Seasonal Photon Output Trend from Linear Accelerator in Sokoto, North-Western Nigeria

Hassan Ibrahim¹, Usman Bello²

¹Department of Radiotherapy, Usmanu Danfodiyo University Teaching Hospital, Sokoto, Nigeria
²Dept. of Morbid Anatomy and Forensic Medicine, College of Health Sciences, Usmanu Danfodiyo University/Teaching Hospital, Sokoto, Nigeria

Abstract

Background: Linear accelerators are so sensitive to variability of temperature, pressure, humidity and dust; thus, weather factors can cause common errors in photon output which in turn can compromise constancy and consistency in precise delivery of tumor dose. Dose checker is such a dose measuring devices that has an inbuilt correction factor for bunker temperature and pressure changes which ensures the photon output is within the accepted values to the patient. The aim of the study is finding the effect of seasonal changes on Linac and its influence on the patient.

Methods: This is a retrospective study and daily records of 6 and 15 MV photon output with their corresponding temperature and pressure from January 2019 and December 2021 were extracted and reviewed. Precision mercury-in-glass thermometer and Barometer (OPUS 10 TH) were used to keep daily records of bunker temperature and pressure while their seasonal behaviours were recorded. Mean values of each month of the year was calculated and arranged according to three seasons of the year; results were represented in graphs, tables and bar charts.

Results: The overall mean photon outputs were 0.997 and 0.828 cGy/MU for 6 and 15 MV respectively. The deviation of photon outputs from their reference values were ±2% for 6MV and ±3% for the 15MV energy. The mean bunker temperature was 27.07°C. The overall mean bunker pressure was 977.23 hpa. During harmattan season the temperature and pressure ranged between 26.8-25.4°C and 978-976.1 hpa respectively. In hot season bunker temperature was between 25.7-29.5°C and pressure was between 976.1-975.0 hpa. For the wet season, the temperature was between 29.5-25.7°C, and the corresponding bunker pressure ranged between 980.0-976.3 hpa.

Conclusion: The seasons of year influenced variation in bunker temperature and pressure with corresponding seasonal photon output variation despite the use of dose checker. Low photon outputs were recorded during harmattan and hot seasons while higher outputs were recorded during wet season.

Keywords: Season; Trend; Photon output, Linear Accelerator

Introduction

The Usmanu Danfodiyo University Teaching hospital Sokoto is located in the extreme north-western region of Nigeria, it lies between Latitude 13°05' N and Longitude 05°15'E. The area is sandy savannah with hills that are sparsely distributed, it has an annual average temperature of 28.3°C (82.9°F), maximum daytime temperatures are generally under 40°C (104.0°F) but can exceed 45°C (113.0°F) during dry hot season. The rainy season is short and begins from June to October, from late October to February the climate is dominated by the Harmattan, wind blowing Sahara dust over the land (1). The linear accelerator (Linac) is the most favorable and commonly used radiotherapy machines in developed countries (2), but it has now started gaining acceptance in developing world. In the past, 60Cobalt was the only available radiotherapy machine in Nigeria, but recently we are witnessing a gradual replacement of those machines with modern Linacs. The Linacs have an advantage of dual function over 60Cobalt; it emits both electron and photons for the treatment of benign and malignant tumours. In Linac, accelerated electrons with high kinetic energy in a linear tube collide with a target. After this interaction the bremsstrahlung x-ray beam exits the machine head or sometimes electrons were emitted when target is removed along their path way. Despite high accuracy in mounting and installation of this equipment, quality control (QC) is needed for the purposes of constancy and consistency in precise delivery of tumor dose that will not exceeds ±5% of the prescribe dose (3-5). To achieve and improve often those QC, weather factors has to be considered, because Linacs are so sensitive to variability of temperature, pressure and dust, those weather factors can cause common errors which in turn can
interrupt the treatment sessions. This source of errors also increases with increasing complexity of technology for such type of machines, hence the need for routine quality control and regular inspection to prevent or identify impending errors before they have any impact on patient care (6-9). The QC which is an integral component of quality assurance (QA), especially the calibration of machine by defining the specific dose rates, has to be considered with great importance. Different dose rates may change the collection efficiency of the ionization chambers (IC) located in the Linac head, as well as the relative biological effectiveness (RBE) of radiation doses (10). Therefore, the calibration of the ionization chamber of a Linac should be determined at all available dose rates (10, 11). This procedure is a responsibility of medical physicist by using the national or international protocols like TG-51 by the American Association of Physicists in Medicine (12) or TRS398 by the International Atomic Energy Agency as a standard guide (13). The procedure is conducted annually on any installed Linac, but impact of seasonal variation on the Linac output, necessitates the choice of months without extreme air humidity (14). The geographical location of our centre with Linac (Elekta precise) in the north western region of Nigeria an area with distinct seasons of harmattan, hot and wet seasons. These three seasonal factors had been cited to affect linac performance even in the developed western world. The linac machines are just evolving in Nigeria and no study of this kind has been conducted in our environment to ascertain the influence of such factors to the newly installed Linac, hence the need for this study.

