

Introduction

Intensity Modulated Radiation Therapy (IMRT) is currently commonly used for treatments requiring highly conformal radiation doses while avoiding critical structures. Typical linear accelerator based IMRT dose calculations are performed by algorithms adapted to the specific user's linac. These algorithms must be commissioned prior to clinical use.

The commissioning dataset is measured directly by the physics staff and may be supplemented with manufacturer provided beam data. Measuring, interpreting, converting, importing, and verifying these data is a very time consuming, costly, and resource intensive. The time required to perform these tasks is often several weeks of full time work for a clinical physicist, depending on experience and the clinical applications of the accelerator.

In this study we focused on the photon dose deposition algorithm used in the Eclipse treatment planning system (TPS), the Anisotropic Analytical Algorithm (AAA) (Varian Medical systems, Palo alto, CA). Currently, Varian provides Golden Beam Data (GBD) to their customers for use in TPS commissioning and is considered a gold standard dataset. GBD were measured using a relatively large CC13 ion chamber (0.13 cm³ active volume), moderate sampling frequency (2.5 mm), and did not include small field measurements (< 3 x 3 cm field size). It has been shown that the commissioning dataset has a strong correlation to calculation accuracy as well as QA results [1]. For example, volume averaging effects of the ion chamber used to measure GBD have been thoroughly discussed as well as corrective methods and their impact on calculation accuracy [2]. Furthermore, discrepancies between GBD and measurements for open field profiles are reported in the literature [3] and an example of discrepancies observed by our research group are shown in Figure 1.

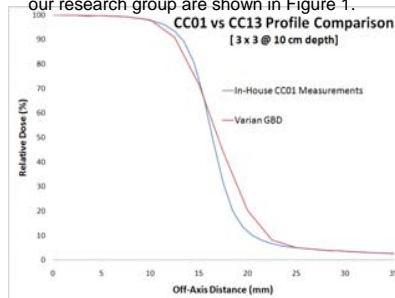


Figure 1: Comparison of profiles measured using a CC01 (0.01 cm³ active volume) in-house versus a profile measured using a CC13 (0.13 cm³ active volume) as provided by Varian.

Purpose

An important objective of commissioning is to configure a beam model that maximizes the TPS's accuracy. However, there is often a limited amount of time and resources available for TPS commissioning. With these competing factors in mind, it is important to determine which categories of the beam data the have the greatest impact on the accuracy of the beam model. This will allow physics resources to focus on the most crucial components of beam data acquisition.

Considering these factors, as well as the lack of a comprehensive study on this topic in the literature, a better understanding of the sensitivity of the commissioning dataset to dose calculations in the AAA is needed. Such information may improve the accuracy of dose calculations and increase the efficiency of the commissioning process. In this study we evaluated the effects of the commissioning dataset to the calculations produced using the AAA as implemented in the Eclipse TPS v8.6.

Materials and Methods

We analyzed the effects of variations in the (1) source of data (e.g. in-house vs. GBD), (2) sampling frequency, (3) smoothing, (4) manipulation (e.g. corrections for detector size), (5) measurement variation, and (6) breadth of the beam data. In particular, we looked at the following four beam and dosimetric data categories: (1) Cross-plane profiles, (2) depth dose, (3) MLC leaf transmission and (4) MLC gap. To obtain these data we performed relative and absolute dosimetry measurements using a 6MV photon beam incident on a Scanditronix Wellhofer Blue Phantom (Uppsala, Sweden). The accelerator used was Varian 2300 C/D with model Millennium 120 MLC.

We independently investigated the effect of each variation listed above, by holding all other factors constant in a particular dataset.

In order to minimize the volume effects our measurements were taken with a CC01 ionization chamber (0.01 cm³ active volume). In comparison, GBD was obtained with a CC13 ionization chamber (0.13 cm³ active volume). Figure 2 shows the relative size of these two chambers to scale.



Figure 2: Scanditronix CC01 and CC13 ionization chambers. (Wellhofer, IBA Dosimetry America, Bartlett, TN, USA)

Eleven different calculation models were commissioned to evaluate cross plane variations. Evaluation consisted of profile and penumbra analysis for field sizes ranging from 0.5 cm to 40 cm at various depths.

