# Comparison of dose distribution by the difference of dose calculation algorithm for the same treatment plan

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## INTRODUCTION

Stereotactic Ablative Body Radiotherapy (SABR) has been increasingly used as an alternative approach to surgery for early-stage Non-Small Cell Lung Cancer (NSCLC) patients who are medically inoperable or decline surgery [1].

Dose calculation for small field radiotherapy with inhomogeneity often involves discrepancies due to electronic disequilibrium [2,3,4].
Moreover, the effect of tumor location on the differences between different algorithms has been reported in several studies [2,5].

The dose distribution even for the same treatment plan may differ between the two calculations if the new treatment planning system (TPS) and algorithm are introduced.
The optimal dose is not delivered, which may result in local recurrence.

Many previous studies examined the accuracy of dose calculation algorithms using a thorax phantom [2,3,4]; however, few reports have focused on the differences between different algorithms in clinical cases.

## AIM

To analyze the difference in target dose distributions calculated using different algorithms and to investigate the impact of the tumor location, in clinical cases of SABR for lung cancer.

## METHOD

A total of 96 patients who underwent SABR for lung cancers
using non-coplanar 3-D conformal radiotherapy (3DCRT) at Kyushu University Hospital from 2014 to 2017.
All treatment plans were calculated using Acuros XB in Eclipse TPS,
normalized such that 95% of the planning target volume (PTV) received the prescription dose.

■ TPS and algorithms
i. Acuros XB in Eclipse TPS (**AXB**) (Varian Medical Systems, Palo Alto, CA, USA)
ii. Collapsed Cone Convolution/Superposition in RayStation (**CCC**)
(Raysearch Laboratories, Stockholm, Sweden)

■ Equipment used
- Planning CT: Aquilion PRIME (TOSHIBA, Japan)
- Thorax phantom: Dynamic Thorax Phantom Model 008A (CIRS, Norfolk, USA)
- Dosimeter: Semiflex Ionization Chamber 31010 (PTW, Freiburg, Germany)
- Statistical analysis software: JMP Pro 14 (SAS Institute Inc, NC, USA)

■ Tumor locations
I. Attached (n=64): PTV included the chest wall
II. Island (n=32): PTV did **not** include the chest wall

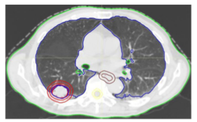
■ DVH parameters
a. Maximum target dose (**Dmax**)
b. Minimum target dose (**Dmin**)
c. Homogeneity Index (**HI**) = Dmin / Dmax
d. Conformity Index (**CI**) = PTV covered by prescribed dose / PTV
e. The dose received by 95% of the PTV (**D95**)

■ Statistical analysis
- Shapiro-Wilk's W test
- Wilcoxon signed-rank test
- Two-sided paired F-test
- Two-sided paired t-test
- Welch's t-test
- Effect size (ES) [6]

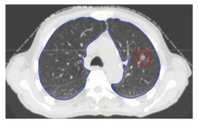
➢ Statistical significance
was accepted with a $p$-value < 0.05.

Patients characteristics

| | Patients (n = 96) |
|---|---|
| Age | |
| Median | 76 |
| Range | 31-91 |
| Sex | |
| Male | 67 |
| Female | 29 |
| Stage | |
| IA | 36 |
| IA2 | 33 |
| IB | 12 |
| Meta | 15 |

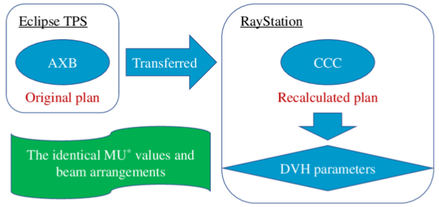


I. Attached tumor



II. Island tumor

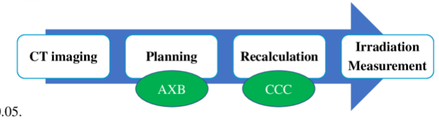
◆ **Study 1**

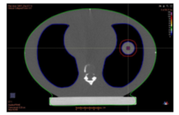



AXB plans were recalculated using CCC with the identical Monitor Unit (MU) values and beam arrangements.

We investigate the difference between the results of the two calculations and also examined the impact of tumor location by comparing the following left 5 DVH parameters.

◆ **Study 2**



Treatment planning CT image

We determined the target central dose using the ion chamber and then assessed the calculation accuracy of the two algorithms by comparing the irradiated dose and calculated doses for each fraction.

