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Dosimetric Comparison of Lattice Radiation Therapy Plans Using Varian C-Arm Linacs and Radixact TomoTherapy

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INTRODUCTION

Spatially fractionated radiation therapy (SFRT) delivers radiation in an intentionally nonuniform pattern, creating alternating high-dose peaks and low-dose valleys within the treated volume. This approach delivers high doses to selected regions within a large tumor, maintains lower doses in the valley regions between them, and helps limit dose to surrounding normal tissues.

Lattice radiation therapy (LRT) extends the SFRT concept into three dimensions. Multiple small, high-dose spheres are distributed throughout the tumor, while low-dose regions are maintained between the spheres. This creates a highly heterogeneous dose distribution within the tumor.

This study compared the dosimetric quality of LRT plans generated for Varian TrueBeam, Edge, and Radixact TomoTherapy using the same lattice geometry and planning goals. The purpose was to identify differences and trade-offs between the platforms, rather than determine a single best treatment system.

METHODS AND MATERIALS

Twenty-five previously treated patients with tumors larger than 5 cm were retrospectively selected. Treatment sites included lung/chest, liver, abdomen, and pelvis.

For each patient:

- A grid boundary was created from the CTV while maintaining a 2 cm clearance from surrounding organs at risk.
- Lattice spheres were 1.5 cm in diameter with 3 cm center-to-center spacing.
- The number of spheres ranged from 5 to 75, with a median of 23.
- Edge and TrueBeam VMAT plans were created in Varian Eclipse v16.1 using 6 MV FFF beams and four full arcs.
- TomoTherapy plans were created in Radixact Precision v3.5.0.3 using a 2.5 cm dynamic jaw and a pitch of 0.1.
- All plans were normalized so that 95% of the total sphere volume received 100% of the 18 Gy prescription dose.
- Edge and TrueBeam plans used a single fraction. TomoTherapy plans used four fractions because of beam-on time limitations.

Plans were evaluated using conformity index (CI), conformity number (CN), gradient index (GI), peak-to-valley dose ratio (PVDR), and mean sphere dose. Paired comparisons were performed using paired t-tests.

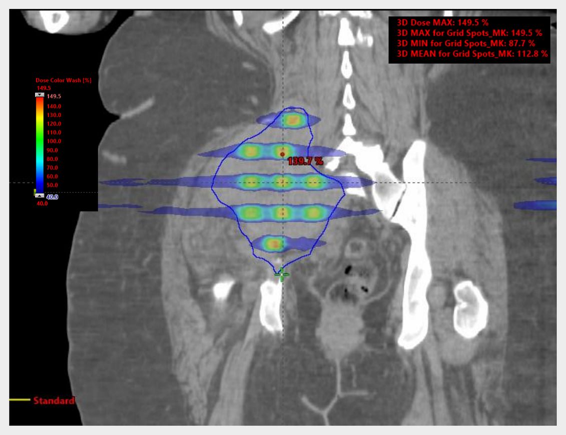

Fig 1. Coronal view of the dose distribution showing the high-dose lattice spheres within the grid boundary.

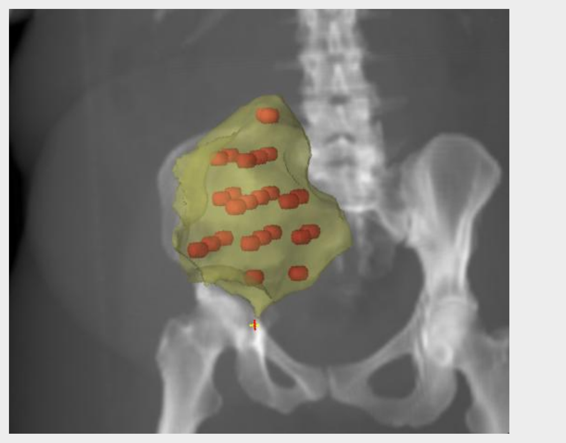

Fig 2. Beam's-eye view showing the three-dimensional arrangement of lattice spheres within the grid boundary.

