

QUALITY CONTROL OF A SIEMENS ONCOR ACCELERATOR: DAILY CHECKS

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Abstract. *Quality control and quality assurance for units that produce ionizing radiation for radiotherapy, summarizes, archives, and currently dates the performance of these units of irradiation by comparison to the parameters since the time of commissioning. Siemens ONCOR Impression is an advanced linear accelerator that can be used for routine clinical applications as well as for complex and advanced treatments such as stereotaxic radiosurgery. The linear accelerator enables the production of two clinical photon beams with energies 6 MV and 7 MV as well as beams of electrons with energies from 6 MeV to 18 MeV. Quality control of a linear accelerator consists on dosimetric, mechanical and safety checks based on international standards and departmental decisions. This work presents the daily dosimetric measurements of the flattened filter 6MV photon beam with the Octavius 729 matrix detector. Data were collected over a 12-month period and results obtained by daily measurements showed that the output of linac (dose), the uniformity and symmetry of the 6 MV photonic beam were within 2% to 3 % from reference values in compliance with recommendations of AAPM 142. The output mean value was 1.55 ± 0.01 Gy, the flatness mean value was 109.44 ± 0.28 % and 109.56 ± 0.45 % in TG and LR profiles and the mean symmetry value was 102.07 ± 0.53 % and 101.69 ± 1.09 % in TG and LR profiles.*

Keywords: *quality control, linear accelerator, photon beam, output, dose*

1. INTRODUCTION

The quality assurance program for a linear accelerator is needed to assure that the machine characteristics do not deviate significantly from their baseline values acquired at the time of acceptance and commissioning which are entered into treatment planning systems to model the treatment machine, and therefore can directly affect treatment plans calculated for every patient treated on that machine [1, 2].

Procedures and conditions for acceptance testing, commissioning, and periodic quality assurance of radiotherapy equipment are provided by the International Electrotechnical Commission, IEC067 [3], American Association of Physicists in Medicine AAPM [1, 2, 4, 5, 6, 7], International Atomic Energy Agency IAEA 398 [8].

The quality control of a linear medical accelerator (Linac) is typically categorized into Daily, Monthly and Annual checks in time including the safety, mechanical and dosimetry measurements [AAPM40.142].

The radiotherapy treatment with Linac starts with patient immobilization and Computed Tomography (CT) image acquisition. Images are first transferred to the Treatment Plan System (TPS), where the volumes of interest Planning Target Volume (PTV) and Organs at risk (OAR) are contoured over patient images. Thus, the treatment plan is prepared and optimized after selection of beam/Source technique and the algorithm for dose

calculation, using the virtual machine commissioned for Linac in the TPS.

Then plan is evaluated, approved and data are transferred through the oncologic information system to be ready for dose delivering to the patient with the ionizing radiation beams produced by the Linear accelerator.

The Siemens ONCOR Impression Plus is an advanced linear accelerator and has been installed at Neurosurgery Service, University Hospital “Mother Teresa” in the beginning of 2013, where Stereotactic Radiosurgery (SRS) and 3D-conformal radiotherapy for treatment of central nervous system tumors was implemented immediately after acceptance (SRS in November 2013 and 3d-CRT in October 2014).

In this study, the dosimetry Daily checks of the 6 MV clinical photon flattened beam, with a dose rate of 300 Monitor Unit (MU)/minute, commissioned for the SRS modality and 3d-CRT will be considered. The output constancy, beam flatness and symmetry will be analyzed for a 12-month period from February 2016 to January 2017.

2. MATERIALS AND METHODS

2.1. Linac Specifications

The Siemens Oncor Impression accelerator has been installed at Neurosurgery Service, University Hospital

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“Mother Teresa” at the beginning of 2013. The linac produce two photon beams with the energies of 6 (flattened filter Free) photon beams with a dose rate of 300 Monitor Unit (MU)/minute and 1000 Monitor unit (MU)/minute, respectively.

It has an asymmetric jaw collimator and an Optifocus Multileaf Collimator (MLC) with 82 Leaves, with a maximum field size of 40 cm by 40 cm. Also, virtual wedges and physical wedges, and electronic portable imaging device (EPID), used to verify patient positioning. Treatments are realized using the high precision treatment table, suitable for stereotactic radiosurgery. Accessories as Stereotactic frames by Radionics and 12 anti-scattering cone collimators (sizes 12.5 to 40 mm in 2.5 mm increments) are useful for achieving the SRS of brain tumors [9, 10, 11, 12].

The linac was calibrated for each X-ray energy photon to give an absorbed dose to water of 1cGy per 1 MU (1 Gy per 100 MU) at depth of dose maximum for a standard open field of 10x10 cm using a source to surface distance (SSD) of 100 cm.

