Comparison of build-up region doses in oblique tangential 6 MV photon beams calculated by AAA and CCC algorithms in breast Rando phantom

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Abstract. The purpose of this study is to compare the build-up region doses on breast Rando phantom surface with the bolus covered, the doses in breast Rando phantom and also the doses in a lung that is the heterogeneous region by two algorithms. The AAA in Eclipse TPS and the collapsed cone convolution algorithm in Pinnacle treatment planning system were used to plan in tangential field technique with 6 MV photon beam at 200 cGy total doses in Breast Rando phantom with bolus covered (5 mm and 10 mm). TLDs were calibrated with Cobalt-60 and used to measure the doses in irradiation process. The results in treatment planning show that the doses in build-up region and the doses in breast phantom were closely matched in both algorithms which are less than 2% differences. However, overestimate of doses in a lung (L2) were found in AAA with 13.78% and 6.06% differences at 5 mm and 10 mm bolus thickness, respectively when compared with CCC algorithm. The TLD measurements show the underestimate in build-up region and in breast phantom but the doses in a lung (L2) were overestimated when compared with the doses in the two plannings at both thicknesses of the bolus.

1. Introduction

Radiation is currently important in the medical field that used for diagnostic and treating the patients, especially in cancer patients. The giving radiation doses to the patients must be precise, accurate and appropriate for the local of any type of cancer. The evaluation of delivered doses on surface area, in build-up region or in the heterogeneous medium is quite uncertain due to the algorithm calculation that may cause the effect directly to the patients such as erythema and hyperpigmentation. Too low doses from the uncertain calculation are insufficient to damage the gross tumor or too high doses are over limited for curing cancer and affected to the result of treatment.

Nowadays, new technologies of treatment machines are developed due to the complex of planning and treatment. Dose calculation algorithms are influential and controlled the accuracy of radiation doses in treatment planning process. In all superposition/convolution methods, the analytical anisotropic algorithm (AAA) and the collapsed cone convolution algorithm (CCC) are popular because of the accuracy in heterogeneous media calculation, especially in the lung. However, both algorithms cannot well predict the surface doses and build-up region doses in solid water phantom shown by the study of James, Runqing and Micheal [1]. On the other hand, the study by Hasenbalg et al. [2] have shown that
CCC algorithm performed overall better than AAA algorithm compared to Monte Carlo in clinical cases of lung and breast.

Mostly irradiation treatment in breast cancer case is oblique tangential photon beam technique. The prediction of surface doses variation for the tangential like photon beams are extremely caution in radiation therapy. James and Grigor [3] have shown that the relative dose profile in the phantom skin did not change with oblique beam using full phantom geometry. Nevertheless, the surface relative depth dose was increased for half phantom geometry (phantom-air interface) like the breast. Above all, in this study is to compare the build-up region doses on Breast Rando phantom surface with the bolus covered, the doses in Breast Rando phantom and also the doses in a lung that is the heterogeneous region by two algorithms (AAA and CCC). Thermoluminescent dosimeters (TLDs) were calibrated with Cobalt-60 and used to measure the doses in irradiation process.

2. Materials and methods

2.1. AAA and CCC algorithms

The analytical anisotropic algorithm (AAA) was developed by the research group of Varian Medical Systems. The calculation of dose distribution for photon beams consists of two parts (the configuration module and the dose calculation module) [4]. The purpose of configuration module is to characterize the phase space of a photon beam. The phase space is approximated using a multiple source model: a point source radiation from the target, a finite source for extra focal radiation, and a third source to model the electron contamination. The dose calculation module is calculated as a superposition of the dose deposited by the primary and secondary photons and the contamination electron for every beamlet. The collapsed cone convolution algorithm (CCC) determines the distribution of total energy released per unit mass (TERMA) in a 3D matrix of the irradiated volume, based on the ray-tracing technique [5].

The analytical anisotropic algorithm (AAA) version 8.9 available in Eclipse treatment planning system and the collapsed cone convolution algorithm (CCC) version 9.2 available in Pinnacle treatment planning system were used for planning and calculation in this study.