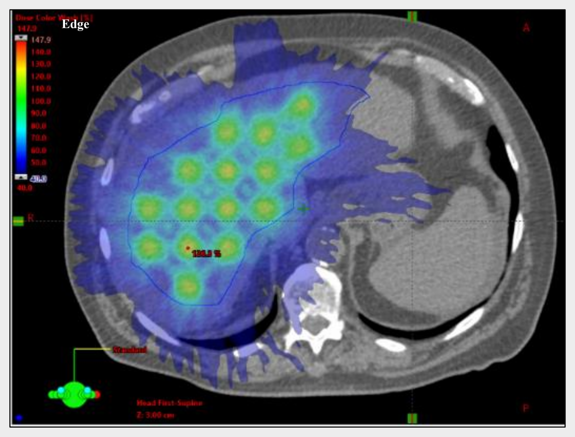

Fig 3. Axial dose distribution of an Edge LRT plan showing the high-dose lattice spheres and low-dose valley regions within the grid boundary.

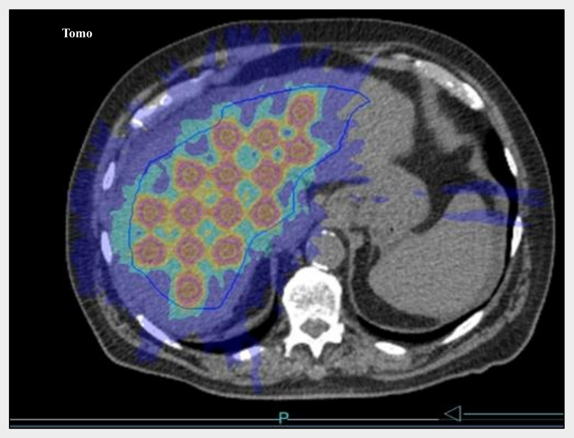

Fig 4. Axial dose distribution of TomoTherapy LRT plan showing the high-dose lattice spheres and low-dose valley regions within the grid boundary.

RESULTS

All three platforms produced similar dose conformity, with CI values close to 1 and only small differences in CN.

TomoTherapy had a lower GI than Edge and TrueBeam, indicating a sharper dose falloff outside the lattice spheres. These differences were statistically significant ($p < 0.001$).

Edge and TrueBeam produced higher PVDR values than TomoTherapy, indicating stronger separation between the high-dose spheres and low-dose valleys. Both comparisons were statistically significant ($p < 0.001$).

GI increased and PVDR decreased as the number of spheres increased for all platforms. Mean dose to the lattice spheres remained similar across all three platforms.

Table 1	Summary of grid structure characteristics for all patients, including treatment site, number of grid spheres, corresponding volumes, and volume ratios between grid spheres, grid boundary, and CTV.						
Patient	Site	Number of Spheres	Grid Spheres Total Vol / cm3	Grid Boundary Vol / cm3	CTV Vol / cm3	Ratio (Grid Spheres Vol / Grid Boundary Vol)	Ratio (Grid Spheres Vol / CTV Vol)
Grid001	Lung	5	7.5	146.7	252.8	5.11%	2.97%
Grid002	Pelvis	22	33	979.6	1702.3	3.37%	1.94%
Grid003	Liver	75	112.9	2669.7	3782.5	4.23%	2.98%
Grid004	Pelvis	25	37.6	981.4	1693.6	3.83%	2.22%
Grid005	Pelvis	20	30.1	750	818.1	4.01%	3.68%
Grid006	Pelvis	20	29.6	716.7	791.2	4.13%	3.74%
Grid007	Pelvis	35	51.8	1414.8	1692.7	3.66%	3.06%
Grid008	Pelvis	9	13.3	322.4	478.6	4.13%	2.78%
Grid009	Pelvis	16	23.6	561.53	659.85	4.20%	3.58%
Grid010	Pelvis	17	25.2	568	726.6	4.44%	3.47%
Grid011	Pelvis	15	22.3	538.4	1159.3	4.14%	1.92%
Grid012	Lung	14	20.8	510.4	557	4.08%	3.73%
Grid013	Chest	25	36.9	877.3	1253	4.21%	2.94%
Grid014	Abdomen	14	20.7	675.8	1284.1	3.06%	1.61%
Grid015	Abdomen	46	68	1698.3	2228.4	4.00%	3.05%
Grid016	Liver	36	53.2	1232.9	1460.9	4.32%	3.64%
Grid017	Liver	26	39.1	970	1711.8	4.03%	2.28%
Grid018	Liver	24	35.5	816.3	1098.2	4.35%	3.23%
Grid019	Liver	34	50.6	1344.7	2475.3	3.76%	2.04%
Grid020	Liver	23	34.1	798.2	1691.4	4.27%	2.02%
Grid021	Liver	27	39.9	881.4	1322.4	4.53%	3.02%
Grid022	Liver	14	20.7	559.6	825.8	3.70%	2.51%
Grid023	Liver	35	51.3	1159	1451.1	4.43%	3.54%
Grid024	Liver	12	17.7	475	641	3.73%	2.76%
Grid025	Liver	33	49.5	1104.9	1512.7	4.48%	3.27%