The quality control (QC) was set up after commissioning of the Linac for 3D-CRT modality in Eclipse TPS, in October 2014, regarding the 6MV X-ray photon beam and electron beams.

The QC program at Xknife Unit was implemented based on AAPM 142, IAEA TRS 398, separated in daily, monthly and annual checks, with the action limits of the SRS modality, and usage of dosimeters and phantoms available in the department.

2.2. Quality Control Protocol

The output of a megavolt machine such Linac are defined as the absorbed dose to water per monitor unit. 1 cGy in the standard conditions is defined as one Monitor Unit (MU) for the linacs [13].

Beam uniformity, flatness, or homogeneity can be specified as a maximum permissible variation from average dose across the central to 80% of the full beam width of the profile in a plane transverse to the beam axis (Figure 1, Figure 2).

Beam flatness is typically calculated by percentage Dose Ratio (1) or percentage Dose Difference according to IEC 60976 (2) as written below:

$$\text{Flatness [\%]} = \frac{D_{\max}}{D_{\min}} \times 100 \% \quad (1)$$

or

$$\text{Flatness [\%]} = \frac{D_{\max} - D_{\min}}{D_{\max} + D_{\min}} \times 100 \% \quad (2)$$

where D_{\max} and D_{\min} are the maximum/minimum dose in flattened region.

Beam symmetry is defined as a maximum permissible percentage deviation of the “left side” dose from the “right side” dose of a beam profile often at 80% of the FWHM points. A typical symmetry specification is that any two dose points on a beam profile, equidistant from the central axis point, are within 2% of each other and is expressed with equations as follow:

$$\text{Symmetry} = \frac{D(x)}{D(-x)} \times 100 \% \quad (3)$$

where $D(x)$ is the dose at the point x ; x and $-x$ are points within the flattened region, symmetrical to central axis.

Symmetry is defined as being the maximum ratio within the flattened region, multiplied x 100.

$$\text{Symmetry} = \frac{\text{area left} - \text{area right}}{\text{area left} + \text{area right}} \times 100 \% \quad (4)$$

where areas are delimited by the central axis and the 50 % field limit [13,14,15].

The homogeneity refers to the transverse dose variation across the beam and is characteristic of beam energy. The symmetry refers to a tilt in the beam between positions equidistant from the central axis of the beam and is dependent upon the alignment of the electron beam onto the target.

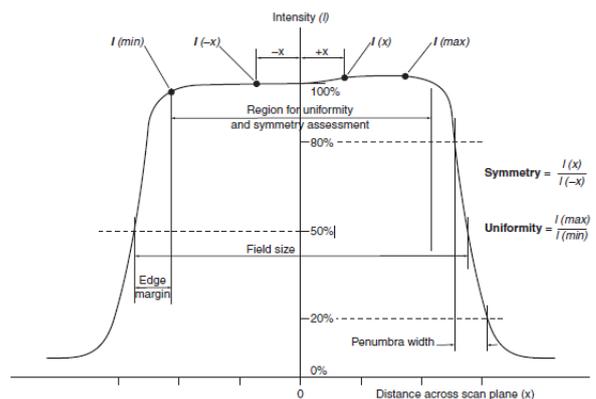


Figure 1. Illustrations of the symmetry and uniformity by [14]

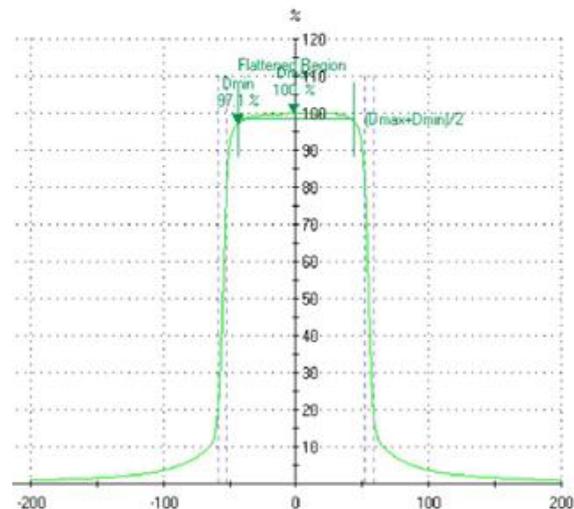


Figure 2. Dose profile of the 6MV photon beam in an open field of 10 x 10 cm at 10 cm depth in a water phantom, for Siemens Oncor

The machine related problems can occur at the start of the day, during the warmup period, or during the treatment day. The dosimetry problems, such as miscalibration, of the beam or lack of symmetry,

flatness, are readily apparent only during the morning checks [6].

