Assessment of peak voltage accuracy and reproducibility of conventional X-radiography units in Palestine

Mohammad Hjouj*
Department of Medical Imaging / Faculty of Health Professions /Al-Quds University – Jerusalem

Deema Budeiri
Department of Medical Imaging / Faculty of Health Professions /Al-Quds University – Jerusalem

Sara Abu Khalaf
Department of Medical Imaging / Faculty of Health Professions /Al-Quds University – Jerusalem

Deana Jaghama
Department of Medical Imaging / Faculty of Health Professions /Al-Quds University – Jerusalem

Abrar Rajabi
Department of Medical Imaging / Faculty of Health Professions /Al-Quds University – Jerusalem

ABSTRACT

Introduction: All components of diagnostic X-ray system must be committed to a periodic quality control program, in order to achieve accurate and quick diagnosis and low radiation dose to patients, which is the real purpose of medical imaging.

Aim and objectives: the main objective of this study is to determine voltage (V) accuracy and reproducibility for the individual diagnostic X-ray units, as well as evaluate if the X-ray units age and average daily load have significant correlation on mean kVp accuracy.

Materials and methods: In this experimental study, kVp accuracy and reproducibility tests were performed on 12 conventional X-radiography units (A-1_H-1) in 3 cities in Palestine, which, the tests were conducted according to the relevant acceptance limits recommended by the American Association of Physicists in Medicine (AAPM), using the multiple-purpose analyzer the Radcal Accu pro (model: 9096).

Results: The findings revealed that 11 of X-ray units passed the kVp accuracy test (91%), and all the evaluated X-ray units passed the kVp reproducibility test, and there was a weak statistically significant relationship between X-ray unit age and mean kVp accuracy p-value = 0.008, while there was no significant relationship between the Average daily load and the mean kVp accuracy p-value = 0.238

Conclusion: kVp accuracy and reproducibility test are not performed in most of the evaluated X-ray units, while enhancement the performance of quality control programs will lead to a higher degree of professionalism, However Machine age appears to have a major impact on kVp accuracy.

*correspondence author: mhjouj@hotmail.com, mhjouj@staff.alquds.edu

DMIP 2022, November 10–13, 2022, Kyoto, Japan

ACM ISBN 978-1-4503-9764-3/22/11.
https://doi.org/10.1145/3576938.3576947

KEYWORDS

quality control, Diagnostic x-ray units, kVp accuracy, kVp reproducibility

ACM Reference Format:
Mohammad Hjouj, Deema Budeiri, Sara Abu Khalaf, Deana Jaghama, and Abrar Rajabi. 2022. Assessment of peak voltage accuracy and reproducibility of conventional X-radiography units in Palestine. In *2022 5th International Conference on Digital Medicine and Image Processing (DMIP 2022), November 10–13, 2022, Kyoto, Japan.* ACM, New York, NY, USA, 8 pages. https://doi.org/10.1145/3576938.3576947

1 INTRODUCTION

1.1 Historical Background

Medical imaging is a key component of the entire continuity of healthcare, and medical imaging is a critical tool in disease detection and treatment tracking. Since Wilhelm Conrad Roentgen discovered X-ray in November 1895 while he was using a vacuum tube to study the cathode rays (electrons) and he noticed when wrapping the tube with black paper a glimmer of light on a fluorescent screen across the room , he concluded the present of unknown and invisible rays which have the ability to penetrate the black paper wrapped around the tube [1] , Roentgen observed that the transmitted x-rays can sensitize a photographic film to produce a visible image. Indeed, Roentgen obtained the first radiographic image of his wife's hand. Roentgen was awarded the first Nobel Prize for Physics for his discovery of x-rays. In the years following, physicists found that x-rays were just a new member of the electromagnetic spectrum, a term used to describe many types of radiation. An immediate well-known application of x-rays in the medical field was the conventional x-ray imaging, which is made by allowing the x-rays to diverge from a source, pass through the body of the subject, and then fall on a sheet of photographic film . Later, Radon's Theory was employed as a mathematical tool, [2-5] develop the Computed tomography (CT), which allows for complete exclusion of sections not under study. Since then, many modalities of medical imaging as well as imaging for other fields were invented includes, magnetic resonance imaging (MRI), Angiography, digital rock physics and image processing, [6-12].

