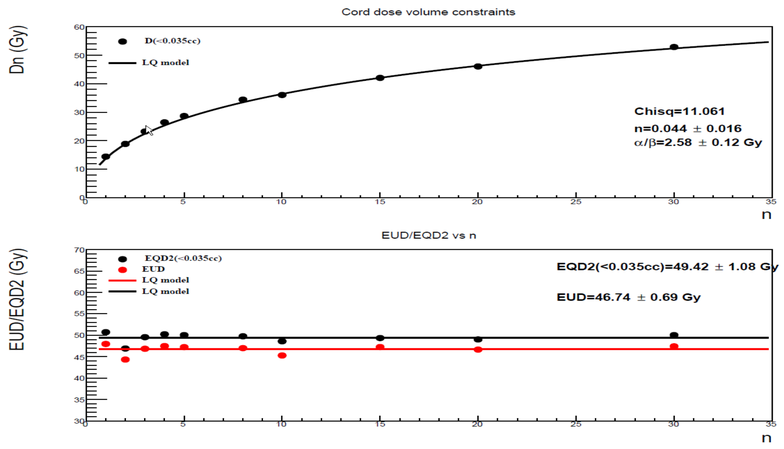

Fig.1 Extracted model parameters with an iso-EUD fitting of dose volume constraint data for Cord

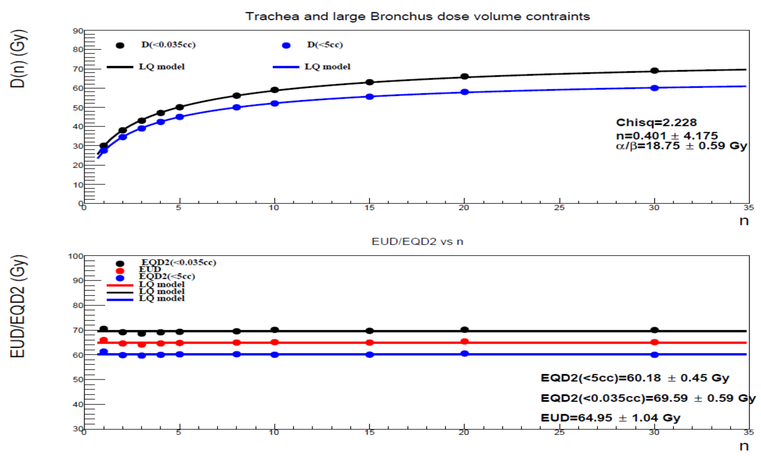

Fig.2 Extracted model parameters with an iso-EUD fitting of dose volume constraint data for bronchus.

Tab. 1 α/β ratios for OARs extracted from data in Timmerman's table

OARs	α/β	EQD2(0.035cc)	Endpoint(grade≥3)
SpinalCord	2.6	49.4	Myelitis
Lungs	4.0		Pneumonitis
Esophagus	10.3	58.7	Esophagitis
BrachialPlex_L/BrachialPlex_R	2.1	69.0	Neuropathy
Heart/Pericardium	8.1	57.2	Pericarditis,heart problems
GreatVes(aorta,vena cava pulmonary A&V)	28.1	71.1	Aneurysm
Trachea/Bronchus	18.7	69.6	Impairment of pulmonary toilet
Ribs	19.0	81.9	pain or fracture
Stomach	8.6	56.0	Ulceration/fistula

Tab. 2 showed that EQD2 was overestimated with α/β =3 Gy for SBRT while similar EQD2 were obtained for all fractions with α/β =18.7 Gy for Bronchus

Fx	Bronchus physical dose D(<0.035)	EQD2Gy3	EQD2Gy18.7
1	30	198	71
2	38	167	69
3	43	149	69
4	47	139	69
5	50	130	69
8	56	112	70
10	59	105	70
15	63	91	70
20	66	83	70
30	69	73	70

Tab. 3 An example shows how EQD2 calculations with organ-specific α/β affect composite EQD2 summation. This patient was treated to 50 Gy in 5fx in 2010 for a right lung tumor and retreated for another right lung tumor in 2022 to 60 Gy in 10fx. The highlighted EQD2 shows most changes due to α/β values of these OARs

OARs	SpinalCord	Esophagus	A_Aorta	Bronchus_R	Heart	Rib	Stomach	Lungs-ITV (mean dose)
Composite EQD2(<0.03 cc) cGy (α/β =3 Gy)	3524	4112	4515	29663	3895	12838	41	1470
Composite EQD2(<0.03cc) cGy (Organ-specific α/β)	3551	3346	3794	15120	3578	8330	49	1439

CONCLUSIONS

Organ-specific variations in radiosensitivity should be incorporated into EQD2 conversions and summations to reduce inconsistencies and improve clinical interpretation of composite plans for reirradiation.