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Original Article

Calypso's array attenuation

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Abstract

Introduction: The Calypso 4D Localization System gives the possibility to track the tumour during treatment, with no additional ionising radiation delivered. To monitor the patient continuously an array is positioned above the patient during the treatment. We intend to study, for various gantry angles, the attenuation effect of the array for 6- and 10 MV and flattening filter free (FFF) 6- and FFF 10 MV photon beams.

Materials and methods: Measurements were performed using an ion chamber placed in a slab phantom positioned at the linac isocenter for 6 MV, 10 MV, FFF 6 MV and FFF 10 MV photon beams. Measurements were performed with and without array above the phantom for 0°, 10°, 20°, 40° and 50° beam angle for a True Beam STx linac, for 5×5 and 10×10 and 15×15 cm^2 field size beams to evaluate the attenuation of the array. A VMAT treatment plan was measured using an ArcCheck with and without the array in the beam path.

Results and discussion: Attenuation measured values were up to 3%. Attenuation values were between 1 and 2% with the exception of the 30°–50° gantry angles which were up to 3.3%. The ratio values calculated in the ArcCheck for relative dose and absolute dose 10 were both 1·00.

Conclusion: Attenuation of the treatment beam by the Calypso array is within acceptable limits.

Keywords: ArcCheck; array; attenuation; Calypso

INTRODUCTION

Higher accuracy and reproducibility in radiotherapy has led to great development in imaging and monitoring systems. Megavoltage imaging has been used clinically for many years, and kV imagers have also been installed in linacs all over the world. Monitoring systems for tracking movement during treatment have been used to monitor patient surface – for example infrared tracking of external markers or virtual view of the patient surface – or the tumour movement – for example fluoroscopy.[1–11]

The Calypso 4D Localization System (Varian Medical Systems, Palo Alto, CA, USA) is a monitoring system that gives the possibility to track the tumour during treatment, with no additional ionising radiation delivered, a great advantage when compared with other systems available.[12]

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This system has five components: Beacon transponders, the console, the array, the optical localisation subsystem and the monitoring station. The array consists of optical targets, 4 sources and 32 receiver coils.[13] An oscillating signal (25 Hz) through the source coil generates resonance in the transponders. When this signal is turned off, the transponders emit electromagnetic signals, which are detected by the receiver coils in the array, thereby localising their positions relative to the array. Meanwhile, the in-room infrared camera system tracks the array relative to the isocenter.[14]

To monitor the patient continuously an array is used. This array is positioned above the patient during the treatment.[13,15]

Although the array lies between the patient and the beam, it is not included in the dose calculation of the treatment planning system.

Zou et al. studied the array attenuation effect for the regular energies 6 and 15 MV photon beams for various gantry angles – and concluded that the dose difference due to the placement of Calypso array was clinically insignificant to the treatment.[16] In our institute the Calypso system is mainly used in the irradiation of flattening filter free (FFF) beams. Given that the removal of the flattening filter lowers the mean energy of the beam we propose to study, for various gantry angles, the attenuation effect of the array for FFF 6 and FFF 10 MV photon beams. It is also to be noticed that point measurements of an inhomogeneous array may lead to uncertainties, as it contains source coils, sensors and infrared targets. Considering that the Calypso system has been used mainly in prostate treatments, a QA of a prostate VMAT treatment plan was performed with and without the Calypso array in the beam.

MATERIALS AND METHODS

All transmission measurements were performed on a True Beam STx linear accelerator (Varian Medical Systems) using a CC13 ionisation chamber of 0·13 cm^3 of sensitive volume (IBA Dosimetry, Germany) connected to a Dose 1 electrometer (IBA Dosimetry, Germany). Corrections for temperature and pressure were applied.

Attenuation effect of the array for 6- and 10 MV and FFF 6- and FFF 10 MV photon beams

The ionisation chamber was inserted in a slab phantom and positioned in the isocenter at 5 cm depth. The array was positioned above the phantom in the (0, 0, 0) position indicated by Calypso software system, in the same way it is positioned above the patient during treatment (see Figure 1).