1.2 Background and Significance

According to the Palestinian ministry of health a previous study concerning medical imaging procedures conducted in 2020 showed that conventional radiography images were 488.027 (75%) , Computed Tomography 92.796(14%) ,ultrasound 48.298 (8%) and magnetic resonance imaging 18.213 (3%) ,[13].

The study also concluded that conventional X-ray radiography is the most used imaging modality in Palestine, and according to the ALARA (As Low as Reasonably Achievable) principle , conventional X-ray examinations should produce images containing precious diagnostic information while using the least amount of radiation possible ,[14]. , to accomplish this purpose a full attention should be given to the quality control programs inside the medical imaging department , The results of several studies demonstrated the positive effect of quality control of radiology equipments in Hospitals in Sistan and Baluchistan province, and showed that quality control programs would improve image quality and reduce the patient's absorbed dose. [15].

To ensure optimal performance of x-ray equipment, exposure optimization requires the establishment of quality assurance (QA) and quality control (QC) programs. The main purpose of quality assurance is to ensure that all components of the radiography equipment's are maintained and their performance is in accordance with the applicable quality standards [16]. One of these major components of radiographic equipment is the X-ray tube, the purpose of the X-ray tube is to produce X-ray photons spectrum using electrical energy provided by the X-ray generator. Several factors influence X-ray emission most notably X-ray tube voltage and X-ray tube current [17].

Tube voltage – measured in Kilo voltage (kV) and tube current and exposure time product – measured in milliamp second (mAs) are the basic settings of x-ray equipment that can be modified to manage image quality and patient dose. Peak voltage which refer to the highest value of the tube voltage during an exposure [18]., its function is to accelerate electrons from the cathode (negatively charged)to the anode (positively charged) in the X-ray tube in modalities utilizing X-ray photons [19]. , The speed at which electrons travel and hit the anode is affected by the high voltage between the cathode and the anode , The higher the kV the faster the electrons and therefore the more energy the electrons have. So producing x-rays with greater penetrating energy. the milliampere (mA) setting on control console control the filament temperature , higher filament temperatures will result in a larger stream of electrons that hit the anode , therefore mA is responsible on the quantity of X radiation [20].

Beside the subject density, thickness and atomic number Radiographic contrast is dependent on the technical factors used , Kilo voltage Peak kVp is the primary controlling factor of contrast , it will determine the energy of the primary beam , When increasing the energy ,it will cause more penetrating power and less absorption of the primary beam (Lower attenuation differences) and a long scale contrast which means the difference in densities is very small and many shades of gray are presented so produce lower contrast radiograph , but using low kVp means lower penetrating power of the primary beam with short scale contrast and a greater difference in attenuation between the different subjects [21] , while the product of tube current and exposure time (mAs) is the primary control of image density doubling , mAs will double the radiographic image density .

When the suitable kVp and mAs values are chosen, a final accurate radiograph can be achieved and selected exposure factors can only be precise if the X-ray machine is optimum performance, therefore the aim of this present paper is to assess some exposure parameters of conventional X-ray units such as kVp accuracy, kVp reproducibility and mA linearity. Previous studies pointed to the dereliction in performing these routine maintenance checks and quality control tests this is partly due to the lack of skilled employees, but primarily to the flaws in the guidelines and the lack of proper equipment for QC test [22, 23].

2 RESEARCH QUESTION

- What Percentage or the number of X-ray units that pass the kVp accuracy/reproducibility tests according to a relevant acceptance limit?
- How many radiographic departments perform kVp accuracy/reproducibility tests annually?
- Is there a significant correlation between X-ray unit age/average number of acquired images per day and average kVp accuracy?

