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Dosimetric Quality Index in Lattice Radiotherapy Treatments

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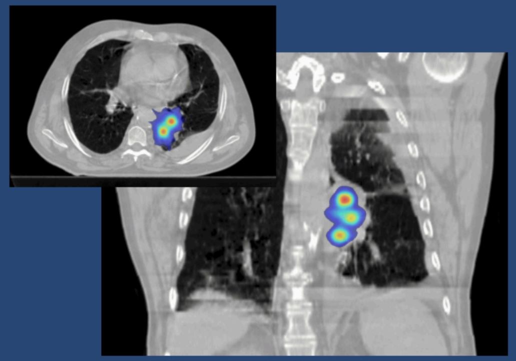
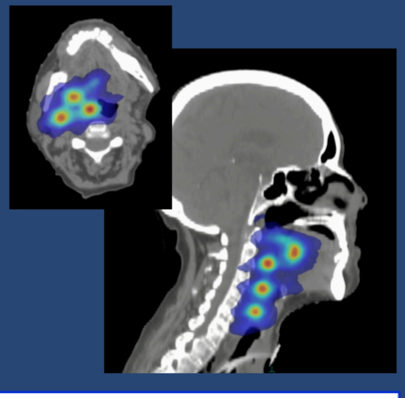
INTRODUCTION

Lattice Radiotherapy Treatment (LRT) consists on administration multiple high dose, in a single fraction, distributing mini-targets within the GTV with a degree of separation to form lower dose regions, that allows to deliver the concomitant dose to the PTV treatment in standard fractionation.

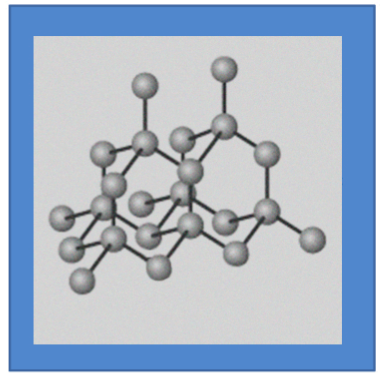




AIM

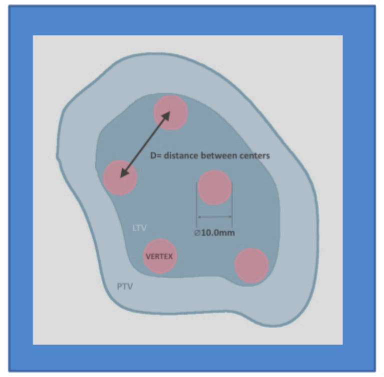
This work includes the initial steps taken to implement LRT technique, setting quantitative treatment quality criteria focused on achieving, in addition to PTV coverage, reaching high dose levels in spherical mini-targets besides developing tests to verify the accuracy of the dose delivered. We have analyzed the geometric and dose modulation parameters to settle the quality criteria of the LTR treatments.

METHOD



A node structure has been defined following diamond crystal lattices with adjacent center distance (D) from 20mm to 35mm. Each node serves as the center to generate a 1cm diameter sphere that constitutes the Vertex Tumor Volume (VTV).

By means of a theoretical simulation, we tried to obtain the optimal separation according to the PTV dimensions and prescription dose. These templates can be automatically imported over the PTV by means a RTPS automatic routine.



RESULTS (I): PREVIOUS DOSIMETRIC STUDY

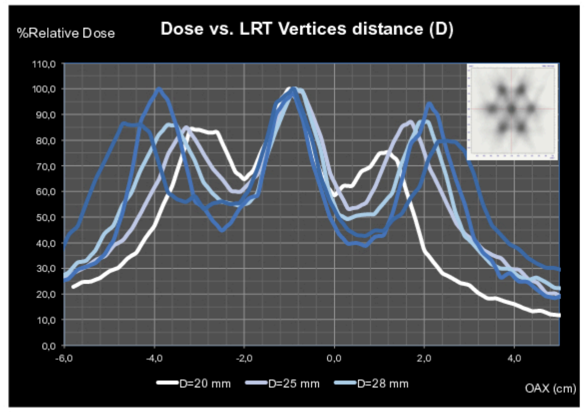


Fig .1. Dose profile related to maximum for distance between adjacent vertices from 20mm to 35mm.