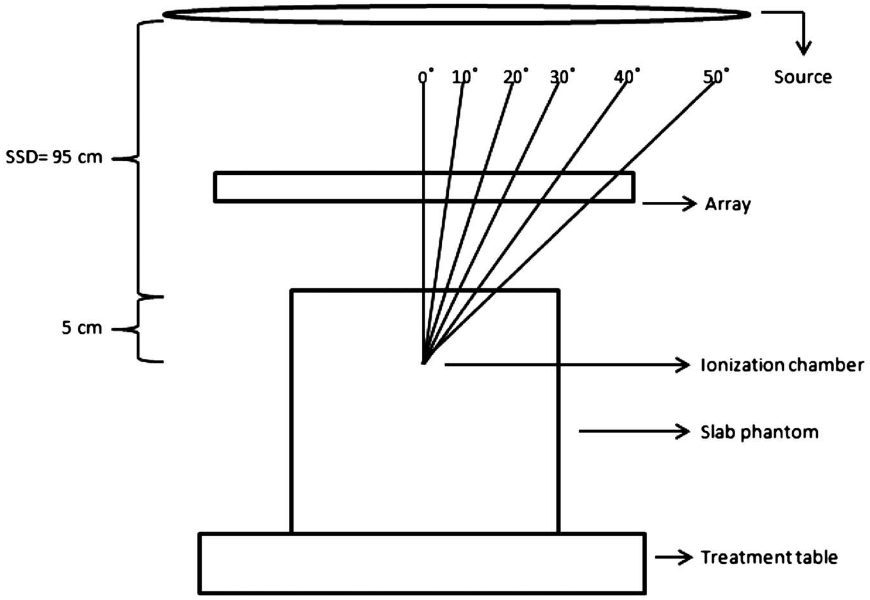

Figure 1. Gantry angle measurements acquisition scheme.

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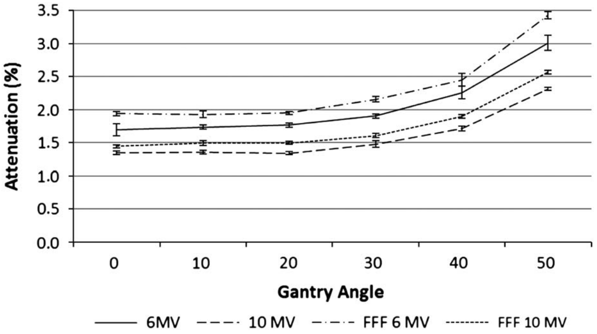

Figure 2. Attenuation by Calypso array of 5 × 5 cm² field size beams.

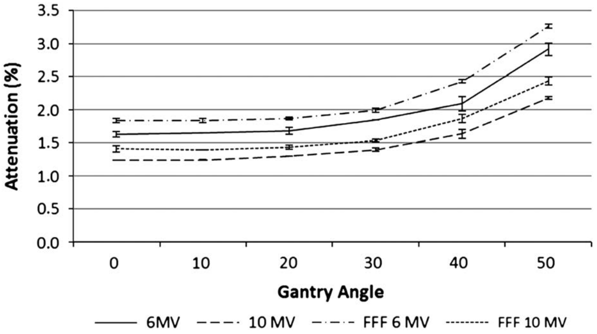

Figure 3. Attenuation by Calypso array of 10 × 10 cm² field size beams.

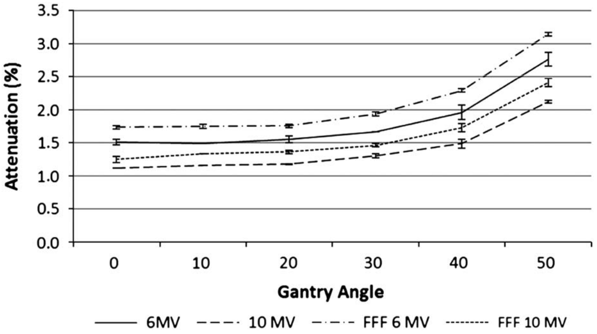

Figure 4. Attenuation by Calypso array of 15 × 15 cm² field size beams.

