COMPARISON OF DOSE MEASUREMENTS USING IONIZATION CHAMBER AND POINT DOSE FROM THE TREATMENT PLANNING SYSTEM AS A STRATEGY FOR THE LIMITED-RESOURCE CENTRES IN PATIENT-SPECIFIC QUALITY ASSURANCE

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Abstract— **When a verification plan is created, it generates a Monitor Unit (MU) which delivers a single fraction. The two-dimensional/three-dimensional (2-D/3-D) array detectors are suitable for performing Intensity Modulated Radiation Therapy (IMRT) / Volumetric Modulated Arc Therapy (VMAT) for Patient-Specific Quality Assurance (PSQA) as they check the fluence of entire fields. However, ionization chambers can play a significant role in the measurement of the point doses and absolute doses. The objective of this study was to compare the Dose measurement using an ionization chamber versus the Point dose in the treatment plan for Patient-Specific Delivery Quality Assurance in a Hypo-fractionated (HF) regimen.**

The mini-phantom made up of Perspex filled with water, marked with small pieces of the lead wire at the center and lateral sides were scanned with an ionization chamber placed inside of the hole at the mini-phantom. The scanned image was exported into the treatment planning system. The verification plans were mapped to the mini phantom that has been computed tomography (CT) scanned. The dose was measured at 100 cm Source-Axis Distance (SAD), at 5 cm depth. The sensitive volume of the chamber was marked and point dose measurements from the TPS were collected. The IMRT-HF plans of 33 patients were prepared after acquiring the CT dataset of each patient and their contours drawn. The verification plan was created using point dose measurements from the treatment plan. The point dose at the ionization chamber was measured based on the calculation of the TPS Analytical Anisotropic Algorithm (AAA). The measurement of the absolute dose of each patient was verified using an ionization chamber. The point dose measurements from the TPS were compared to the measurements of the absolute dose.

Median doses for measured dose by ionization chamber and TPS Point doses were 3.986±0.22Gy and 3.888±0.22Gy respectively. The minimum and maximum doses were (3.56 ±0.22Gy, 4.43±0.22 Gy) and (3.42± 0.22Gy, 4.32±0.22Gy) for measured and TPS point doses respectively. The mean doses measured by the ion chamber at 5cm depth and the point dose from the TPS were (3.9854 ±0.216) Gy and (3.8858± 0.229) Gy. The agreement in 90% of the measured dose and TPS point doses are in agreement within ±5% as recommended by the International Commission on Radiation Units and Measurements.

The agreement of the measured dose and point doses to within ±3 % suggests that the LMIC may utilize an ionization chamber for verification of the IMRT/VMAT plans.

Keywords— **Dose, treatment planning system, patient-specific quality assurance.**

I. INTRODUCTION

It has been found that in Low-Middle Income Countries (LMIC) such as Sub-Saharan Africa, there are limited resources for the treatment of cancer despite a gradual increase in new cases (Ngwa et al. 2020). It was suggested that the treatment decisions should consider increasing patient access to the treatment in the few radiotherapy equipment areas that are currently available (Ngwa et al. 2020). The novel solution proposed to use a hypofractionation regimen instead of conventional treatment (Ngwa et al. 2020) allows more patients to be treated at a given center. However, a hypofractionation regimen needs advanced radiotherapy planning such as Intensity Modulated Radiation Therapy (IMRT)/ Volumetric Modulated Arc Therapy (VMAT) which can allow dose escalation and reduce toxicity to the normal tissue (Zelefsky et al. 2000). It has been reported that the scarcity of 2D or 3D array detectors for patient delivery quality Assurance of IMRT/VMAT as among the challenges in the implementation of hypofractionation (Olatunji et al. 2023) in the HypoAfrica clinical trial. Patient-Specific Quality Assurance(PSQA) is a cornerstone in the radiotherapy

workflow especially when advanced techniques are involved (Stambaugh and Ezzell 2018). It helps to discover any discrepancies between the radiation dose that is calculated by the algorithm of Treatment Planning Systems (TPS) and the dose that is delivered by the radiotherapy machine (Moran et al. 2011). This step is important to ensure the safety and accuracy of radiotherapy delivery (Moran et al. 2011). Therefore, the study aimed to show a possible strategy for PSQA in a limited resource setting such hypofractionation regimens could be safely implemented using IMRT/VMAT: Measuring the absolute dose using a mini phantom and ionization chamber compared with the point dose calculated by the Algorithm of the TPS.

