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ASSESSMENT OF KILOVOLTAGE PEAK (kVp) ACCURACY AND REPRODUCIBILITY TEST OF X-RAY MACHINES AS QUALITY ASSURANCE MEASURES IN ABUJA HOSPITALS, NIGERIA

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ABSTRACT

Background: Conventional radiography practices using X-rays have been a crucial radio-diagnostic tool for detecting internal organ ailments, malformations and disease conditions in humans and animals for many years. However, these practices are not without its challenges; overexposure to ionizing radiation due to machine factors is often neglected. Patients are often subjected to multiple X-ray examinations as their initial radiographs are rejected due to poor image quality, which can be because of overexposure or under exposure to the ionizing radiation.

Objective: This study was performed to evaluate the accuracy and reproducibility of kVp in X-ray machines installed in selected hospitals in Abuja as a measure to ensuring that the radiation doses selected are the ones delivered to patients.

Methodology: Data was obtained from FEZIKA LOGISTICS LTD, a company licensed by Nigeria Nuclear Regulatory Authority (NNRA) to conduct quality control (QC) test and provide Radiation Safety Advisory Services for Hospitals, Industries, and Oil and Gas Companies. A total of five hospitals were selected from the list of clients serviced by FEZIKA LOGISTICS LTD for this investigation. A Cobia Smart R/F semiconductor detector (model- CB3-19098461) calibrated to measure tube potential within the range of 50kV to 200kV was used. The detector was positioned at the center of the table, and the central ray of the X-ray beam was directed towards the meter, utilizing a focus-to-film distance (FFD) of 100cm. Values for kVp accuracy and Reproducibility were taken at different points and readings were obtained using calibrated kVp meter.

Results: The result for kVp accuracy for machines XM-1, XM-2, XM-3, XM-4 and XM-5 shows average percentage error of 1.83%, 1.83%, 2.03%, 3.03%, 1.29% and 2.40% respectively which are within the tolerance limit of ±5 % while the kVp reproducibility of the machines XM-1, XM-2, XM-3, XM-4 and XM-5 exhibit values of 0.39%, 0.32%, 1.64%, 0.10% and 0.07% respectively and these are also within the normal limit of tolerance of less than ±5%.

Conclusion: The results for kVp accuracy and reproducibility for the machines used for medical diagnosis in the hospitals in Abuja investigated were within normal limits.

Introduction:

The discovery of X-ray technology has been a significant advancement in the field of medicine, providing numerous benefits for diagnostic and therapeutic purposes. However, studies have shown that the use of radiation in medical procedures, particularly in diagnostic radiology, can pose some health hazards (4).

For instance, a study conducted in Delaware, USA, revealed that an average of 9% of radiographs taken had to be repeated due to poor equipment performance, which contributed to the rejection of the initial radiographs as cited in (1, 9). Similarly, in some Nigerian hospitals, equipment malfunctioning and human factors have been identified as contributing factors to the rejection or retake of radiographs (2). These situations not only expose patients to excess radiation but also incur extra costs for the hospital, leading to lost revenue.

To mitigate these risks, the International Commission on Radiation Protection has developed justification and optimization practices to minimize unusual exposure of patients due to machine error (2, 9).

Quality control measures, such as measuring and comparing actual quality performance with existing standards, have also become essential for machines used in radiological examinations. One of the critical parameters affecting both radiation exposure and image contrast is the tube peak kilo voltage (kVp). If the peak energy of the output beam is not accurate or reproducible, important details of the image can be lost, resulting in retakes and increased radiation exposure for the patient. Therefore, it is crucial to ensure that the exposure is made at the same kVp to minimize the risks associated with radiation exposure (9).

To ensure that the right and accurate radiation doses selected are the ones delivered, it is essential to assess the accuracy and reproducibility of kVp as a measure to ensuring that the radiation doses selected are the ones delivered to patients. This quality assurance measure is crucial to maintaining the radiation safety of patients, healthcare workers and the general public.
The aim of this study was to evaluate the accuracy and reproducibility of radiation exposure factors especially the selected kVp in X-ray machines installed in various hospitals in Abuja, Nigeria.

2.0 Materials and Method

2.1 X-ray Unit

This work was carried out in five hospitals in Abuja, Nigeria that have NNRA authorizations and included five X-ray units from the centres thereafter refereed as: XM-1, XM-2, XM-3, XM-4 and XM-5 as indicated in Table 1. The centres were chosen based on the significant number of X-ray examination performed regularly.

