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Research Paper

Effect of Local Temperature and Pressure on the Photon Beam Outputs from Linear Accelerator

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Abstract

Daily quality control (QC) is mandatory in radiotherapy so that tumor dose delivery should be within ±3% of the prescribed dose. However, daily variation of Local temperature and pressure are reported to affect machine outputs, hence the need for daily quality audit. Three years (January 2011 - December 2013) daily records of 6 and 15 MV photon output from Elekta precise machine using standard set up procedure with quality control tools were extracted. Corresponding bunker temperature and pressure were also retrieved and reviewed. SPSS Software package was used to determine ranges, means and standard deviations of all the factors. The photon outputs for the two energies were also plotted against temperature and pressure. The most frequently observed photon outputs over the study period were 0.975 cGy / MU for 6 MV and 0.800 cGy/MU for 15 MV with ±2.5% and ±3.1% deviation from the reference values of 1.00 and 0.826 cGy/MU respectively. Temperature and pressure showed inverse correlation with p-value < 0.01. The magnitude of photon outputs for 6 and 15 MV attained peak values of 1.000 and 0.900 cGy / MU respectively at the lowest bunker temperature of 24.05oC, but dropped to 0.870 and 0.800 cGy / MU as bunker temperature raised to 30.02oC. The bunker pressure showed a linear relationship with photon output, as bunker pressure raises from 972.3 to 981.7 hpa their corresponding outputs also rises from 0.870 to 1.000 cGy / MU for 6 MV and 0.8000 to 0.8900 cGy/MU for 15 MV respectively. Daily variation of bunker temperature and pressure influenced photon outputs from LINAC, despite the use of dose checker with sealed ionization chamber. However, daily quality control should be maintained to ensure safety in dosimetry.

Keywords: Quality audit; photon output; Temperature and pressure

Introduction

Linear accelerator (LINAC) has been described as the most favorable and commonly used radiotherapy machines in developed countries over the years [1]. However; it has now started gaining acceptance in the developing world. In the past, ^{60}Co had been the only available radiotherapy machine in Nigeria, but recently we are witnessing a gradual replacement of those machines with modern Linac. The LINAC have an advantage of dual function over ^{60}Co units by emitting both electron and x-ray radiation for the treatment of benign and malignant tumors. In a LINAC, accelerated electrons collide with a target via a linear tube where they possess high kinetic energy. 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 exceed ±5% of the prescribe dose [2-4]. To achieve and improve often those QC, weather factors have to be considered, because

LINACs are so sensitive to variability of temperature, pressure and dust. These weather factors can cause common errors which in turn can interrupt the treatment sessions. These sources of errors also increase with increasing complexity of technology for such type of machines, hence the need for routine QC and regular inspection to prevent or identify impending errors before they have any impact on patient care [5-8]. 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), as well as the relative biological effectiveness (RBE) of radiation doses [9]. Therefore, calibration of the ionization chamber should be determined at all available dose rates, [9, 10] the procedure is a responsibility of medical physicist under the guidance of either national or international protocols like TG-51 or TRS 398 [11, 12]. The procedure is conducted annually on any installed LINAC, but it was suggested to be conducted in a month without extreme air humidity to avoid increase chamber ionization and false reference values [13].

Since the radiation output of LINAC had been reported to be affected by change of weather (temperature, pressure and humidity) [13], and the geographical location of our centre is in the north western region of Nigeria, an area of extreme temperature and pressure variability mandates the conduct of this study to ascertain the effects of temperature and pressure changes on the photon output of the linac installed for the first time in this region. This will also help to minimize errors that may arise due to effect of those weather factors, other stakeholders planning to install similar may be kept aware of such effects. In the future, this study may assist the manufacturers to provide a LINAC adaptive to our environmental weather condition.

Materials and Methods

This is a retrospective study conducted in the Radiotherapy Department of Usmanu Danfodiyo University Teaching Hospital Sokoto, Nigeria. Data were extracted from previous records of daily bunker temperature and pressure with their corresponding photon outputs of 6 and 15 MV from Elekta precise LINAC. A dose checker (LINACHECK) with model number T42010-00427 calibrated after each two years at the secondary laboratory in Ibadan with percentage deviation of 0.01%, Nigeria. The device was placed at the central axis of the photon beam corresponding to the centre of 10 x10 field size designed on the dose checker and the source-to-surface of phantom distance (SSD) was kept at 100 cm when gantry angle was at 0^{o}. The dose rate of the machine was set at 100 MUs before it was beamed. After beaming, the readings (outputs) obtained for both 6 and 15 MV were corrected for temperature and pressure (automatic correction by dose checker) were recorded daily. The two readings (outputs) for 6 and 15 MV were compared with the commissioning values and only deviation greater than ±3 % (using TG-51/TRS-398 protocols) from the commissioning values that required medical physicist intervention of tuning the machine to recommended values of 1.00 for 6 MV and 0.826 for 15 MV.