The objective of this study is to compare Point Dose measurement using an ionization chamber versus Point dose in the treatment Plan as a part of Patient-Specific Delivery Quality Assurance.

II. METHODOLOGY

The mini phantom marked with small pieces of lead wire at the center and lateral sides were scanned with a slice thickness of 5mm embedded with an ionization chamber placed in the central slot provided in the mini phantom as shown in Figure 1(a). The scanned image was imported into the treatment planning system. The verification plans were mapped to the mini phantom that has been computed tomography (CT) scanned. The dose was measured at a distance of 100 cm from the Source to Axis Distance (SAD), at 5 cm depth. The sensitive volume of the ion chamber was marked and point dose measurements from the TPS were collected. The IMRT-HF plans of 32 patients were prepared after acquiring the CT dataset of each patient with the required contours. The verification plans were created using point dose measurements from the treatment plan. The verification plans were attached to the mini phantom. The point dose at the ionization chamber was measured based on the dose to the calculation of the TPS algorithm as shown in Figure 1. Then the measurement of the absolute dose of each patient was verified using a cylindrical ionization chamber placed at 5 cm depth, Source-Surface Distance of 95 cm. Then the doses predicted by the TPS at the center of the ionization chamber were compared to the absolute dose measurements by the ion chamber. All treatment plans were delivered with the gantry at zero degrees. The reference point of the ion chamber was at the central axis of the beam and 5 cm depth. The ionization chamber was connected to the Electrometer and the correction of Temperature and Pressure was performed. The fundamental equation of absolute dose measurement from IAEA -TRS 398 (Oguchi 2012)was used.

$$D_{w,Q(Zref)} = M_Q K_{TP} N_{DWQ} K_{QQ_o} \quad \ldots\ldots 1$$

whereby $D_{w,Q(Zref)}$ is the reading of dose at a reference depth z_{ref}, M_Q is the amount of charges collected by the Electrometer from the ionization chamber positioned at Z_{ref}, K_{TP} Correction for influence quantities, Temperature, and Pressure. N_{DWQ} is calibration factor in terms of absorbed dose to water for a dosimeter at a reference beam quality Q. K_{QQ_o} Is a chamber-specific factor that corrects for the difference between the reference beam quality Q_o and the actual quality being used Q. When verification plans are created for either to be mapped by the Portal Dosimetry or the phantom, it uses a dose of a single fraction (3.10 Gy) with their corresponding Monitor Unit per each field. The dose measured using an ionization chamber is the dose expected to be uniformly distributed in the entire active volume of the ion chamber.

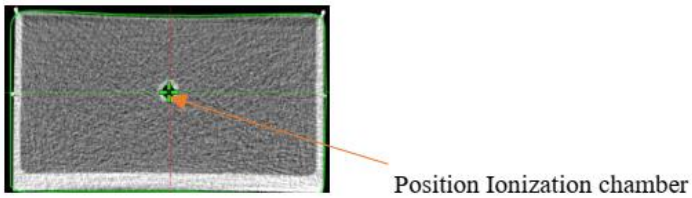

Figure1(a): The image of the mini phantom scanned before creation of verification plan

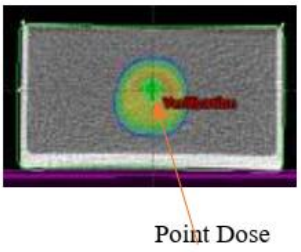

Figure 1(b): The image of the Mini-Phantom scanned Point of after creation of the verification plan