3 RESEARCH OBJECTIVES

The main objectives of this study were:

- To evaluate exposure parameters of conventional X-ray units, including kVp accuracy and reproducibility according to relevant acceptance limits, and to evaluate X-ray equipment performance in the Palestinian health system.
- To determine whether radiographic departments perform quality control testing such as kVp accuracy/reproducibility annually.
- To assess whether X-ray unit age and daily X-ray tube load have a statistically significant relationship with the kVp accuracy test.

4 MATERIALS AND METHODOLOGY:

The current experimental study was carried out during March and April 2022 in twelve Radiology departments including: seven conventional X-ray radiography units in three public hospitals referred as (A, B and C) which considered as high load radiology departments , and five private radiology department (referred as D, E, F, G, H). Selected Radiography equipment underwent kVp accuracy and reproducibility tests. The study was conducted in three major cities in Palestine (Ramallah, Hebron and Bethlehem) to achieve the aim of this study. Technical characteristics that may affect the optimum performance of the kVp parameter were collected for each equipment in table (Table 1), and other information that may have an effect in the parameter's readings were collected in (Table 2).

kVp was measured using the Radcal Accu pro (model :9096) a multi-purpose x ray analyzer which is a member of the Accu family instruments (Figure:1) that provide measurements of the characteristics of a diagnostic x-ray machine, which used for Radiography, Fluoroscopy, Mammography, CT, and Dental measurements. The

Figure 1: the Radcal Accu pro

Figure 2: Experimental setup of the X-ray unit and acuu pro meter

dose from the X-ray tube measured with ion chambers or diode-dose of sensors connected directly to a digitizer-electrometer and Radcal Accu-kV sensors determine kV using an array of solid-state detector.

Tests were carried out by placing the Radcal Accu pro at the center of the X-ray beam at distance (SID)=100cm (Figure: 2), 100 cm was selected because it’s a common distance used in most conventional radiography studies.

The kVp accuracy test evaluate if the kV set of the control panel deliver the same amount of voltage through the tube, The kVp accuracy test was performed on twelve x-ray unit by using a constant 20 mAs with a series of growing kVp (60,80,100,120), readings were repeated three times and the average measured kVp was recorded, then the kVp accuracy for each device was calculated using:

$$\mathrm{k}Vp\ accuracy\ =\ \frac{measured\ Kvp - selected\ Kvp}{Selected\ Kvp}\ x100\%$$

kVp reproducibility test was performed on all X-ray units, to measure the ability of the X-ray generator to faithfully deliver the same output when the same exposure factors are used, 3 consecutive measurements at the same SID (100cm), and fixed mAs (20) and a fixed kVp. Then the kVp reproducibility for each device was calculated using:

$$kVp\ reproducibility = \frac{Kvp\ max - Kvp\ min}{Kvp\ \mathrm{max} + Kvp\ min}\ x100\%$$

According to the American Association of Physicists in Medicine [24], The kVp accuracy and reproducibility tests must be within ±5% , result which is < ±5% is termed “Acceptable” while any result which is ≥ ±5% is termed “Not acceptable

The Statistical Package for the Social Sciences (SPSS version 23) was used to determine the statistically significant relationship between X-ray unit age/average number of Images per day and mean kVp accuracy. This was done by relying on the p-value obtained using the bivariate Pearson Correlation whose role is to determine if there is a linear relationship between two continuous variables and measure the strength and direction of the linear relationship.

P-value below 0.05 will indicate to reject the null hypothesis (there is a significant relationship), p-value above 0.05 indicate to accept the null hypothesis (there is no significant relationship).