The data obtained were analyzed using the Statistical Package for Social Sciences version 20.0 (Chicago L). Results were presented in Tables, bar charts, Pie charts, and graphs. The range, mean and standard deviation of temperature and pressure were calculated. Similarly, the Range, Mean and Standard deviation of photon output of the two energies were also calculated and represented in a tabular form. The daily photon output for the entire study periods were plotted inform of a bar chat for 6 and 15MV energies separately. A scattered plot graph was also generated for bunker temperature and pressure to assess for any correlation between the two factors. Time history graph of the two photon outputs was constructed from the overall monthly mean photon outputs of the two energies to assess their behaviours over the study periods. Similarly, graphs of photon outputs of the two energies were plotted against temperature and pressure changes.

Results

Table 1 shows the range, mean and standard deviation for the photon output of 6 and 15 MV photon energies. The 6MV shows higher magnitudes of photon output compared to the 15MV. The standard deviation of the mean photon output of 6 and 15MV energies were all within the acceptable limits of ±0.02 and ±0.03 respectively. Bunker temperature and pressure varies on daily basis and the measure of dispersion from their ranges were more marked on the bunker pressure with standard deviation of ± 2.6 when compared to temperature with ± 1.6 (Table 2). Figure 1 and 2 presents a frequency distribution of photon output for 6MV and 15MV respectively, the most frequently used photon output for clinical practice were (0.975, 1.00 and 1.005 cGy/MU) for 6MV and (0.800, 0.810 and 0.820 cGy/MU) for 15MV. Figure 3 presents a scattered plot indicating a strong correlation between bunker temperature and pressure over the study period. The daily change of bunker temperature affect both 6 and 15 MV photon outputs inversely as shown on figure 4. Similarly, the daily change in bunker pressure also affects the outputs of the two photon energies and it shows positive correlations as depicted on figure 5. Figure 6 presents the time history of daily output of 6MV and 15MV from LINAC plotted at six monthly intervals, which exhibits a phenomenon of periodic rising and falling due to augmented effects of daily bunker temperature and pressure variation.

Table1. Range and mean of photon output for 6 and 15 MV.

Energy in MV	Output (cGy | MU)		Standard Deviation
	Range	Mean	
6.0	0.797 – 1.187	0.997	±0.02
15.0	0.786 – 1.174	0.828`	±0.03

MV= Mega voltage, cGy= Cent gray, MU= Monitor unit

Table 2. Range and mean of daily bunker temperature and pressure

Weather factors	Range	Mean	Standard deviation
Temperature (oC)	23.10 – 31.00	27.07	± 1.6
Pressure (hpa)	966.9 – 988.7	977.23	± 2.6