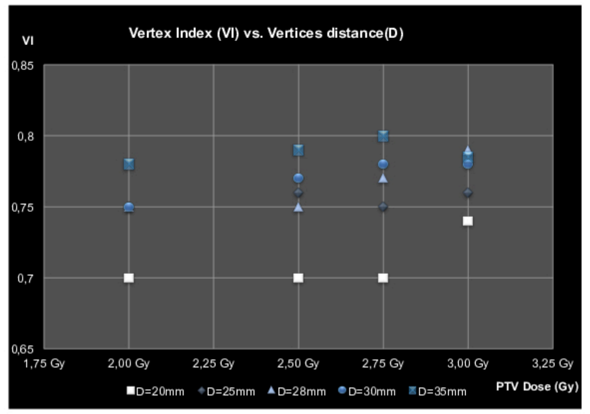


Fig. 2. Vertex index (VI= D50%/D2%) values obtained for distances between adjacent vertices (D) and Dose prescribed to PTV.

The following recommendations can be drawn from these theoretical studies:

- Vertices distances less than 20 mm produce high dose overlaps; distances greater than 35 mm limit the number of vertices inside GTV
- If the volume of GTV allows it, it is recommended to avoid vertices surrounded by other vertices due to the difficulty of obtaining the correct doses that avoid overdoses.
- The ratio **D50%/D2% reflects a good** index for assessing the resolution of the dose peaks.

	Parameter	d = 20mm (vol = 115 cc)				d = 25mm (vol = 325 cc)				d = 28mm (vol = 352 cc)				d = 30 mm (vol = 382 cc)				d = 35mm (vol = 771 cc)			
PTV	D95%	2Gy	2.5Gy	2.75Gy	3Gy	2Gy	2.5Gy	2.75Gy	3Gy	2Gy	2.5Gy	2.75Gy	3Gy	2Gy	2.5Gy	2.75Gy	3Gy	2Gy	2.5Gy	2.75Gy	3Gy
	V5Gy	32%	41%	49%	45%	29%	45%	30%	44%	29%	31%	31%	37%	25%	30%	30%	41%	21%	24%	38%	30%
VTV	D2%	13.0 Gy	12.4 Gy	13.6 Gy	14.0 Gy	14.1Gy	15.4Gy	14.0Gy	15.4Gy	15.7Gy	15.7Gy	15.3Gy	15.2Gy	15.8Gy	16.0Gy	15.8Gy	15.3Gy	15.4 Gy	16.6 Gy	17.4 Gy	16.8 Gy
	V_{12Gy}/V_{GTV}	1.0%	0.5%	1.6%	2.8%	1.2%	2%	1.1%	1.9%	2.3%	1.52%	2.3%	2.7%	2.2%	2.7%	2.8%	2.4%	1.2%	1.7%	2.2%	1.8%
	$D_{50\%}/D_{2\%}$	0.70	0.70	0.70	0.74	0.75	0.76	0.75	0.76	0.75	0.75	0.77	0.79	0.75	0.77	0.78	0.78	0.78	0.79	0.81	0.78
VV	V8Gy	3.16%	17.5%	23.7%	16.7%	6.3%	4.0%	6.3%	14.8%	7.9%	8.3%	7.3%	8.9%	4.0%	5.0%	4.7%	6.25	5.2%	7.5%	18.4%	9.7%

Table I. The results show the ability to achieve an optimal dose gradient related to dosimetric quality parameters established. For common size GTV the optimal distance between vertices (D) is from 25mm to 30mm. The quality criteria are not reached for a separation between vertices of D<20m or D>35mm.

CONCLUSIONS (I): DOSIMETRIC STUDY

Volumes	Mean ± σ	Min	Max
GTV (cc)	191.9 ± 87.2	80	338.9
LTV (cc)	144.4 ± 84.3	25.5	303
PTV doses	**Mean ± σ**	**Min**	**Max**
Dose/fx	2.7 ± 0.2	2.0	3.0
D95%	2.7 ± 0.3	2.0	3.0
V5Gy(%)	23.3% ± 7.0%	4.0%	31.3%
Vertex	**Mean ± σ**	**Min**	**Max**
Number	6.8 ± 2.7	4	14
Dist. max (mm) (*)	29.8 ± 4.8	21	38
Dist. min (mm) (*)	18.2 ± 3.6	12	25
D2% (Gy)	14.8 ± 0.8	13.4	15.5
D50% (Gy)	12.2 ± 0.8	9.9	13.5
V12Gy (cc)	3.3 ± 2.1	0.6	8.6
V12Gy/VGTV	1.8% ± 0.9%	0.6%	3.0%
D50/D2 (**)	0.82 ± 0.05	0.73	0.89
D2/Dmean_valley	2.63 ± 0.41	1.98	3.44
Valley	**Mean ± σ**	**Min**	**Max**
V8Gy	18.2 ± 8.2	5.7	33.8

Table II. Outcomes for 14 patients (7 lung tumor, 4 soft tissue tumor, 2 gynecological and 1 bone metastasis).
(*) Distances max and min measured taking into account four nearest vertex for each one.
(**) The ratio $D_{50\%}/D_{2\%}$ is defined as Vertex Index (VI).

$$\text{Vertex Index } (VI) = \frac{(\text{Vertex Dose})_{50\%}}{(\text{Vertex Dose})_{2\%}}$$

To homogenize the prescription criteria for LRT treatments, we have applied the dosimetric constraints listed in Table III. As a major development we propose the use of VERTEX INDEX which allows us to ensure that the necessary gradient conditions for LTR treatments are met when this value reaches VI>0.75.