III. RESULTS

The boxplot (Figure 3) below summarizes the results of the study, the median doses for measured dose by ionization chamber and Point dose from the TPS were 3.986±0.22Gy and 3.888±0.22Gy. The minimum and maximum doses of measured and point doses from the TPS were (3.56 ±0.22Gy, 4.43±0.22 Gy) and (3.42± 0.22Gy, 4.32±0.22Gy) respectively. The average doses measured by the ion chamber at 5cm dept and the point dose from the TPS were (3.9854 ±0.216) Gy and (3.8858± 0.229) Gy respectively. Figure 4 shows the percentage deviation between measurement and prediction for all patients. Blue and orange trend lines show good agreement between the measured dose and the predicted TPS point dose. Figure 5(a) shows the relation between the Monitor Unit versus point dose and measured dose by ion chamber. The Figure 5(b) boxplot of the Monitor Unit used for verification of the plans.

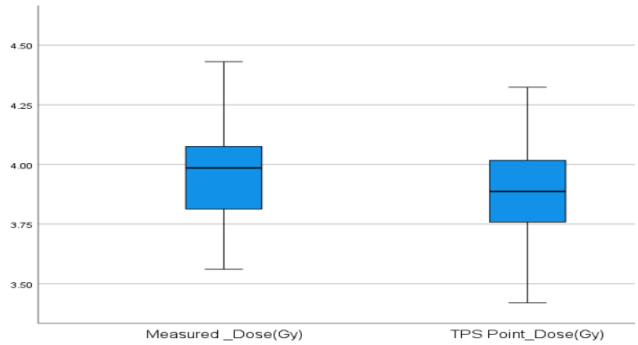

Figure 3. The boxplot of the dose Measured Ionization chamber and the TPS point dose

Table 1: Statistical information of the measurement

Parameter	Measured Dose (Gy)	TPS Point Dose (Gy)
Mean	3.9854	3.8858
Median	3.9856	3.8875
Mode	3.56	3.42
STD	0.21605	0.22936
Variance	0.047	0.053
Minimum	3.56	3.42
Maximum	4.43	4.32

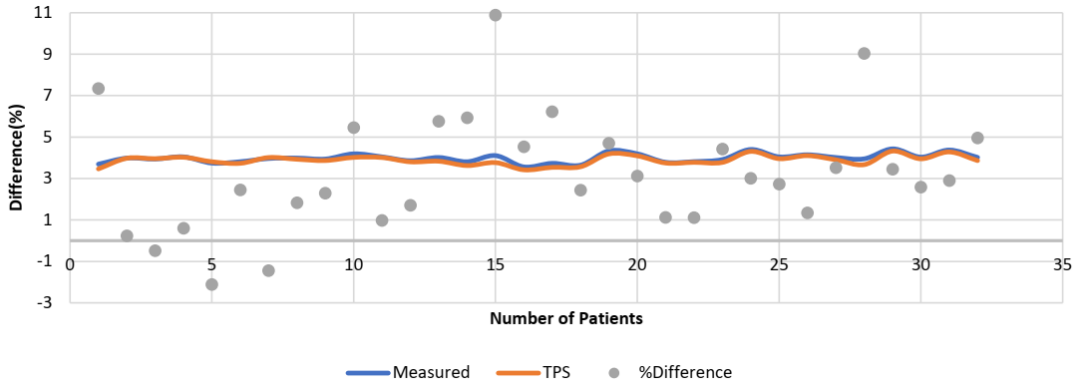

Figure 4: Agreement of the dose measured by an ionization chamber and TPS

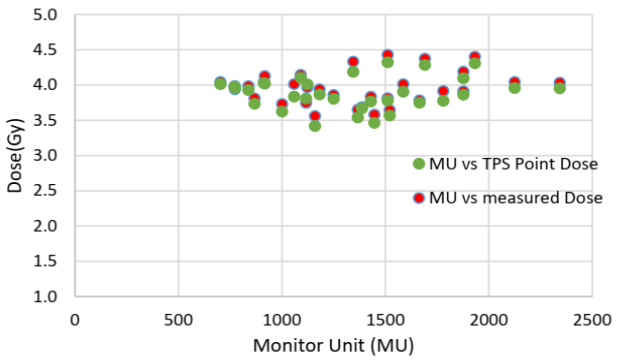

Figure 5(a): Relation between Monitor Unit and dose measured by ion chamber and point dose measurement