2.2. TLDs preparation and calibration

Cobalt-60 teletherapeutic machine (Theratron Elite 80 unit) was used to irradiate radiation dose for TLDs. Harshaw TLD-100 rods with 1mm×5mm size were used. Firstly, all of 200 rods TLD were irradiated and annealed 4 times. TLDs were calibrated at dose 200 cGy at the depth of maximum dose 0.5 cm (d_{max} = 0.5 cm), field size 15×15 cm² and SAD technique 80 cm with bolus 0.5 cm. TLDs selected depend on their responsiveness and uniformity. Finally, linearity test of TLDs was done and prepared for measuring the radiation dose in irradiation process.

2.3. Dose calculation in treatment planning

TLDs were put in the rod holders and put into totally 13 holds in Rando phantom (see figure 1 and 2) follow these points

- 4 points in the right upper Breast Rando phantom slab. There was a superior point (B1), a medial point (B2), an inferior point (B3) and a lateral point (B4).
- 4 points in the right lower Breast Rando phantom slab. There was a superior point (B5), a medial point (B6), an inferior point (B7) and a lateral point (B8).
- 2 points in Lung Rando phantom slab that close to the breast phantom. There was a lateral point (L1) and a medial point (L2).

And other 3 points of TLDs with holders free were placed on Breast Rando phantom surface under bolus covered (5 and 10 mm). There was a lateral point (S1), a center point (S2) and a medial point (S3).

After that, CT scan was used to scan the Breast Rando phantom with 5 and 10 mm bolus covered and obtained the slice images of the Breast Rando phantom. Images were sent to treatment planning system both Eclipse and Pinnacle. The planning was done by SAD technique with Varian ClinaciX 6 MV photon beams and prescribed 200 cGy per fraction to 100% of point dose at point B6. Opposing
tangential field technique with no wedge was planned with $69^\circ$ in medial gantry angle and $240^\circ$ in lateral gantry angle. Field sizes were $5 \times 7.9$ cm$^2$ (X collimators), $8 \times 8$ cm$^2$ (Y collimators) in medial fields and $7.9 \times 5$ cm$^2$ (X collimators), $8 \times 8$ cm$^2$ (Y collimators) in lateral fields. Both Eclipse and Pinnacle were planned by the same technique and calculated with dose contribution method at a prescription point. The comparisons of all 13 points between Eclipse (AAA) and Pinnacles (CCC) were analyzed.

**Figure 1.** The points of TLD in Breast Rando phantom slab.  
**Figure 2.** The points of TLD in lung and on the surface with bolus covered.

2.4. **Irradiation and measurement**

TLDs were put into the points and placed on the surface points followed 2.3 of all 13 points. Varian Clinacix was used to follow the planning both AAA and CCC algorithms. The irradiation was done 3 times for each algorithm. TLDs were read by Harshaw TLD reader and converted to average doses for each point. The comparisons of all 13 points between both algorithms planning and TLD measurements were found.

3. **Results**
3.1. TLD preparation

TLDs were selected and separated into 3 groups followed their uniformity (±10%) to give the dose of 200 cGy. The linearity test was found by a linear relation of $R^2 = 0.996$ which shows a good performance for measurement.

3.2. Radiation dose in treatment planning

The results show in Table 1 that the doses on Breast Rando phantom surface with bolus covered (point S1, S2, and S3) were closely matched in both algorithms and both thicknesses of the bolus. The differences were between -0.21 to 1.33%. The doses in Breast Rando phantom (Point B1 to B6) were also well matched in both algorithms and both thicknesses of the bolus in which the differences were -0.2 to 1.16%. The lung does in point L1 were somewhat similar with 0.95% and 0.42% differences at 5mm and 10 mm bolus thicknesses. Nevertheless, overestimate doses in a lung (point L2) were found in AAA with 13.78% and 6.06% differences at 5 mm and 10 mm bolus thicknesses, respectively when compared with CCC algorithm.

| POINTS | Bolus 5 mm | Bolus 10 mm |
|--------|------------|-------------|
| S1     | AAA (cGy)  | CCC (cGy)   | AAA (cGy)  | CCC (cGy)   |
|        | 189.9      | 187.4       | 199.2      | 199         |
| S2     | 202.5      | 202.1       | 208.6      | 208.5       |
| S3     | 186.2      | 186.6       | 195.3      | 195.3       |
| B1     | 209.3      | 206.9       | 207.9      | 207.1       |
| B2     | 203.2      | 203.5       | 204.2      | 203.2       |
| B3     | 209.4      | 207.6       | 209.9      | 207.9       |
| B4     | 206        | 204.9       | 206.1      | 204.8       |
| B5     | 201.8      | 202.1       | 200.8      | 200.4       |
| B6     | 200.1      | 200.5       | 200        | 200.2       |
| B7     | 203.6      | 203.5       | 202.2      | 202.1       |
| B8     | 200.9      | 201.2       | 200        | 200.3       |
| L1     | 191.9      | 190.1       | 188.8      | 188         |
| L2     | 89.2       | 78.4        | 89.2       | 84.1        |