Measurements were performed for regular 6- and 10 MV and FFF 6- and FFF 10 MV energies, for 5 × 5 and 10 × 10 and 15 × 15 cm² square field sizes. The readings were obtained in six different gantry angles: 0°, 10°, 20°, 30°, 40° and 50°. Further gantry angles were not considered in this study as the centre of the beam would not traverse the array. For each measurement, 200 monitor units (MU) were delivered at a dose rate of 600 MU/minute for regular beam energies and 800 MU/minute for FFF energies.

Measures were performed with and without the array in the beam path. Each measurement was repeated five times. The transmission measurements were registered in a table. The attenuation was calculated according to the formula:

$$\text{Attenuation}(\%) = \left(1 - \frac{\text{Measurement with array}}{\text{Measurement without array}}\right) \times 100$$

The attenuation calculated values were registered and analysed. Mean and standard deviation were calculated.

A fit was done to the attenuation curves to evaluate the goodness of the fit.

Attenuation effect of the array for a FFF 10 MV prostate treatment

An ArcCheck system (SunNuclear, Melbourne, FL, USA) was used to measure the dose delivered and to compare with the expected dose.

A computed tomography of the ArcCheck was imported in our Treatment Planning System (TPS) Eclipse (Varian Medical Systems). A prostate patient previously treated was selected randomly. The treatment consisted of a VMAT plan for a 28 × 2·25 Gy irradiation of prostate and seminal vesicles. This plan was recalculated in the ArcCheck CT.

The ArcCheck was positioned in the isocenter, and the array was positioned above the phantom in the (0, 0, 0) position indicated by Calypso software system, as performed during patient treatment.

Repeated ArcCheck measurements of the patient treatment were performed with and without the array in the beam path. A standard deviation was calculated for both conditions.

All measured maps were compared to the dose map calculated. Comparison was evaluated for 3% dose for 3 mm for relative dose (RD) and absolute dose (AD) for all measured points except those with 10% dose or less, according to the local protocol.

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The ratio percentage dose (between measures with and without the array) was calculated and analysed.

RESULTS AND DISCUSSION

Attenuation effect of the array for 6- and 10 MV and FFF 6- and FFF 10 MV photon beams

The attenuation values measured were higher for 5 × 5 cm^2 fields than for 10 × 10 cm^2 fields for all energies and for the same measurement conditions. Also, the attenuation values measured were higher for 10 × 10 cm^2 fields than for 15 × 15 cm^2 fields for all energies and for the same measurement conditions. Therefore, the data shows that the beam attenuation is field size dependent. This dependency was not calculated. Field size dependency has been previously reported in other devices attenuation studies, although this dependency was also not quantifiable in those reports.[17–19]

These studies usually also report an angular dependence on the attenuation of the beam by devices. A second degree polynomial fit was applied to the attenuation curves. For the 5 × 5 cm^2 field size curves, the r^2 value for 6 MV, 10 MV, FFF 6 MV and FFF 10 MV of 0·98; 0·97; 0·97 and 0·97, respectively. For 10 × 10 cm^2 field size curves, the r^2 value was 0·96; 0·98; 0·98 and 0·99, for the same energies, respectively. For 15 × 15 cm^2 field size curves, the r^2 value was 0·97; 0·96; 0·98 and 0·96, for the same energies, respectively. Therefore, there is a tendency for higher attenuation values as the gantry angle increases, as it is shown in Figures 2, 3 and 4.

All points measured showed 0·0 or 0·1% standard deviation. Measurements can be considered precise.