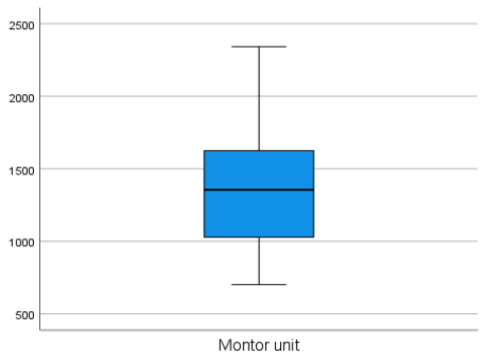

Figure 5(b): Shows the boxplot of the Monitor Unit used for verifaication of the plans

IV. DISCUSSION:

The dose measured by the ion chamber is not exactly a point dose as it is an averaged dose over several points within the chamber's active volume. 90% of the measured dose and TPS point dose are in agreement within ±5% as recommended by the International Commission on Radiation Units and Measurements. The 10% were not in agreement within ±5% may have contributed to the high-dose gradient around the point of dose verification. Therefore, lack of exact point dose in the TPS the average dose of several points around the verification point could be considered in the point dose measurement. Also, uncertainty in measuring temperature and pressure for correction of mass of air in the ionization chamber may contribute to 10% of the outliers in the selected sample. Since there is good agreement between the measurements performed by the ionization chamber and the ones calculated by the TPS algorithm, this method could be used for patient-specific Quality Assurance.

V. CONCLUSION

When a verification plan is created it generates MU which delivers a single fraction. The 2D/3D array detectors are suitable for performing IMRT/VMAT PSQA as they check the fluence of entire fields. However, the ionization chambers can play a significant role in the measurement of the point doses and absolute doses. The agreement of the measured dose and point doses suggests that the Low-Middle Income Countries (LMIC) may utilize an ionization chamber for verification of the IMRT/VMAT plans. Understanding the outliers could make this technique usable for future use in patient-specific QA in LMIC.

REFERENCES

Moran JM, Dempsey M, Eisbruch A, Fraass BA, Galvin JM, Ibbott GS, and Marks LB 2011 Safety considerations for IMRT: Executive summary. *Med. Phys.* 38 (9): 5067–5072.

Ngwa W, Addai BW, Adewole I, Ainsworth V, Alaro J, Alatise OI, Ali Z, Anderson BO, Anorlu R, Avery S, Barango P, Bih N, Booth CM, Brawley OW, Dangou J, Denny L, Dent J, Mutebi M, Nakaganda A, et al. 2020 The Lancet Oncology Commission Cancer in sub-Saharan Africa : a Lancet Oncology Commission. 23 (6): E251–E312.

Oguchi H 2012 [Change of absorbed dose determination in external beam radiotherapy (sequel)]. *Nihon Hoshasen Gijutsu Gakkai Zasshi* 68 (7): 906–910.

Olatunji E, Swanson W, Patel S, Adeneye SO, Aina-Tofolari F, Avery S, Kisukari JD, Graef K, Huq S, Jeraj R, Joseph AO, Lehmann J, Li H, Mallum A, Mkhize T, Ngoma TA, Studen A, Wijesooriya K, Incrocci L, et al. 2023 Challenges and opportunities for implementing hypofractionated radiotherapy in Africa: lessons from the HypoAfrica clinical trial. *Ecancermedicalscience* 17: 1–10.

Stambaugh C and Ezzell G 2018 A clinically relevant IMRT QA workflow: Design and validation. *Med. Phys.* 45 (4): 1391–1399.

Zelefsky MJ, Fuks Z, Happersett L, Lee HJ, Ling CC, Burman CM, Hunt M, Wolfe T, Venkatraman ES, Jackson A, Skwarchuk M, and Leibel SA 2000 Clinical experience with intensity modulated radiation therapy (IMRT) in prostate cancer. *Radiother. Oncol.* 55 (3): 241–249.

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