Table 1: Specification of X-ray machines in the selected centres

X-ray Unit	Manufacturer	Type of machine	Serial No	Model	Year of Manufacture	Country of manufacture
XM-1	GE GENERAL ELECTIRC	Mobile X-ray	20897ED5	AMX4 XFMR	07/1995	CHINA
XM-2	PHILIPS	Mobile X-ray	SN11000060	PRACTIX 360	02/2011	GERMANY
XM-3	GULFEX MEDICAL & SCIENTIFIC	Floor Mounted	20043006	XM-300	04/2020	CHINA
XM-4	GE HAULUN MEDICAL SYSTEM	Floor Mounted	143603BC9		10/2018	CHINA
XM-5	TOSHIBA DIGITAL JAPAN	Floor mounted	8H01410	TOSHIBA ROTANO DE	08/2018	JAPAN

2.2 Data Collection

Data was obtained from **FEZIKA LOGISTICS LTD**, a company licensed by Nigeria Nuclear Regulatory Authority **(NNRA)** to conduct quality control (QC) test and provide Radiation Safety Advisory Services for Hospitals, Industries, and Oil and Gas Companies. A total of five hospitals were selected from the list of clients serviced by **FEZIKA LOGISTICS LTD** for this investigation.

A Cobia Smart R/F semiconductor detector (model- CB3-19098461) calibrated to measure tube potential within the range of 50kV to 200kV was used. The detector was positioned at the center of the table, and the central ray of the X-ray beam was directed towards the meter, utilizing a focus-to-film distance (FFD) of 100cm. To ensure accurate measurements, the X-ray field was collimated in such a way that it slightly exceeded the size of the meter in order to cover the circular part of the meter, marked with a cross sign. A total of five exposures were conducted using a constant value of 20mAs. Following these exposures, the kVp was systematically adjusted in increments of 10 kVp, ranging from 60 to 100 kVp. At each specific kVp setting on the control panel, the corresponding measured kVp value was meticulously recorded. It is important to note that after each exposure, the meter was reset to zero to ensure accurate subsequent readings.

2.3 Parameters and Calculating of Percentage Average Error

The recorded readings obtained from this experimental setup were then utilized to determine the percentage error associated with the accuracy of the tube potential. This determination was made using equations (1) and (2), which were specifically designed for this purpose. By analyzing the percentage error, valuable insights can be gained regarding the precision and reliability of the tube potential measurements.

$$\text{Percentage kVp error} = \frac{Vo - Vs}{Vs} \times 100\% \quad \ldots\ldots (1)$$

Vo = measured value

Vs = the dial value

kVp = peak kilo voltage

$$\text{kVp reproducibility} = \frac{\text{kVp}\,max - \text{kVp}\,min}{\text{kVp}\,max + \text{kVp}\,min}\, x100\% \quad \ldots\ldots (2)$$

3.0 Results and Discussion

Table 2 presents the result for kVp accuracy and percentage (%) errors in the selected five machines in the five centres. The dial kVp is the kVp set on the machine, while the measured kVp is the result recorded on the meter after exposure. The dial kVp was the same for the five machines and ranged from 60 to 100 while the measured kVp and the % error for the five machines varies. The measured kVp ranged from 61.30 to 98.65, 58.35 to 98.80, 56.25 to 98.55, 60.45 to 98.10 and 58.45 to 98.25 for machines XM-1, XM-2, XM-3, XM-4 and XM-5 respectively while that of % errors ranged from 0.50 to 2.56 with average % error of 1.83, 1.20 to 2.75 with average % error of 2.03, 1.08 to 6.25 with average % error of 3.03, 0.75 to 1.94 with average % error of 1.29 and 1.75 to 3.16 with average % error of 2.40 for machines XM-1, XM-2, XM-3, XM-4 and XM-5 respectively. Hence, the evaluated values of the kVp accuracy for the five selected machines using equation 1 are 1.83, 2.03, 3.03, 1.29 and 2.40 for XM-1, XM-2, XM-3, XM-4 and XM-5 respectively and this indicated that all the machines fall within the recommended limit ±5% by International Commission on Radiological Protection (ICRP) recommendation for the safe exposure of patients (6,7).