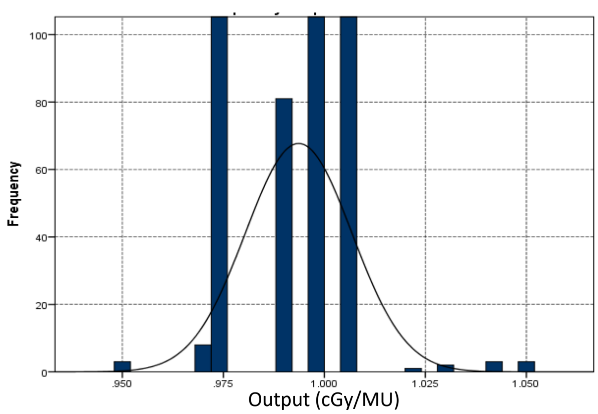

Figure 1. **Frequency distribution of 6MV photon output over the study period**

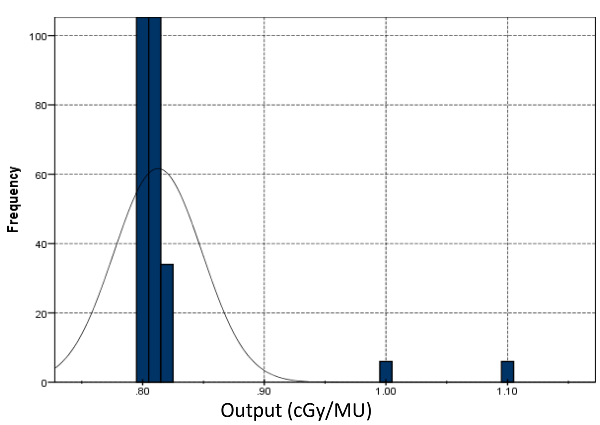

Figure 2. **Frequency distribution of 6MV photon output over the study period**

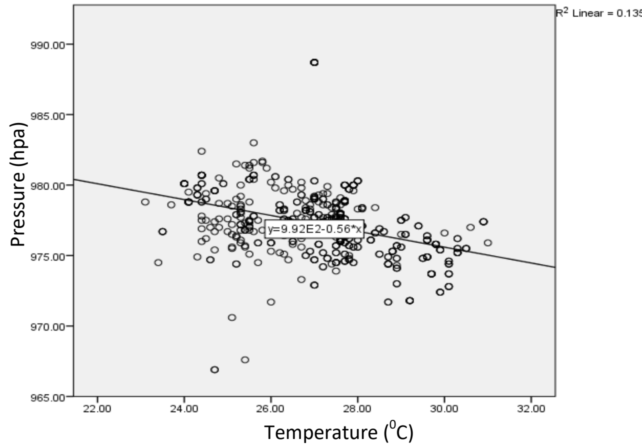

Figure 3. **Scattered plot showing correlation between bunker temperature and pressure**

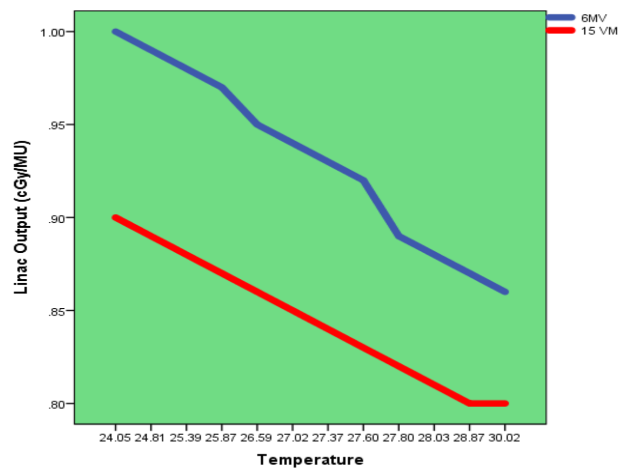

Figure 4. **Effect of temperature on photon output of 6 MV and 15 MV over the study period.**

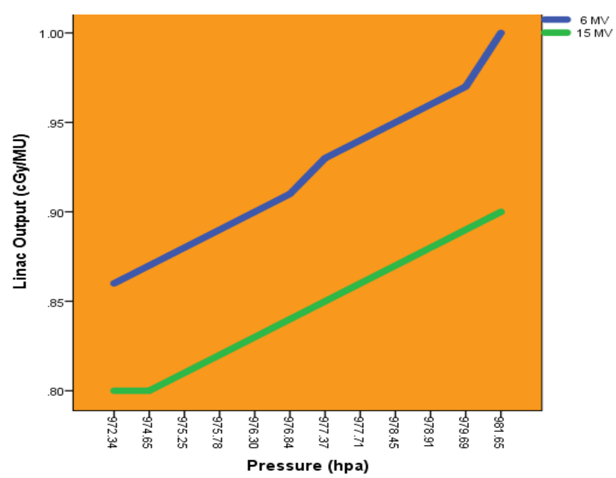

Figure 5. **Effect of bunker pressure on photon output of 6 and d 15 MV over the study period**

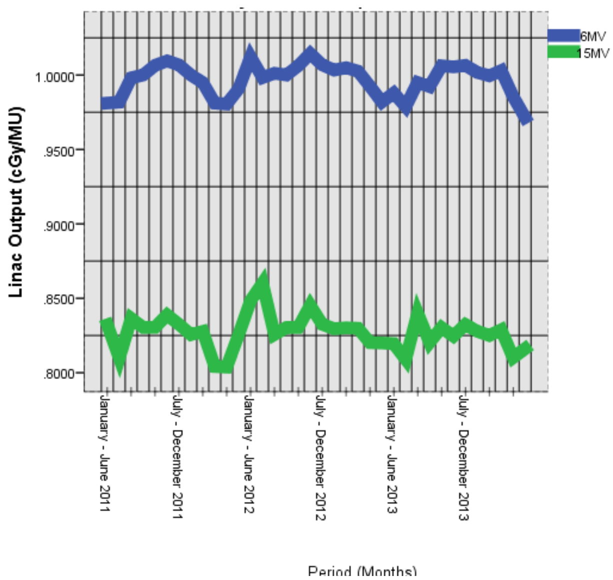

Figure 6. **Time history of photon output of 6 and 15 MV from Elekta precise LINAC**