The quality control of Siemens Oncor was organized in Daily, Monthly and Annual checks in time including in each category the Safety; Mechanical and Dosimetry measurements that must be performed [AAPM 142. 40]. In Table 1, there are listed Daily control checks performed for linac, where the upper three parameters will be considered in this study.

Table 1. Daily checks for Siemens Oncor

Frequency	Procedure	Action level
Daily	Xray output constancy	2 %
	Beam flatness	3 %
	Beam symmetry	2 %
	Lasers	1 mm
	Distance indicator	1 mm
	Door interlocks	functional
	Audiovisual monitor	functional

In this study, the Daily dosimetry checks of 6 MV clinical photon flattened radiation will be considered.

The clinical x-ray photon beam of 6 MV is a flattened filter beam (FF) with a percentage depth dose at 10 cm depth equal to 67.2 % and with a depth of dose maximum of 1.5 ± 0.2 cm, as measured for an open field of 10×10 cm² with Source Surface Distance (SSD) equal to 100 cm. The photon beam quality $Q_i = 0.674$ for the Siemens Oncor linac [IAEA 398].

The linac was calibrated for the 6MV flattened filter beam to give 1cGy per 1 MU (or 1Gy for 100 MU) at standard conditions. These baseline measurements were performed at commissioning by scanning the beam in a MP3 -PTW water phantom with the PTW semiflex and Roos ionization chambers.

For Daily checks of the 6 MV radiation beam consistency in the output, symmetry and flattens, the Octavius 729 detector and a PMMA solid phantom were used.

2.3. Measurement Setup and Procedure

At Knife Unit the Quality control tests of Linac was implement based on international recommendations [AAPM 40.142, IAEA 398] and departmental decision based on the dosimetry equipment that we had in use.

Dosimetry daily checks were performed using a solid phantom, made of 10 plates of Polymethyl methacrylate (PMMA) of 30 x 30 cm x 1 cm in dimensions and the PTW Octavius 729 detector (Figure 3).

OCTAVIUS Detector 729 is a matrix of 27 x 27 ionization vented chambers (10 mm center to center). Chambers size 5mm x 5mm x 5 mm with an active volume 0.125 cm³. The arrangement of the ionization chambers in a matrix allows performing measurements of central axis dose as well dose distributions; beam profiles in Gun-Target and -Left-Right direction. The effective point of measurements lies at 7.5 mm depth and is laterally indicated by cross- hairs on the three sides of the array. The area density above the chamber volume is with density of 0.8 g/cm³. Measure dose rates

in low range from 0.5 to 8 Gy/min and in high range from 3 to 48 Gy/min [16].

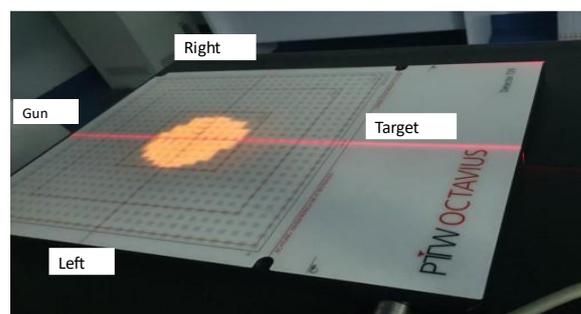


Figure 3. Illustrations of detector under the head of accelerator oriented in Target-Gun (Y- Inplane axis) and Left -Right (Cross plane X -axis)

Daily check for geometrical and dosimetrically parameters were performed by placing the Octavius 729 detector on at least 3 cm backscatter material over the couch, perpendicular to the photon beam.

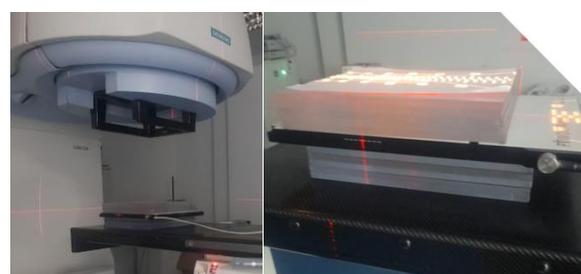


Figure 4. Detector between 5 plates of PMMA under the head of Linac

The Octavius has an orientation noted on its surface to be positioned according to gantry axes. Typically, the Y axis is the Gun-Target or (inplane) and the X- axis is the cross-plane direction (or left -right) in coordination with the linac axis.