The results of kVp reproducibility using equation 2 for the selected five machines when the kVp was constantly set at 70kVp are presented in Table 3 and the calculated values of the kVp reproducibility for the five selected machines are 0.39%, 0.32%, 1.64%, 0.10% and 0.07% for XM-1, XM-2, XM-3, XM-4 and XM-5 respectively and it also indicated that XM-1, XM-2, XM-3, XM-4 and XM-5 have kVp reproducibility within normal limit which is less than the tolerance 5% (6,7).

Furthermore, the kVp output of an X-ray machine at a given setting must be accurate and reproducible. A graphical plot of the dial kVp against the measured kVp for the selected five machines XM-1, XM-2, XM-3, XM-4 and XM-5 are given in Figures 1, 2, 3, 4 and 5 respectively and they all indicated accuracy in the kVp as they fall below tolerance level of ±5%.

This could be attributed to the fact that the selected centres where this research was carried out on these five machines are under the regulatory control of Regulatory Body and hence regulatory standard such as quality control test carried out on the machine are up to date and also designation of Radiation of Safety Officer who ensures standard operating procedures are followed is done.

Table 2: kVp Accuracy and % Error (20mAs) for machines XM-1, XM-2, XM-3, XM-4 and XM-5

XM-1		XM-2		XM-3		XM-4		XM-5	
Measured kVp	% Error	Measure d kVp	% Error	Measure d kVp	% Error	Measur ed kVp	% Error	Measur ed kVp	% Error
61.30	2.17	58.35	2.75	56.25	6.25	60.45	0.75	58.45	2.58
69.65	0.50	68.35	2.36	68.65	1.08	68.95	1.50	68.50	2.14
77.95	2.56	78.25	2.19	77.55	3.06	79.70	0.37	78.10	2.38
87.70	2.56	88.50	1.67	87.00	3.33	88.25	1.94	87.15	3.16
98.65	1.35	98.80	1.20	98.55	1.45	98.10	1.90	98.25	1.75

Table 3: kVp reproducibility for machines XM-1, XM-2, XM-3, XM-4 and XM-5

mAs	Recorded kVp XM-1 (at 70 kVp)	Recorded kVp XM-2 (at 70 kVp)	Recorded kVp XM-3 (at 70 kVp)	Recorded kVp XM-4 (at 70 kVp)	Recorded kVp XM-5 (at 70 kVp)
	69.10	68.20	67.30	69.85	68.15
	69.25	68.50	68.50	69.90	68.20
	69.30	68.05	67.95	69.80	68.20
	68.85	68.05	68.50	69.95	68.20
	68.75	68.50	69.55	69.95	68.25