Table 2	Results		
Metric	Truebeam	Edge	TomoTherapy
Mean CI	1.04	1.02	1.01
Mean CN	0.87	0.88	0.89
Mean GI	10.23	9.37	8.09
Mean PVDR	4.83	5.47	3.39
Mean Sphere Dose	112.50%	111.50%	114.60%

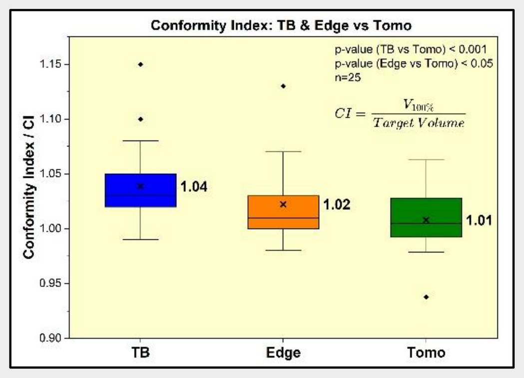

Fig 5. Comparison of the Conformity Index (CI) between TB, Edge and Tomo.

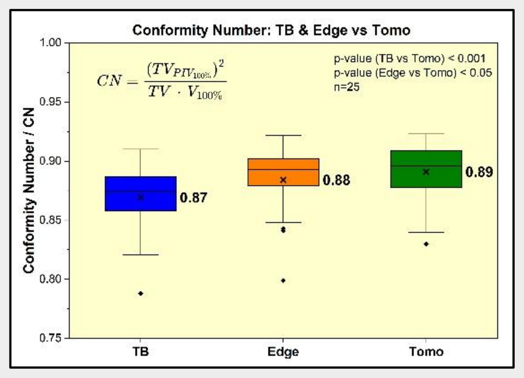

Fig 6. Comparison of the Conformity Number (CN) between TB, Edge and Tomo.

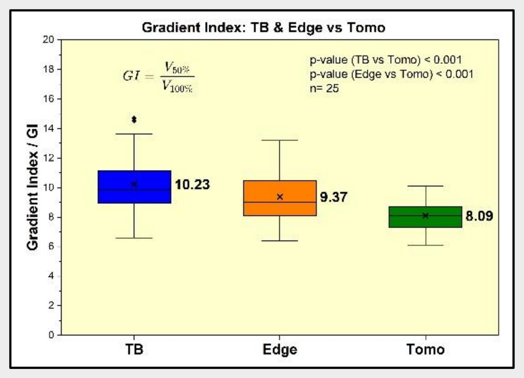

Fig 7. Comparison of the Gradient Index (GI) between TB, Edge and Tomo.

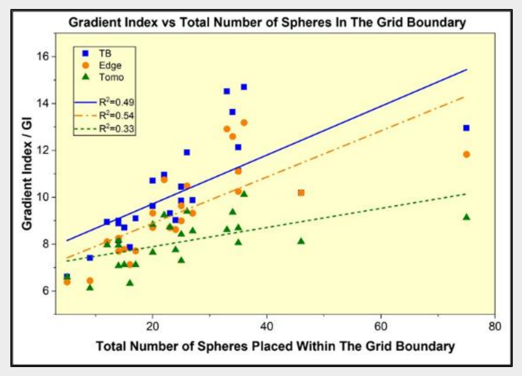

Fig 8. Gradient Index vs total number of spheres placed within the grid boundary.