Align Octavius using the position lasers and the light field indicator at the desired SSD (source surface distance, usually 99.25 cm) (Figure 3, Figure 4). Then by placing 5 plates over the active zone of the detector and moving the detector with all 5 PMMA at an SSD=100 cm at the top surface of 5cm PMMA plates (source-ionization chamber distance of 105 cm) at the same setup as in the reference measurement, daily checks are performed in continuity.

After setting the setup of the detector with the slab phantom within the bunker, on remote, at the control console of linac, was programmed delivering 200MU, 6MV modality, 10 x 10 cm open field.

In synchronous, at dosimetry software, PTW Mephysto opens the Linac QA>Multichek daily QA: where is called the reference of the corresponding photon beam 6MV; entering the Temp= degree Celsius and pressure P= hPa measured in the bunker; START measurements for the clinical photon beam energy, with the field 10 x 10 cm² and 200 MU (Figure 5).

In the window of Muticheck (Figure 5), once a measurement is performed, the software taking into consideration correction factors such as temperature and pressure, first calculates the selected dosimetric parameters and then displays their values with a comparison with the reference values. Specifically, as depicted in Fig. 5, the displayed data are: the Dose deviation from the reference value as Central Axis DOSE Deviation in [%], Homogeneity [%], Symmetry [%], in both axes Left-Right and Target - Gun direction [17].

The dosimetry parameters are calculated based on international dosimetry protocols included in the Software module. The difference in dose deviation to the center axis will be calculated by equation (5).

$$\text{CAX Dose dev. [\%]} = \frac{D_{\text{meas}} - D_{\text{ref}}}{D_{\text{ref}}} \times 100 \% \quad (5)$$

while flatness and dosimetry with the equation (1) and (3) as mentioned above.

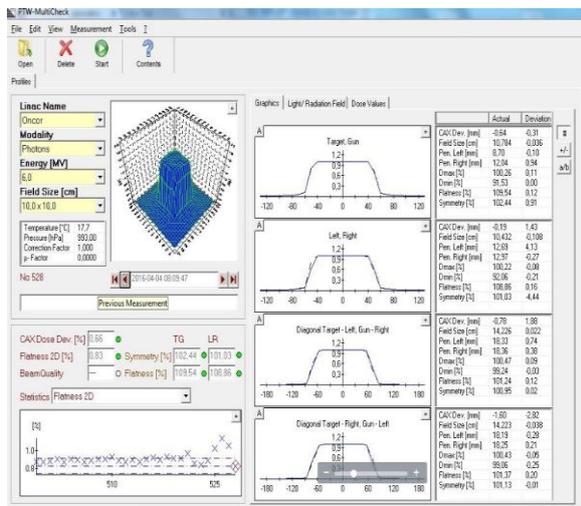


Figure 5. PTW Multicheck module window

3. RESULTS

The Daily dosimetric data for the 6MV flattened photon beam were collected from measurements of our Linac over a twelve-month period, from February 2016 to January 2017. The overall daily data measured were around 227 with an average of 20 daily data per month.

The output value measured as the reference in the same set up and MU gave the output value of 1.543 Gy/200 MU delivered to the central ionization chamber of the matrix 729 detector.

The output consistency of linac, presented as dose difference deviation in percentage, is presented graphically in Figure 6.

From the distribution of values within a 12-month period, it seems that in the cold months December – January – February, there was a slight variation in CAX dose compared with the other periods but does not show a pattern of negative or positive sign such in literature [19]. The variations could be related to humidity or very low temperatures, which might affect the associated electronic response in linac units.

The mean output value deviation of linac was $0.55 \pm 0.43 \%$, ranging from 0.01 to 1.99 %. The equivalent output mean value, in terms of absolute dose, was 1.55 ± 0.01 Gy, ranging from 1.53 to 1.57 Gy.

The reference beam profiles regarding symmetry and beam flatness across the transversal axis were flatness TG [%] = 109.24 in TG direction (in plane) and flatness LR [%] = 109.11% in LR direction cross plane and Symmetry [%]: 101.98 % in TG direction (in plane) and 102.68 % in the left-right direction.