3.3. Irradiated doses versus planning doses

The irradiated TLDs were read in charge particle and converted to average doses shown in table 2. The irradiated doses on Breast Rando phantom surface with bolus covered (point S1, S2 and S3) and the irradiated doses in Breast Rando phantom (Point B1 to B6) were underestimated in both algorithms and both thicknesses of bolus when compared with planning dose which the differences were ranged between -10.98% to -3.00% and -15.35% to -4.26%, respectively. However, the irradiated doses in a lung (point L2) were overestimated in both algorithms at 10 mm bolus thicknesses when compared with planning dose. Although the irradiated doses in a lung (point L2) in CCC algorithm were overestimated at 5 mm bolus thicknesses, they were underestimated in AAA algorithm. The CCC algorithm performed better in TLD measurements when compared with AAA algorithm.
**Table 2.** A comparison of point doses from TLD measurements versus treatment planning doses in Breast Rando phantom with 5 mm and 10 mm bolus covered in both algorithms.

| POINTS | AAA Irradiated dose (cGy) | AAA Planning dose (cGy) | CCC Irradiated dose (cGy) | CCC Planning dose (cGy) | AAA Irradiated dose (cGy) | AAA Planning dose (cGy) | CCC Irradiated dose (cGy) | CCC Planning dose (cGy) |
|--------|---------------------------|------------------------|---------------------------|------------------------|---------------------------|------------------------|---------------------------|------------------------|
| B1     | 185.3                     | 202.5                  | 192.3                     | 202.1                  | 194.0                     | 208.6                  | 194.3                     | 208.5                  |
| B2     | 177.1                     | 209.3                  | 184.9                     | 206.9                  | 194.4                     | 207.9                  | 192.9                     | 207.1                  |
| B3     | 179.2                     | 203.2                  | 176.1                     | 203.5                  | 189.6                     | 204.2                  | 189.8                     | 203.2                  |
| B4     | 186.8                     | 209.4                  | 183.8                     | 207.6                  | 195.7                     | 209.9                  | 197.6                     | 207.9                  |
| B5     | 178.1                     | 206                   | 185.5                     | 204.9                  | 186.9                     | 206.1                  | 187.8                     | 204.8                  |
| B6     | 170.8                     | 202.1                  | 176.0                     | 202.1                  | 186.2                     | 200.8                  | 190.6                     | 200.4                  |
| B7     | 181.4                     | 200.1                  | 180.7                     | 200.5                  | 185.0                     | 200                  | 189.7                     | 200.2                  |
| B8     | 182.8                     | 203.6                  | 182.9                     | 203.5                  | 187.2                     | 202.2                  | 189.9                     | 202.1                  |
| L1     | 168.0                     | 191.9                  | 164.8                     | 190.1                  | 174.2                     | 188.8                  | 176.2                     | 188                   |
| L2     | 76.9                      | 89.2                   | 94.7                      | 78.4                   | 105.6                     | 89.2                   | 105.5                     | 84.1                   |

4. Conclusions

In this study, both algorithms were not difference in treatment planning of build-up region and breast Rando phantom in which the differences doses were less than 2%. However in the heterogeneous region, lung (point L2), it was overestimated in AAA algorithm. The TLD measurements in build-up region and Breast Rando phantom were underestimated except in lung (point L2) that overestimated in both thicknesses of the bolus. However, the TLD measurements show that CCC algorithm performed better when compared with AAA algorithm at both thicknesses of the bolus. The uncertainties in measurement may cause through the process of placing bolus over the curve of Breast Rando phantom that could make the air gap between bolus and surface of the phantom. Further study might be required in other detectors or other techniques to have more evidence to illustrate the accuracy of dose calculation in build-up region and in lung tissue from the algorithms.

References

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