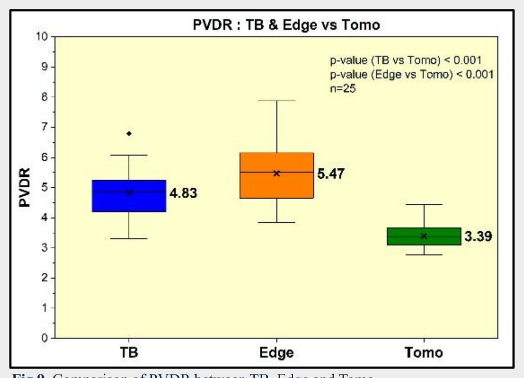

Fig 9. Comparison of PVDR between TB, Edge and Tomo.

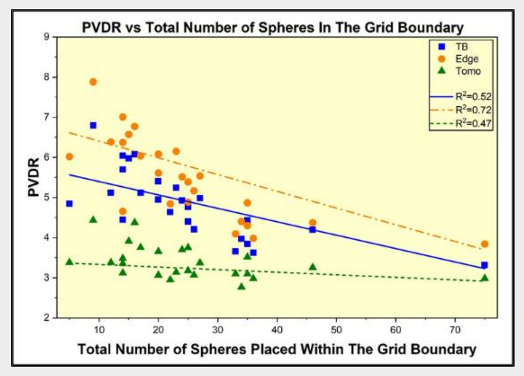

Fig 10. PVDR vs total number of spheres placed within the grid boundary.

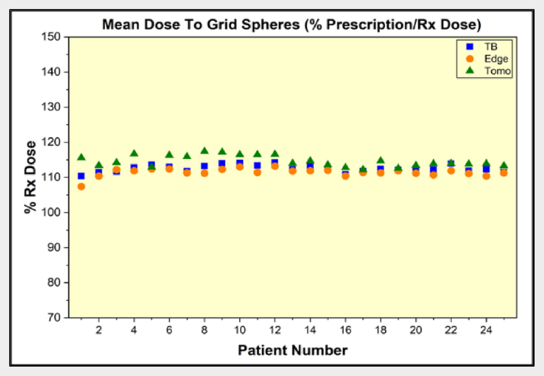

Fig 11. Mean dose to the grid spheres expressed as a percentage of the prescription dose (1800 cGy).

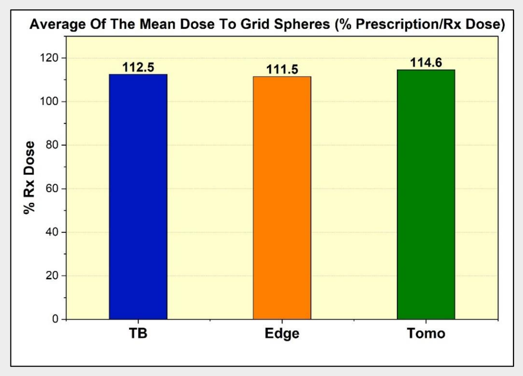

Fig 12. Average mean dose to the lattice spheres for TrueBeam, Edge, and TomoTherapy, expressed as a percentage of the prescription dose (1800 cGy).

DISCUSSION

The largest difference between the platforms was seen in spatial dose modulation. Edge produced the highest PVDR, followed by TrueBeam, while TomoTherapy produced the lowest. This indicates that the C-arm linacs maintained a higher peak-to-valley dose ratio.

TomoTherapy produced the lowest GI, showing better control of dose falloff outside the spheres. However, its helical delivery produced less peak-to-valley dose separation than the VMAT plans.

Increasing the number of lattice spheres made it more difficult for all three platforms to maintain both a sharp dose gradient and a high peak-to-valley dose ratio.

CONCLUSION

TrueBeam, Edge, and TomoTherapy produced LRT plans with comparable conformity indices and similar mean sphere doses. TomoTherapy provided a sharper dose falloff, while the C-arm linacs, particularly Edge, produced stronger spatial dose modulation. Platform selection may therefore depend on whether sharper dose falloff or greater peak-to-valley dose ratio is prioritized.

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