5 RESULTS

Seven governmental X-ray units and five private X-ray units were included in the kVp accuracy and reproducibility tests , and according to (Table 2), kVp accuracy and reproducibility test are not performed in most of the evaluated X-ray units Unless the units require repairing ,Technical characteristics for each unit was presented in (Table 1) , which show that The X-ray units age from the manufacture year to the year when the study was conducted ranged between 1-24 years , and the Average number of images per day which indicate the daily load for the X-ray units ranged between 1-300 Images , the kVp accuracy and reproducibility test for each device shown in (Table 4), this table includes the selected tube voltages ,measured tube voltages and the magnitude of deviations for the kVp accuracy and reproducibility tests , the mean kVp accuracy which presented as mean ± standard deviation for as shown in (Table 3).

The maximum magnitude of deviation for the kVp accuracy test was noticed in H-1 whose machine age was 18 years old and with average daily load 40 image at kVp=100 magnitude of deviation for the kVp accuracy test was 13.1 % and the measured tube voltage was 113.1 which indicate that H-1 fail the kVp. accuracy test according to the (AApm) it’s the only X-ray unit that fail to pass the relevant acceptance limits for the kVp accuracy test in this study, also as shown on (Table 4) the minimum magnitude of deviations for the kVp accuracy was noticed in B-2 which is the youngest X-ray unit.

G-1 which is the oldest X-ray unit in this study (24 years old) pass the kVp accuracy and reproducibility test with magnitude of deviation for the kVp accuracy test >4% at kVp =60,80,100 and with mean kVp accuracy = 3.925 although C-1 have the highest daily load (300 image per day) the unit pass the kVp accuracy test with magnitude of deviation for the kVp accuracy test <3% and by paying close attention at two X-ray units which are (A-3 and C-1) both X-ray units have the same age also the same manufacture and both of them have recently manufactured as shown in (Table 2) ,and although C-1 have a higher Average daily load than A-3 , it have a lower mean kVp accuracy as indicated in (Figure 3) , also variation between selected and average measured kVp in five selected X-ray units is represented in (figure 4).

And by using the bivariate Pearson Correlation test (spss version 23) there was a weak statistically significant relationship between the X-ray unit age and the mean kVp accuracy test (p-value =0.008)

Table 1: Technical characteristics of the evaluated x-ray units

Hospital Number of the device	Manufacture	Year of manufacture	Year of instillation	Maximum kVp	Maximum mAs	Generator type
A-1	Shimadzu	2016	2016	150	800	3 phase generators
A-2	Shimadzu	2010	2010	150	800	3 phase generators
A-3	Shimadzu	2016	2016	150	800	3 phase generators
B-1	Shimadzu	2016	2017	150	800	3 phase generators
B-2	Radiologia	2021	2021	150	125	3 phase generators
C-1	Shimadzu	2016	2016	150	630	3 phase generators
C-2	Care stream	2014	2014	150	504	3 phase generators
D-1	Bennett	2008	2008	120	250	1 phase generator
E-1	JPI healthcare	2018	2019	125	500	3 Phase generators
F-1	RAD-12	2002	2002	150	630	-
G-1	Gendex -Del	1998	1998	125	509	1phase generator
H-1	RAD-12	2004	2004	150	630	-

Table 2: : Specific information about the X-ray units

Hospital-Number of the device	Average number of images per day	How often X-ray tube checked	Has the tube recently manufactured? (yes /No)	Dose the kVp accuracy/reproducibility tests perform annually? (yes/No)
A-1	100	2 months	Yes, one month ago	No
A-2	45-50	10 years	Yes year ago	No
A-3	250	2 months	Yes, few months ago	No
B-1	80	When a defect happens	Yes 2 years ago	No
B-2	80	Never	No	No
C-1	300	4-6months		No
C-2	1		No	No
D-1	20	When a defect happens	No	No
E-1	10	Never	No	No
F-1	25	Never	No	No
G-1	15	Never	Yes	No
H-1	40	Never	No	No

and Pearson r = 0.379, while there was no significant relationship between Average number of images per day and kVp accuracy test p-value =0.238 because it's above the threshold of significance p-value >0.05.

Also, according to (Table 4) all the X-ray units pass the kVp reproducibility test and meet the relevant acceptance limits.