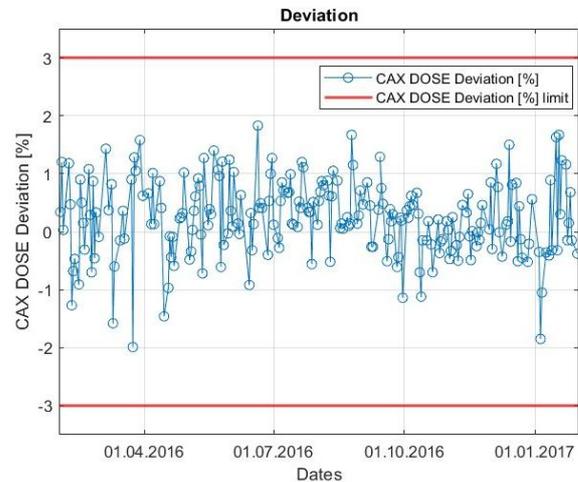


Figure 6. Central axis doses for the period of February 2016-January 2017

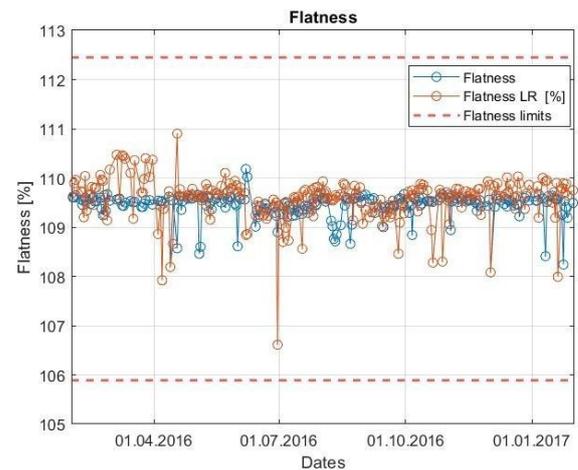


Figure 7. Uniformity of flatten profile photon in TG and LR axis

In Figure 7, it is obvious that values of flatness along the two-transversal axis of the beam LR and TG remain within 3 % of the reference value of 109.2. Both follow the same pattern, but it seems that homogeneity in LR seems to have fluctuations especially in February and then are stabilized over the time. The mean value of linac flatness over a 12-month period was $109.44 \pm 0.28\%$ and $109.56 \pm 0.45 \%$; with values in the ranges of (108.2 – 110.2) and (107.92 – 110.9), for TG and LR profiles correspondently.

In Figure 8, the symmetry data in both axes are presented and is evident that values stay within 2% of the reference value of 102.3 %.

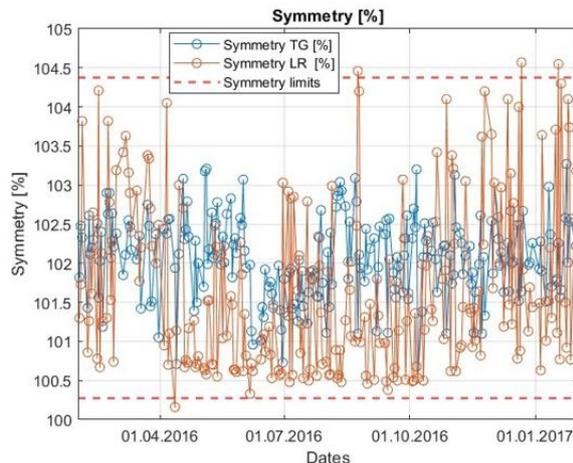


Figure 8. The symmetry indicated as TG -blue color, and LR - in brown color.

The symmetry values in LR direction show a slightly higher variation. Gantry tilt affects the symmetry and in daily checks the user must be careful about gantry positioning during the measurements. The mean value of linac symmetry over 12 months was 102.07 ± 0.53 % and 101.69 ± 1.09 %; value ranges were (100.7 – 102.98) and (1007.67 – 104.19) for TG and LR profiles correspondently.

In overall, as daily checks are fast measurements, it is evident that the machine has a good stability in output values within 2%.

Regarding uniformity and symmetry, the data over time remain within ± 3 % and ± 2 % of reference values. More variability was observed in the LR direction. Considering that daily checks are fast measurements, e.g. improper detector alignment with the radial (Y) axis and transverse (cross-plane) X-axis, a gantry tilt or couch tilt, all could compromise the data in the beam profile characteristics such as field size, flatness, symmetry, etc.

4. CONCLUSION

Data collected over a 12-month period from daily measurements have shown that the output of the 6 MV photon beam (dose), the symmetry and flatness, were within ± 2 % and ± 3 % of their reference value. The output mean value was 1.55 ± 0.01 Gy, the flatness mean value was 109.44 ± 0.28 % and 109.56 ± 0.45 % in TG and LR profiles and the mean symmetry value was 102.07 ± 0.53 % and 101.69 ± 1.09 % in TG and LR profiles.

Results showed that daily checks with the Octavius detector are of high precision and the Linac Siemens Oncor have a good long-term stability on beam dosimetry.

In order to achieve optimal quality assurance of a linear medical accelerator, a close collaboration

between radio-oncologists, medical physicists, and radiotherapists is needed to keep safe dose delivering to patients.

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