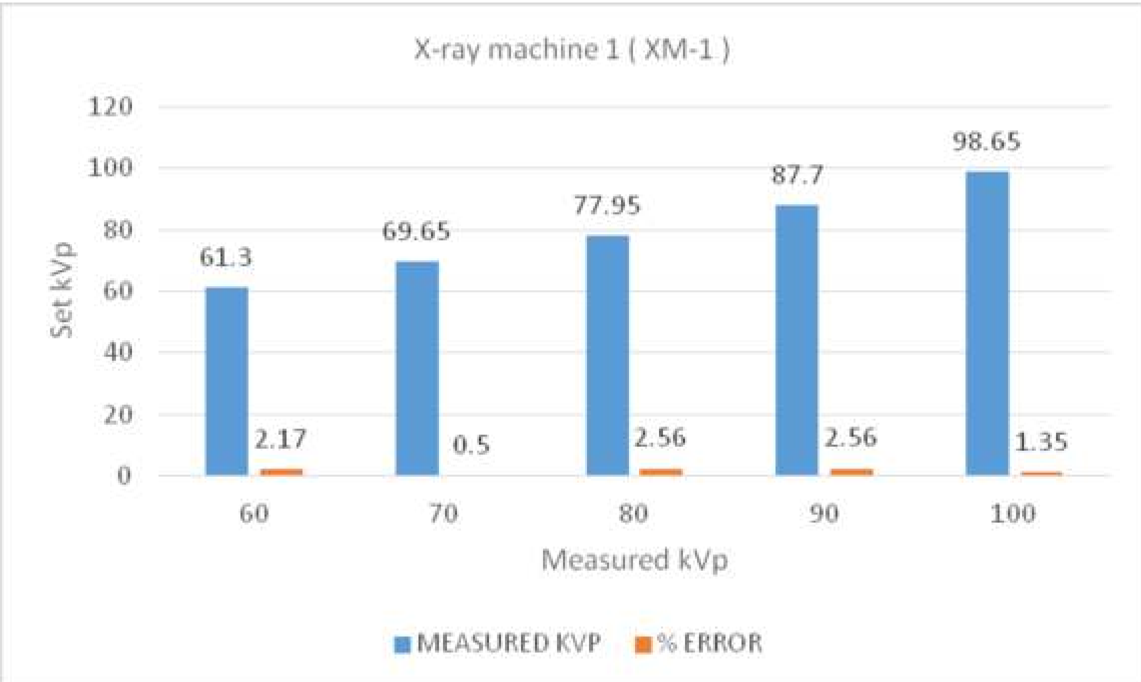

Figure 1: A bar chart of the dial kVp with measured kVp for XM-1

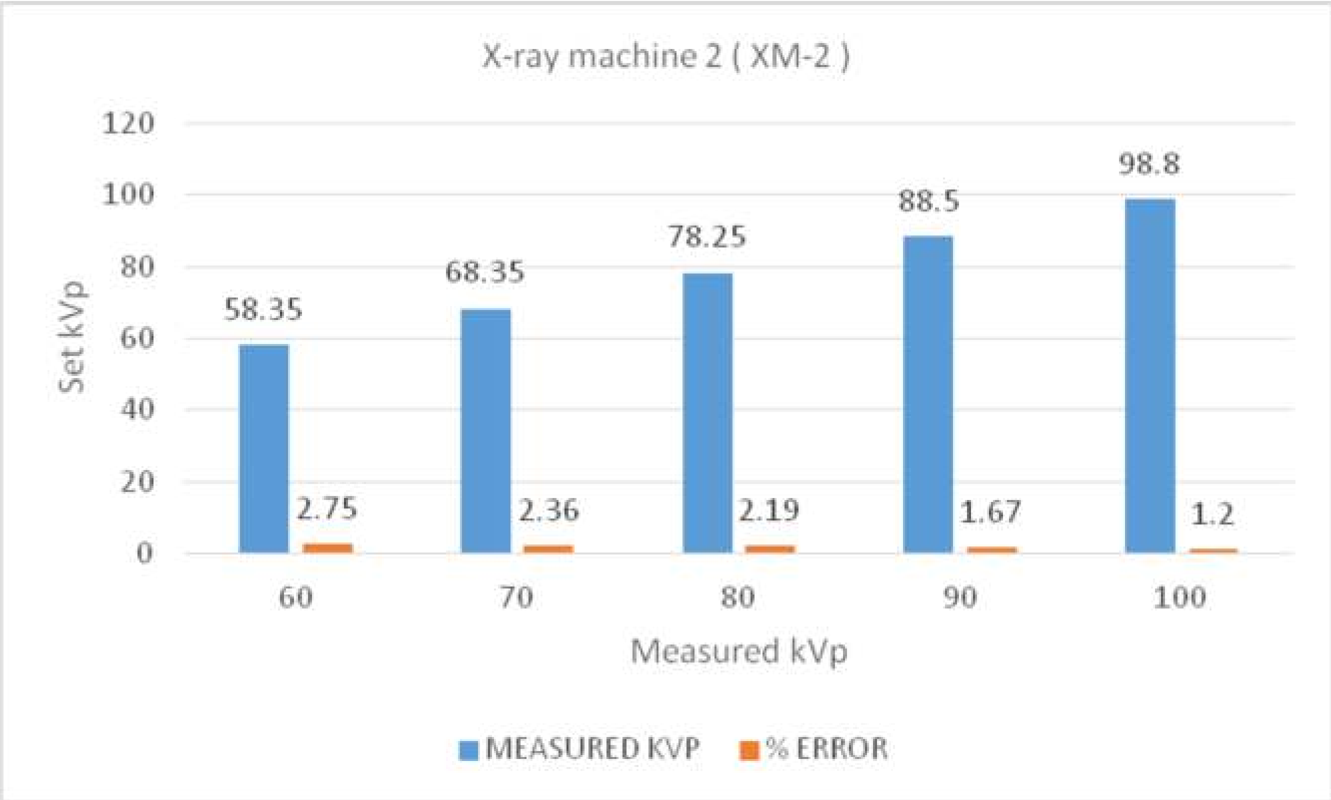

Figure 2: A bar chart of the dial kVp with measured kVp for XM-2

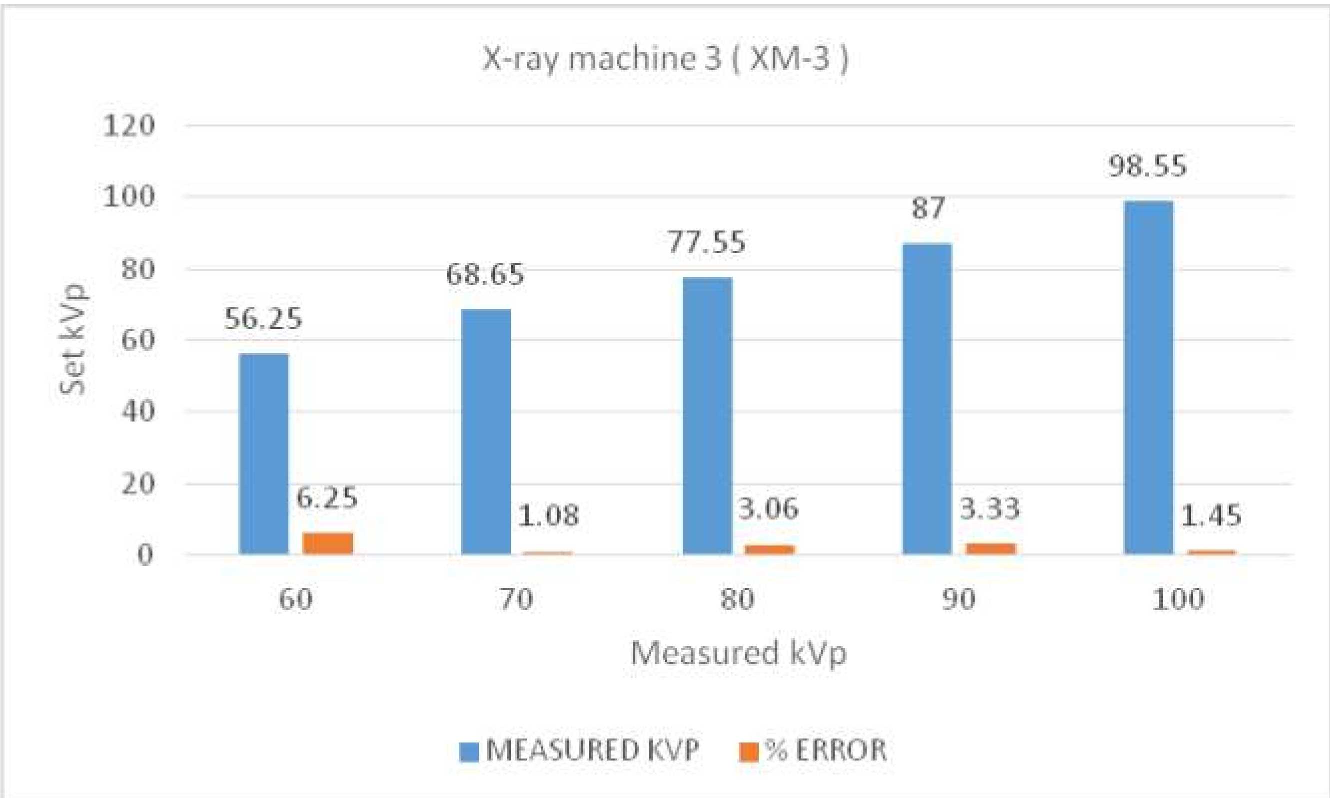

Figure 3: A bar chart of the dial kVp with measured kVp for XM-3

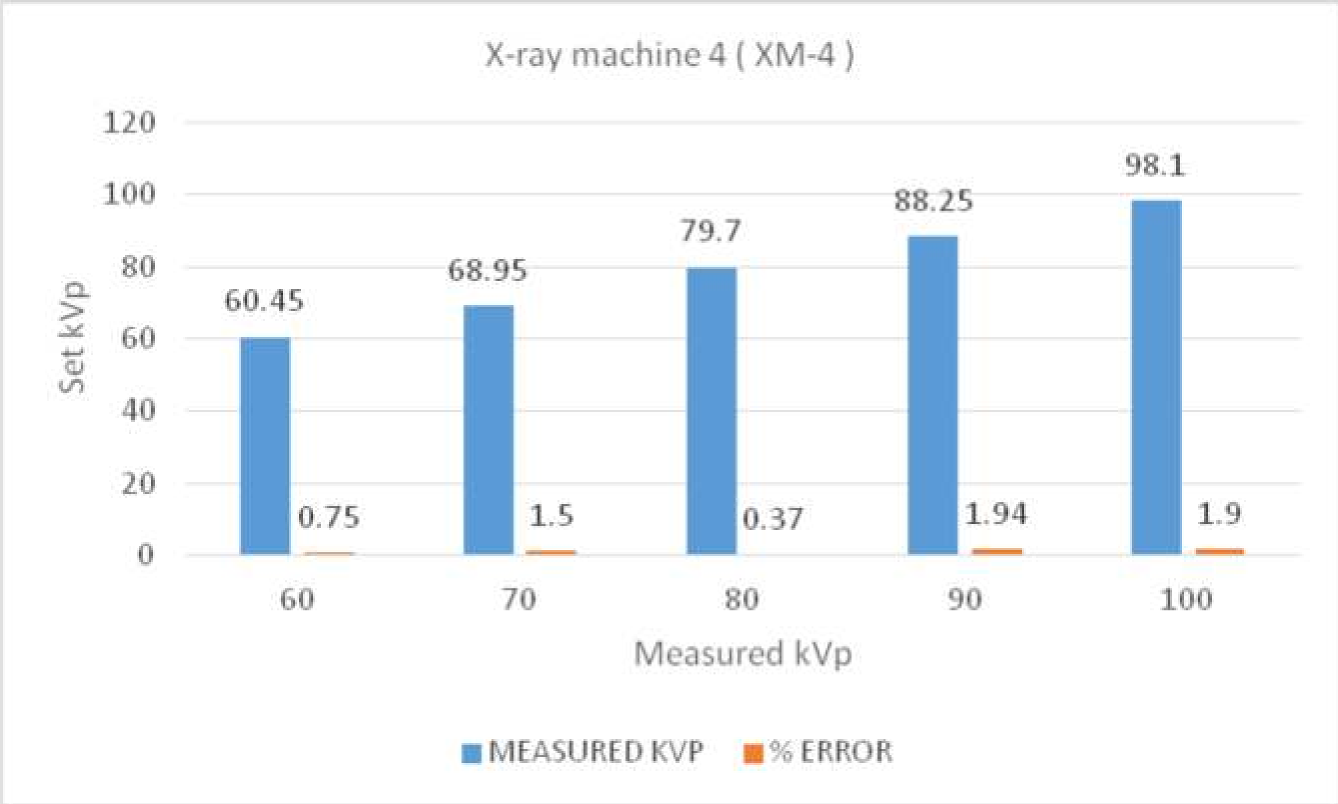

Figure 4A bar chart of the dial kVp with measured kVp fo

4. Conclusion

The results for kVp accuracy and reproducibility for the machines used for medical diagnosis in the hospitals in Abuja investigated were within normal limits.

References

1. Atkinson, S., Neep, M., & Starkey, D. (2020). Reject rate analysis in digital radiography: an Australian emergency imaging department case study. Journal of medical radiation sciences, 67(1), 72-79.