Lattice Radiotherapy Treatment (LRT) constraints

	Dosis (Gy)	*Volumen (%)*
PTV	*Dose /fx (conventional*	**95%**
	5Gy	*<50%*
VTV=Vertices (Spheres Ø10mm)	V_{18Gy} / V_{GTV}	*<3%*
	20Gy	**0.5cc**
Valley Volume (VV) = PTV-Vertices	*8Gy*	*<30%*
VI=Vertex index	***VI=D50%/D2%***	*>0.75*

Table III. Summary of quality constrains set for LRT

RESULTS (II): SPECIFIC PATIENT QA

Fig.3a

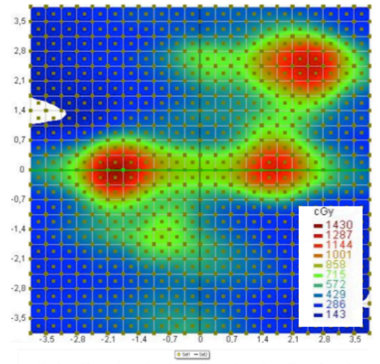


Fig. 3b

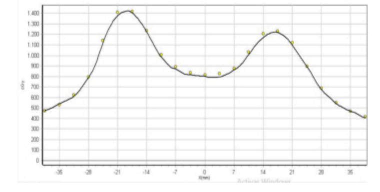


Fig. 4a

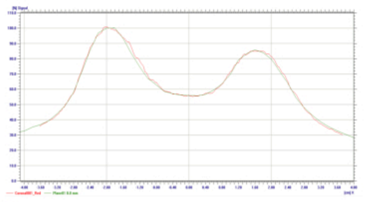
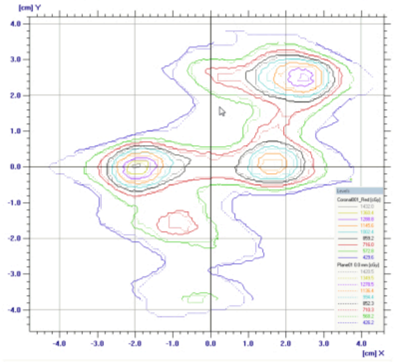


Fig. 4b



SRS-Mapcheck vs. RTPS coronal plane:
Fig. 3a, SRS-Mapcheck coronal plane measurement.
Fig. 3b, X-profile extracted from coronal isodose plane to compare RTPS calculations (solid line) and measurement (dots).

EBT3 vs. RTPS coronal plane.
Fig.4a, X-profile extracted from coronal plane to compare RTPS calculation (green line) and EBT red channel measurement (red line).
Fig 4b, Isodose map to compare RTPS (dot line) and EBT red channel (solid line).

CONCLUSIONS (II): SPECIFIC PATIENT QA

These highly modulated treatments, with multiple small targets that are delivered with a single isocenter, must be verified following rigorous procedures and using high space-resolution measurement equipment. In our case, to verify the treatments, we have used a small volume ionization chamber (Pinpoint of PTW) to measure the dose at discrete points; to validate the isodose planes, we have used radiochromic film (EBT3) and a specific 2D-array for SRT treatment (SRS Mapcheck from Sun Nuclear). The results obtained with both methods are consistent and may allowed us to guarantee the accuracy of the dose delivered by the accelerator.

Ion Chamber (Pin Point) vs RTPS	%Diff
Mean	0,7%
Max	3,3%
min	-1,7%
%σ	1,5%

Table IV. Ion chamber results

EBT3 FILM	Γ(3%,2mm)	Γ(2%,2mm)
Mean	96,7	92,6
Max	99,6	98,6
min	88,2	82,4
%σ	3,0	4,7

Table V. Radiochromic film results

SRS MAPCHECK	Γ(3%,2mm)	Γ(2%,2mm)
Mean	99,5	98,8
Max	100,0	99,9
min	98,3	95,9
%σ	0,5	1,0

Table VI. 2D-Array results

Automated data processing routines simplify the procedure while decreasing the probability of introducing systematic errors that mask the final result; that is the reason why we have always obtained better results in the 2D array than with the radiochromic film.

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