Materials and methods

Source of data:
Daily records of Linac photon outputs measured using dose checker with corresponding bunker temperature and pressure for three years under review (January 2019 to December 2021) were collected.

Data management
The data obtained was analyzed using the Statistical Package for Social Sciences version 20.0 (Chicago L). Mean values of each month were generated, then mean values of same months under the study period was calculated, and the months were arranged according to the seasons of the year. The generated mean values were presented in Tables, bar charts, Pie charts, and graphs.

Results
The extracted data covered the period of 2019 to 2021, with overall mean photon output of 0.997cGy/MU for 6MV energy (range of 0.797 to 1.187cGy / MU) and standard deviation of ±0.02. Similarly, the corresponding overall mean, range and standard deviation of 15MV were 0.828cGy / MU, 0.786 to 1.174cGy/MU and ±0.03 respectively (table 1). In table 2, the overall mean bunker temperature over the study periods was 27.07oC (range 23.1 to 31.0oC) and standard deviation of ±1.6. And the overall mean bunker pressure recorded over the study period was 977.23 hpa (ranged 966.9 to 988.7 hpa) and standard deviation of ±2.6.

Figure 1, shows a bunker temperature change with seasons, the harmattan season (late November to early February) is characterised by a fall in temperature from 26.7-25.4oC. From late February to May (hot season), the temperature rises from 25.4 to 29.6oC in May. The wet season started from late May to early November, and is characterised by a step ladder fall in temperature from 29.5–25.6oC in September, and then followed by a transient rise in temperature as higher as 27.8oC in October. Figure 2, shows seasonal pressure behaviour in the bunker, during harmattan the pressure fall from 978.00 to 976.20 hpa, and during hot season the pressure dropped further from 976.20 to 975.00 hpa. However, in wet season the pressure rises from 975.00 to as higher as 980.00 hpa in September, thereafter, the pressure dropped down to 976.00 hpa in November. The outputs from two photon beam energies were also observed to follow a seasonal trend. During harmattan, the 6 and 15 MV photon output was observed to be steady with minimal step ladder increment from 0.982 to 0.994cGy.MU and 0.821 to 0.834cGy / MU respectively. In hot season there were also step ladder increments from 0.986 to 1.010cGy/ MU for 6MV and 0.826 to 0.837cGy / MU for 15 MV. However, there was a gradual increase in photon outputs for both energies (6 and 15 MV) during wet season from 1.010 to 1.030cGy / MU and 0.837 to 0.845cGy/MU respectively (figure 3).

Table 1: Overall mean values of Linac outputs from photon energies

| Photon energies | Linac outputs (cGy | MU) | SD   |
|---------------|------------------|------|
|               | Mean             | Range|      |
| 6MV           | 0.997            | 0.797 – 1.187 | ±0.02|
| 15MV          | 0.828            | 0.786 – 1.174 | ±1.6 |

SD = Standard deviation, MV = Mega voltage, cGy= Centigray, MU = Monitor unit
Table 2: Overall mean values of Linac bunker weather factors

<table>
<thead>
<tr>
<th>Weather factors</th>
<th>Bunker factors</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature (°C)</td>
<td>27.07</td>
<td>23.10 – 31.00</td>
</tr>
<tr>
<td>Pressure (hpa)</td>
<td>977.23</td>
<td>966.9 – 988.7</td>
</tr>
</tbody>
</table>

SD = Standard deviation, °C = Degree Celsius, hpa = Hecto Pascals

Discussion

In any retrospective study it is always difficult for one to obtain an accurate data record, hence the usual challenges when it comes to the final discussion of the results. The extracted data covered the period of 2019 to 2021, with 0.997cGy / MU (range of 0.797 to 1.187cGy / MU) as the overall mean photon output for 6MV energy and a standard deviation of ±0.02. Similarly, the corresponding overall mean, range and standard deviation for 15MV were 0.828cGy / MU, 0.786 to 1.174cGy / MU and ±0.03 respectively. Two observations were made for the Linac photon outputs with regards to the photon energies (6 and 15 MV).