6 DISSCUSION

A study to determine the kVp accuracy and reproducibility test for 12 diagnostic x-ray units was conducted in three cities in Palestine. Generally, a total of 11 X-ray machine (A-1, A-2, A-3, B-1, B-2, C-1, C-2, D-1, E-1, F-1, G-1) passed the kVp accuracy test at all selected Kilo voltage peaks and were tagged "Acceptable" , they were within the relevant acceptance limits which is < ±5% , while (H-1) failed the kVp accuracy at 100 kVp , In a similar study conducted in Lagos,

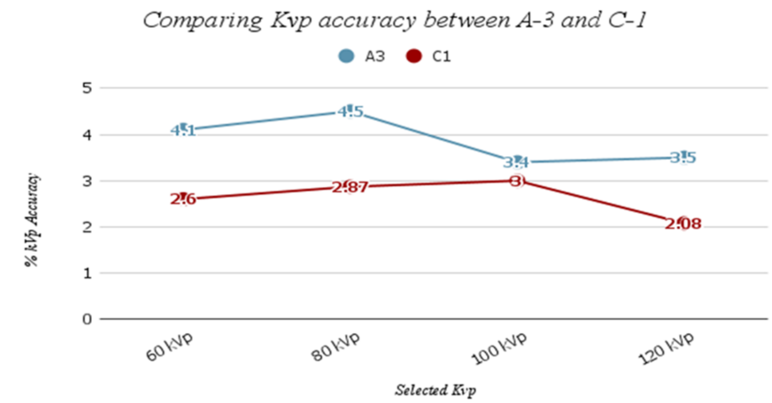

Figure 3: Comparing kVp accuracy between A-3 and C-1

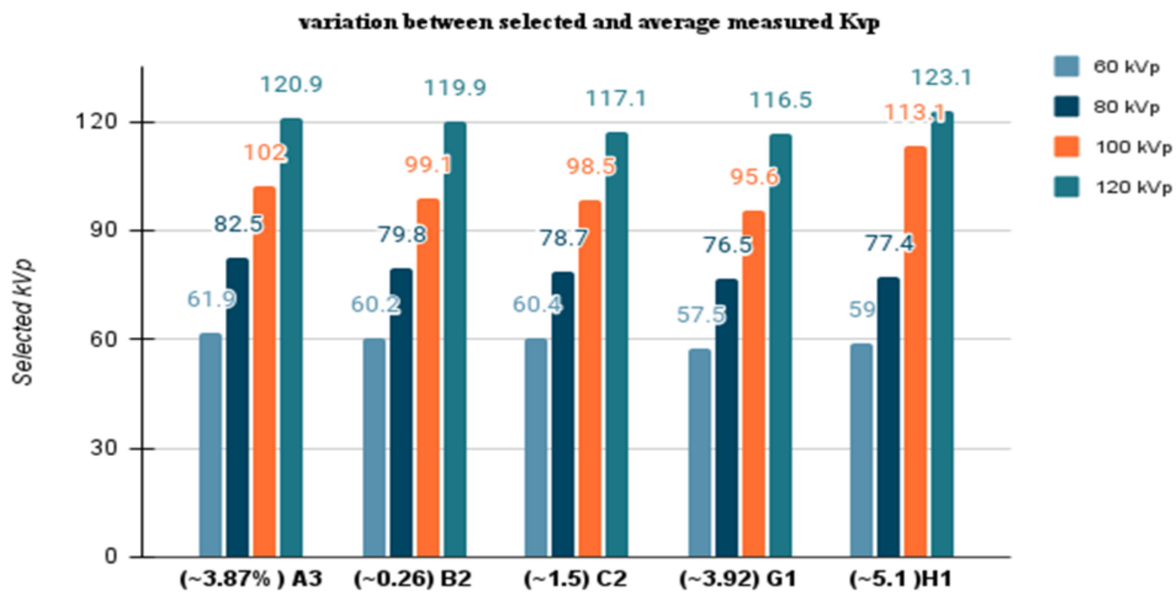

Figure 4: variation between selected and average measured kVp

Nigeria by Akpochafor et al (14) ,two X ray units failed the kVp accuracy test which are (D4 and D9)at 50Kvp and 58kvp, although they were <5 years old , also this study revealed that there was no significant difference between X-ray machine age and mean kVp accuracy (p-value = 0.77) with X-ray units age ranged between 2-11 years old , this result was seen to be not compatible with our study which revealed that there was a weak significant relationship between X-ray unit age and kVp accuracy test p-value =0.008.

In another study conducted in 2017 by Michael et al [25] , on 23 X-ray units , that aged between 4-28 years , revealed that 30.43% failed kVp accuracy test and 34.7% failed kVp reproducibility test, Which revealed less acceptable kVp accuracy findings comparing to our study ,which showed that 8.1% failed the kVp accuracy test , and 0% failed the kVp reproducibility test ,Micheal's study finding also revealed that there was a very good significant difference between machine age and kVp accuracy test with P<0.05, This result was seen to be consistent with our study and the least kVp accuracy deviation was noticed in (XR12) unit which is the youngest unit in this study ,also in our study the least kVp accuracy deviation was noticed in the youngest unit (B2) ,However Zahra et Al [26] , in 2016, conducted a study on 28 X-ray in Kerman Province Iran , units achieved a better kVp accuracy , her result shows that 25% failed kVp accuracy test ,the study showed that 27 out of 28 units all met the kVp reproducibility test acceptance limits , while in our study all 12 X-ray units were within acceptable level <5%.