2. Do, K. H. (2016). General principles of radiation protection in fields of diagnostic medical exposure. Journal of Korean medical science, 31(Suppl 1), S6-S9.

3. Fezika logistics limited, Quality Control/quality assurance X-ray machine data: 2023

4. Frane, N., & Bitterman, A. (2020). Radiation safety and protection.

5. Godfrey, L. D., Adeyemo, D. J., & Sadiq, U. (2015). Radiological kVp accuracy, reproducibility and consistence assessment of some hospitals in Zaria environs of Kaduna state, Nigeria. Arch Appl SciRes, 7, 27-31.

6. Hall, T. J. (2003). AAPM/RSNA physics tutorial for residents: topics in US: beyond the basics: elasticity imaging with US. Radiographics, 23(6), 1657-1671

7. López, P. O., Dauer, L. T., Loose, R., Martin, C. J., Miller, D. L., Vañó, E., ... & Yoder, C. (2018). ICRP publication 139: occupational radiological protection in interventional procedures. Annals of the ICRP, 47(2), 1-118.

8. Odoh, E. O., Umaru, A ., Isa, S., Muhammad, I. (2022). Assessment of KVP Accuracy and Reproducibility as Radiation Protection. Measures in Tertiary Hospitals in Yola, North-East Nigeria." Nigerian Journal of Medical Imaging and Radiation Therapy. Vol. 11.

9. UNSCEAR,. "Sources, effects and risks of ionizing radiation." United Nations Scientific Committee on the Effects of Atomic Radiation, Report to the General Assembly (1988).