First, the lower photon energy (6MV) in this study shows a high output compared to high photon energy of 15 MV, this is contrary to previous finding by Mohammed Ahmed Ali Omer in 2017, where he reported higher Linac output from higher energy and lower output from lower energy (15). Reasons responsible for these contradictory findings might be attributed to differences the Linacs manufacturers, especially in bending magnet arrangement. Similarly, the gun current supply for 6MV photon energy might be higher than that of 15MV for the Linac under study (Elekta precise), this may not be similar to other Linacs (Varian Oncology, Palo Alto, CA). Secondly, we observed that the dispersions from the mean photon output of 6 and 15MV energies were almost similar, ±0.02 and ±0.03 respectively, and this indicates that there is similarity in factors affecting the two photon energies. In addition to the above stated reasons, it also shows that the outputs were measured with dose checker that corrected temperature and pressure changes, hence the deviation is within the accepted values of ±5%.

The climatic condition of Sokoto is tropical continental type characterized by three distinct seasons of harmattan, which start from late November to February, the hot season, from March to May and wet season that start from June to early November (16). Each season differs from one another in terms of magnitudes in temperature and pressure. From our study, the harmattan season is characterised by a low temperature (26.8–25.4°C), followed by a gradual rise...
in temperature in late February (25.6°C) to May (29.5°C) which marked the hot season. Wet season started from late May to early November, it is associated with rainfall and steep fall in temperature (29.5–25.6°C). Towards September to early November the rainfall is light and irregular and there was relative rise in temperature. The temperature behavioural pattern with seasons in Sokoto shows an irregular quadratic pattern which is in accordance with what was reported by S. A. Isezuo in 2003 (16). Figure 7 shows seasonal pressure behaviour in our environment with an inverse relation to temperature, as temperature fall during the harmattan, the pressure rises from 977.6 to 978.0 hpa, and as temperature begins to rise during hot season, the pressure dropped from 978.0 to 975.2 hpa. However, a complex linear relationship was observed between figure 6 and 7, during wet season, temperature rises with corresponding rise in pressure from 975.2 to 980.3 hpa. Towards the end of September and November when rainfall is light and irregular, the temperature rises and pressure fall from 980.3 to 976.5 hpa. The explanation of this complex relationship of pressure and temperature during the raining season might be linked with increase in atmospheric humidity during wet season.

The outputs from the two energies of the photon beams were observed to have a similar bell shape pattern quite different from the complex temperature and pressure relationship. During the winter and first two months of hot seasons the machine photon outputs from 6 and 15MV were low (0.982 to 0.990 cGy/MU and 0.820 to 0.825 cGy/MU respectively). However, during the wet season the photon outputs rises to 0.990 to 1.010 cGy/MU for 6MV and 0.825 to 0.840 cGy/MU for the 15MV. From this study, it had been observed that during harmattan when temperature falls and first two months of hot season when temperature rises, the pressure was low and the outputs was also low. Therefore, an attempt to link temperature variation with machine outputs was very complex and inconclusive. However, this study revealed linear relationship between pressure and photon outputs, as pressure rises, the photon outputs rises and this coincides with raining seasons, hence the assumption of increase in atmospheric humidity that lead to pressure rise. Therefore, it had been considered as part of the limitation of this study for not considering humidity as a factor. We therefore recommend feature study to look into humidity as a factor.

Conclusion
Seasons of year influenced photon output despite the use of dose checker. Low photon outputs were recorded during harmattan and hot seasons when bunker pressure was low. During wet season, the bunker pressure was higher and the Linac outputs were also higher. We therefore recommend to any center in Nigeria willing to install new Linac machine to put this factors into consideration during calibration of dosimetric equipment and collection of commissioning data to minimized feature error in dosimetry.

References