The array attenuation calculated values are comparable to attenuation values presented previously. Zou et al. reported that the attenuation on the array was about 2–3% for both 6 and 15 MV energies, for 1 × 1 cm^2 field size beams at gantry angles between 0° and 40°. The calculated attenuation slowly increased above these values for angles around 50°–60°.[16]

Here the calculated attenuation values were between 1% and 2% for gantry angles 0°, 10° and 20°, for both field sizes for all energy beams. Acquisitions at 30°, 40° and 50° gantry angles

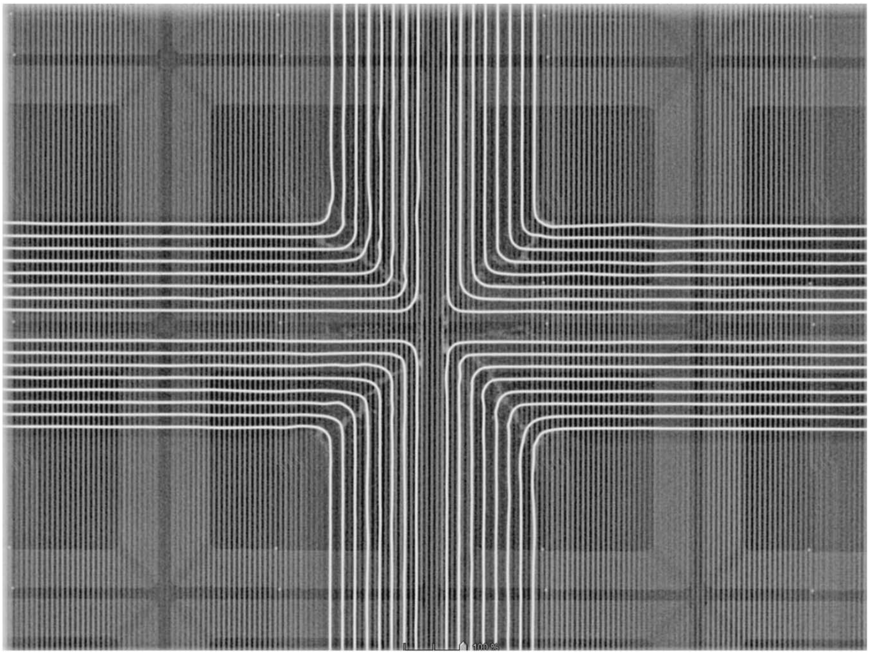

Figure 5. Portal image of Calypso's array.

showed higher attenuation values. The higher attenuation calculated value was 3·4% for a $5 \times 5\ \text{cm}^2$ field for a FFF 6 MV beam (gantry angle: 50°), and 3·3% for a $10 \times 10\ \text{cm}^2$ field and 3·1% for a $15 \times 15\ \text{cm}^2$, both for the same energy beam, at the same gantry angle.

Array attenuation values can be considered acceptable. Nevertheless it is to be noticed that point measurements were performed and because the FFF energy beams are not flat by definition, positioning accuracy of the ionisation chamber can be challenging. Furthermore, the array is also inhomogeneous, as it contains source coils, sensors and infrared targets as it is shown in Figure 5. A 2D Electronic Portal Imaging Device detector could be used to assess that, however it has to be compatible with the use of FFF beams.

Attenuation effect of the array for a FFF 10 MV prostate treatment

The repeated measurements without array above the ArcCheck showed less than 0·4% standard deviation for both RD and AD10 evaluations. The repeated measurements with the array above the ArcCheck showed less than 0·5% standard deviation for the same evaluations.

The ratio values calculated for RD were all 1·00. For the AD there was one ratio value of 1·01. The mean values for the two evaluation methods were all 1·00. Therefore the presence of the array in the beam path is negligible.

CONCLUSION

The behaviour of the array attenuation curves is important to study due to its inhomogeneous structure.

Dose attenuations were measured to be within 1–2% with the exception of the 30°–50° gantry angles which were up to 3·4%. The results indicate that the dose attenuation of the Calypso array may be within acceptable limits.

Future work should assess the Calypso attenuation of radiotherapy treatment beams with more detail.

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Conflicts of Interest

None.

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