A comparison between PET-based biology-guided and linac-based stereotactic body radiotherapy for bone and lung cases

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Abstract:

The RefleXion X1 is a first-of-its-kind radiation therapy system that integrates a 6 MV flattening-free ring gantry linear accelerator and a positron emission tomography (PET) scanner. Biology-guided radiotherapy (BgRT) or SCINTIX is a treatment modality on RefleXion X1 that utilizes the PET signal enabling the real-time tumor tracking.

This study compared the quality of BgRT and linac-based SBRT treatment plans for lung and bone tumors.

Twelve patients, previously treated or emulated with BgRT treatment, were selected for this analysis. Conformity index, the intermediate dose spillage, the minimum dose and the maximum dose to the target, and the dose to organs at risk (OAR) were compared between the BgRT and SBRT plans using paired t-test with $p<0.05$ considered statistically significant.

Results indicated that target coverage and doses to OARs were comparable between BgRT and conventional SBRT plans.

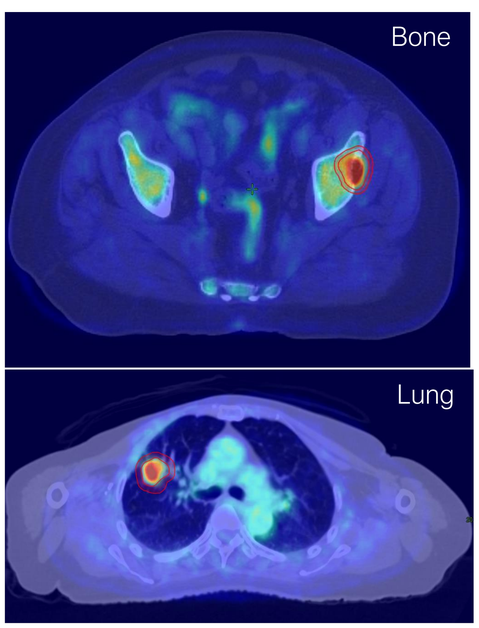

Fig.1 PET-CT scan of a bone cancer patient (top) and lung cancer patient (bottom). The contours indicate GTV and PTV

Introduction:

- Tumor and internal organ motion are of great interest in radiation therapy as they can undermine treatment efficacy and precision.[1]
- In conventional radiation therapy, treatment plans are based on a patient scan acquired in a single session, and treatment plans are created based on the static image.[2] However, daily variations in patient setup and motion can lead to uncertainties in tumor localization, lower tumor control, and an increased risk of side effects, and, therefore, should be accounted for.[1]
- BgRT aims to use PET advantages to treat tumors in real time, reducing motion and set-up uncertainties.[3] The purpose of this study was to compare the quality of BgRT-based and linac-based SBRT treatment plans for lung and bone tumors.

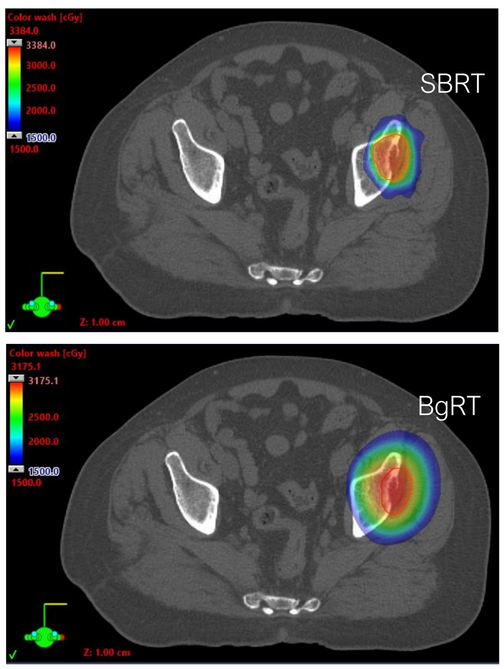

Fig 2. Axial view of the dose distribution for a bone cancer patient treated with multi-fraction SBRT (top) compared to BgRT (bottom). The minimum color wash represents the 50% isodose line.