Nine different calculations models were commissioned to evaluate percent depth dose variations. Evaluation consisted of the location of d_{max} , as well as other dosimetrically relevant points along the PDD curve for field sizes ranging from 0.5 cm to 40 cm.

Six different calculation models were commissioned to evaluate MLC leaf gap and MLC leaf transmission data variations. The leaf gap was varied from 0.18 - 0.24 cm and the transmission varied from 0.5 - 3%.

All calculations were performed using a 1 mm grid size when possible.

To evaluate the clinical impact of the different beam models, we recalculated a 9 field IMRT head and neck (H&N) plan using the models (in the four beam and dosimetric data categories) which deviated the most from the GBD model. Evaluation of these plans consisted of a gamma analysis using a 1% / 1 mm passing criteria. The monitor units (MU) required to achieve a consistent prescription were also noted.

A representative example of our profile results is shown in Figure 3. These results were obtained using calculation models based on two dissimilar datasets, partially shown in Figure 1.

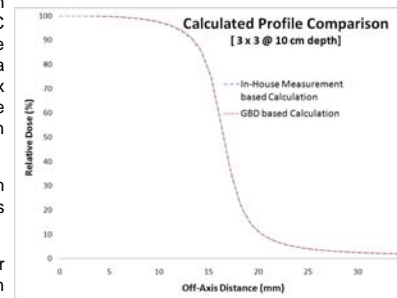


Figure 3: Comparison of profiles calculated using the data measured in this study data CC01 measurements versus Varian measurements.

The greatest difference for profiles and penumbra of all field sizes and depths tested were less than half of the grid sized used. Gamma analysis of the H&N plan using the models with the greatest difference with respect to one another resulted in >98% of pixels passing. The failing pixels occurred on or near the patient surface.

Results from percent depth dose variations proved insensitive to the input data. One exception being the models with d_{max} variations. It was found that changes to d_{max} of the input data corresponded well with d_{max} of calculations.

While the general shape of the PDD matched well for nearly all variations and field sizes tested, MU calculations showed consistent differences of approximately 2% when using any form of measured data in place of GBD while D20/D10 ratios of the two models were within 0.1%.

MLC leaf gap variations resulted in nearly identical results when comparing individual slices. No pixels resulted in gamma values in excess of 0.04. Additionally, MU calculations were at most 0.7% different for an individual field and 0.23% for the total plan.

MLC leaf transmission variations resulted in the greatest deviations occurring between the minimum and maximum transmission values tested. For example, using the 1% / 1 mm gamma criteria the slices with the most variation resulted in >97% of pixels passing. Increasing the criteria to 1% / 2 mm negligibly increased the pixel passing rate, however an increase to 2% / 1 mm resulted in 100% of pixels passing. The variation in calculated MU were less than 0.5% among the greatest deviating models.

Table 1 summarizes the greatest deviations found for the variations in commissioning data tested.

| Beam Data Category | Greatest Deviations | |
|--------------------|---------------------|---------------------|
| | MU (% difference) | % of Pixels Passing |
| Profiles | 1.2% | 98% |
| PDD | 1.8% | 99% |
| MLC Leaf Gap | 0.7% | 100% |
| MLC Transmission | 0.5% | 97% |

Table 1: Partial table of results showing MU and gamma analysis for models with the greatest deviations for a particular data category.

Conclusions

In this study, we observed that the Eclipse AAA is relatively insensitive to variations in the commissioning dataset and do not have a significant impact on dose calculations for IMRT.

PDD variations showed that sampling frequency, breadth of data, and smoothing functions do not play a significant role in dose calculations; however, considerations should be made to ensure the d_{max} region is properly measured and appropriate shifts to the PDD curve are made.

MLC leaf gap variations did not impact the IMRT dose calculations performed in this study. However, as previous studies suggest [4], MLC leaf transmission variations proved to be sensitive to dose calculations. Thus extra care should be taken for such measurements as well as validation tests.

References

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4. LoSasso, T., C.-S. Chui, and C.C. Ling, *Physical and dosimetric aspects of a multileaf collimation system used in the dynamic mode for implementing intensity modulated radiotherapy*. Medical Physics, 1998. 25(10): p. 1919-1927.