## RESULTS

◆ The mean difference between the two calculations in DVH parameters

| | ΔD* (Gy) | ΔD/$D_{AXB}$ (%) | $p$ value |
|---|---|---|---|
| Dmax | 1.17 ± 0.85 | 2.01 ± 1.42 | <.0001 |
| Dmin | 1.95 ± 1.36 | 4.32 ± 3.32 | <.0001 |
| HI | 0.02 ± 0.02 | 2.14 ± 3.17 | <.0001 |
| CI | -0.06 ± 0.06 | -10.19 ± 9.54 | <.0001 |
| D95 | 1.85 ± 0.95 | 3.73 ± 1.80 | <.0001 |

*$\Delta D = D_{CCC} - D_{AXB}$

Significantly difference was observed for all values.

These results indicate that CCC significantly overestimated the dose to PTV, compared to AXB.

CCC predicted a more homogeneous dose distribution inside the PTV, whereas AXB provided a more conformal plan.

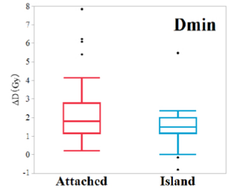
◆ The impact of the tumor location

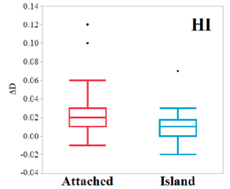
We found that minimum dose, homogeneity index, and D95 exhibited significant correlations with tumor location when the PTV included the chest wall (**Attached tumor case**).

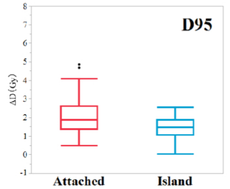
In particular, for HI and D95, the effect size was larger than 0.06, so these two parameters were concluded to be moderately related to tumor location.

The following figures describe this effects in more detail. The difference between the two calculations was greater in cases of Attached tumors.

| | Effect size | $p$ value |
|---|---|---|
| Dmax | <.0001 | 0.9726 |
| Dmin | 0.057 | 0.0092 |
| HI | 0.072 | 0.0080 |
| CI | 0.010 | 0.4090 |
| D95 | 0.086 | 0.0009 |




◆ The calculation accuracy of the two algorithms for each fraction

| | $D_{cal}$* (cGy) | $D_{irra}$** (cGy) | ΔD*** (cGy) | ΔD/$D_{irra}$ (%) | $p$ value |
|---|---|---|---|---|---|
| AXB | 1378.8 | 1380.7 | -1.92 | -0.14 | 0.875 |
| CCC | 1415.0 | 1380.7 | 34.30 | 2.48 | 0.250 |

*Calculated dose
**Irradiated dose
***$\Delta D = D_{cal} - D_{irra}$

AXB underestimated the dose to PTV by approximately 0.02 Gy, which corresponds to the irradiated dose.

In contrast, CCC overestimated the dose by approximately 0.34 Gy for each fraction.

These result suggests that AXB accurately computes the target central dose.

## DISCUSSION

We indicated that CCC overestimated the dose to PTV relative to AXB, which is similar to the findings of several previous studies [7,8]. CCC overestimated the target dose, especially D95, which might have led to a decrease in CI; on the other hand, the overestimation of Dmin may have caused an increase in HI. Another point of view is that AXB would have accurately predicted the complicated dose distributions, which may have led to higher CI and lower HI. These differences between the results of the two algorithms can be attributed to the modeling of the heterogeneity of lung tissue. AXB can account for the impact of the dose reduction on the tumor due to electronic disequilibrium [9]; accordingly, AXB is considered to be more accurate than CCC.

As the previous studies have shown [2,5], we revealed the differences between the two calculations had significant correlations with tumor location when the PTV included the chest wall.
This effect is explained by electronic disequilibrium at the interface between the tumor and air or chest wall.

We demonstrated that AXB calculates the target dose accurately than CCC, which corroborates the results of the previous studies [2,3,4]. The overestimation for CCC can be explained by inherent limitations in non-equilibrium conditions due to inaccurate density-scaling of the water-derived dose deposition kernels [10]. By contrast, AXB computes the absorbed dose to medium contained in each voxel of the image grid, that is, AXB directly describes the effects of heterogeneity by incorporating the chemical composition of each material [9].

## CONCLUSIONS

Significant differences in target dose distribution between different dose calculation algorithms were observed in clinical cases of lung SABR.

These differences were dependent on the tumor location and were more pronounced in cases where the PTV included the chest wall.

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## CONTACT INFORMATION

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