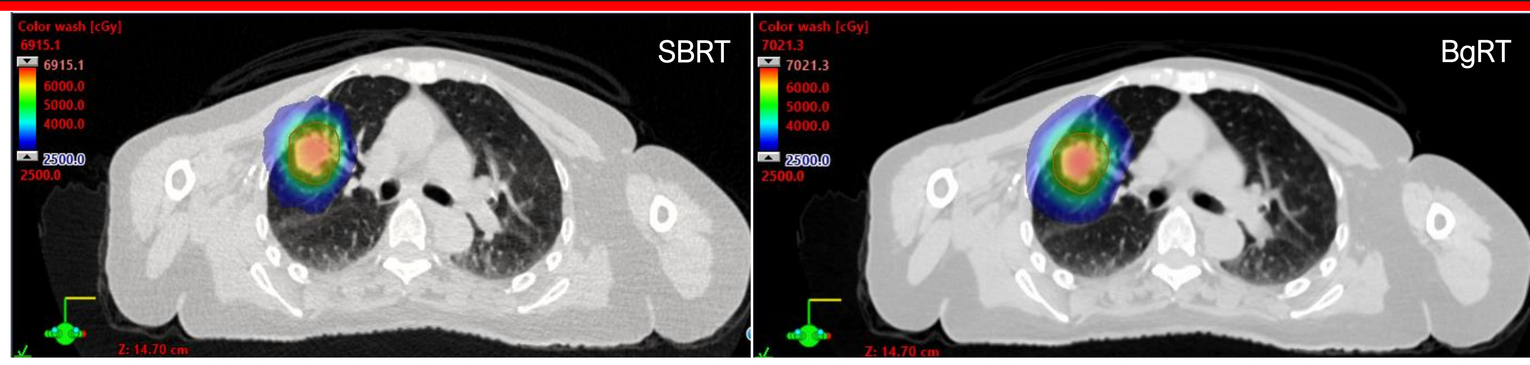

Fig 3. Axial view of the dose distribution for a lung cancer patient treated with multi-fraction SBRT (left) compared to BgRT (right). The minimum color wash represents the 50% isodose line.

Methods:

Twelve patients simulated or previously treated with BgRT were selected for this study- seven lung and five bone cancer patients. Nine patients were treated with SBRT and emulated with BgRT, and three patients who received BgRT treatment.

Some of the inclusion criteria for patient selection were:

- FDG-avid targets between 2 to 5 cm
- Maximum standardized uptake value (SUVmax) > 6.
- Targets at least 2 cm away from other FDG-avid OAR
- Targets with off-axis distances less than 15 cm.

An SBRT plan and BgRT plan were created for each patient.
A paired t-test was used for data analysis comparing the conformality and target coverage between the two plans.

Results:

- The average 100% conformity index for the linac-based SBRT plans was 0.98 compared to 1.27 for the BgRT plans ($p<0.01$).
- The 50% intermediate dose spillage conformity indices were 4.14 and 10.45 for the linac-based and BgRT plans, respectively ($p<0.01$).
- The minimum dose to GTV (Dmin) was an average of 103.4% for the linac-based plans while the BgRT plans resulted in an average of 104.9% ($p=0.06$).
- The dose to 1% of the PTV was 122.0% for the linac-based treatment plans and 128.4% for the BgRT plans ($p=0.05$).
- The dose to 99% of the PTV was an average of 93.8% for the SBRT compared to 94.5% for BgRT ($p=0.2$)
- Both BgRT and SBRT plans met the OAR constraints.

	Linac-based SBRT	PET-based BgRT	P-value
100% conformity	0.98	1.27	<0.01
50% conformity	4.14	10.45	<0.01
GTV Dmin (%)	103.4	104.9	0.06
PTV D1%	122.0	128.4	0.05
PTV D99%	93.8	94.5	0.2

Table 1. Average conformality indices and target coverages of linac-based SBRT and PET-based BgRT. P-value of <0.05 was considered significant.

Discussion:

This is the first study to compare the plan quality between clinically treated and simulated PET-guided BgRT plans versus linac-based SBRT plans for lung and bone cancer patients.
As BgRT uses positron emission to track and target the tumor, the workflow may not be as easily integrated into clinical practice. BgRT requires an extensive workflow with additional steps during patient imaging, plan evaluation, and treatment delivery. Patients receiving BgRT would require a positron radioactive tracer injection before each fraction.

Conclusion:

The resulting BgRT treatment plans are of comparable quality to conventional SBRT plans. The doses to the targets and the OARs were similar between the SBRT and BgRT plans. The intermediate dose spillage was higher for the BgRT plans than the conventional linac-based SBRT plans. Overall, BgRT was a feasible option for treating lung and bone tumors. Although BgRT is only FDA-cleared for lung and bone cancers using SBRT fractionation[4], studies are underway to expand its use to other clinical indications.

References

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