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. Two observations were made for the LINAC photon outputs with respect to photon energies (6 and 15 MV) in table 1, first, the lower photon energy (6MV) in this study shows a high magnitude in 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 an increasing LINAC output with increasing photon energy [1]. Reasons responsible for these contradictory findings may be attributed to differences from the manufacturers of LINACs, different companies, device different technology for gun current supply to the target, in the case of Elekta precise machine the 6MV energy was found to have higher gun current supply than 15MV energy. This is not concordance with other LINACs like Varian Oncology, Palo Alto and CA produced by Varian Company. Secondly, we observed that the dispersions from the mean photon output of 6 and 15MV energies in this study were marginal, that is ± 0.02 and ± 0.03 respectively, and this indicates that the factors affecting the two photon energies were similar and strongly correlated. In figure 1, this study observed that the frequently recorded outputs for clinical use over the study periods were 0.975, 1.00, 1.005 and 0.995cGy/MU for 6 MV with near symmetrical distribution. Similar pattern were also seen for 15MV energy in figure 2, with 0.800, 0.810 and 0.820 cGy / MU as the frequent outputs. This shows that the time at which values are likely to deviate from the reference values can be predicted. Schultheiss et al. (1989) reported similar observations with normal distribution pattern that can predict the time interval for which the photon output deviate by a certain amount from the reference value if the probability of the distribution is known [14]. However, this study also observed that the outputs deviation from the commissioning data for 6 MV was only 0.3% and 0.2% for 15 MV. The reason for the marginal deviation is as a result of sealed ionization chamber found inside the dose checker that is being shielded from experiencing the maximum effect of daily temperature and pressure variation. Despite this marginal deviation, medical physicists have to maintain their daily QA since output deviation can also arise from LINAC itself and not restricted to only measuring devices.

The average annual environmental temperature in Sokoto where this study was conducted can be up to 21°C, however, during hot season the average monthly minimum temperature can be as high as 30°C while the mean maximum can reached 41.4°C and sometimes it can exceed up to 45°C [15]. This environmental temperature pattern was found to have a corresponding effect of bunker condition despite the presence of chillers. Gilgen R. in 1994 reported his observation on decreasing air density and pressure with rising temperature with resultant decrease radiation absorption by the dosimeters and this is in consistence with our findings [16], this is in consistent with our findings as demonstrated on the scattered plot.

The general trend in Figure 4 showed an inverse relationship between the LINAC output reading and increment of bunker temperature for both 6 and 15 MV. This shows that an increase in temperature might have a corresponding effect of decreasing the air density of dose checker despite its sealing effect. Previous report showed that decreasing effects in dosimeter reading following the temperature increment is ascribed to obvious decrement of air density [16]. This study, also observed that the 15MV response more to temperature variability compared to 6 MV, and this is demonstrated by the steep gradient of graph from 15 MV energy. The possible explanation for their differences in response to temperature might be linked to the gun current flow to the targets. The 6 MV energy gun current flow was observed to be higher than that of 15 MV and therefore more likely to resist the effect of increasing temperature on current flow to the gun, hence the lesser effect on the photon output with the resultant observed graphical pattern. The effect of pressure on the other hand was found to be positively correlated with photon output and this is due to the increment of air density in the cavity of dosimeter leading to increase radiation absorption, hence the observed higher dose reading. Due to this complex relationship of bunker temperature and pressure on photon output, a time history of daily Linac output of 6 and 15 MV photon beams were carefully studied over the study periods. The overall monthly photon outputs for the three years were plotted at six months intervals, the graph (figure 6) shows a noisy quasi-periodic behaviour that were characterised by rising and falling of photon output from the two energies. The simple explanation of graphs behaviour might be due to cumulative effect of daily changes of temperature and pressure on Linac and dosimetric devices together with complex role of seasons on temperature and pressure variability.

Conclusions

This study confirmed that daily variation of bunker temperature and pressure affect the photon output of LINAC despite the use of dose checker with sealed ionization chamber which required no temperature and pressure correction. Even though the photon outputs deviation from the reference values were marginal and within the acceptable limits of ±3%, the habits of daily quality audit by medical physicist should be maintained to avoid accumulation of minor deviations that can result to serious dosimetric errors.

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Abbreviations

LINAC: Linear accelerator; QC: Quality control.

Author Contributions

All authors contributed equally to this study and gave their final approval.

Competing Interests

The authors have declared that no competing interest exists.

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