Table 3: mean peak Kilovoltage accuracy for the evaluated X-ray units

Hospital -Number of the device	Mean kVp accuracy test
A-1	2.23 ± 1.13237
A-2	1.7 ± 1.06771
A-3	3.875 ± 0.51881
B-1	1.7875 ± 1.14483
B-2	0.26 ± 0.15406
C-1	2.6375 ± 0.40730
C-2	1.5 ± 0.73485
D-1	1.425 ± 0.99121
E-1	0.625 ± 0.49917
F-1	2.05 ± 0.61373
G-1	3.925 ± 0.69462
H-1	5.1 ± 5.37339

Mohsen et al [27], also conducted a similar study in Iran 2017 , which revealed higher kVp accuracy test failure which was 38.6 % .

In 2021 a quality control study conducted by Akintayo et al [28]., revealed that out of 12 X-Ray units five of them passed the kVp accuracy test ,the results also revealed that age of six X-Ray units was >20 years , these six units demonstrated highest failure in quality control tests compared to younger units, this study also confirmed that there was a statistically significant difference between X-ray units age and kVp accuracy with p value = 0.003 , this study also agreed with our study in terms of the lack of performing quality control tests .

Another study performed by Mehrdad et al [29] , on seven stationary X-ray units of Lorestan province , the findings for the kVp accuracy test revealed that three X-ray units out of seven were beyond the acceptance limits , and the maximum range was for B unit which was 0.30-27.52% , while the maximum range for kVp accuracy in our study shown in H-1 unit which was 1.6-13.1%.

7 CONCLUSION

The study aimed to perform the kVp accuracy and reproducibility tests in twelve X-ray units in Palestine, the study findings revealed the Lack of performing periodic monitoring and quality control tests on stationary conventional radiology devices since seven X-ray units out of twelve does not have a schedule for X-ray tube checking in the study area, also the study revealed that efficiency and accuracy issues are not simply restricted to older or higher load radiography equipment's ,frequent quality control checks every 6 to 12 months can give more reliable and up-to-date understanding of the status of the equipment.

One of the radiation protection objectives that should be performed on a regular basis is stringent quality check on all radioactive devices, which have the greatest impact on improving image Quality and reducing patient dose and reducing repeated radiographs.

REFERENCES

[1] M Tubiana . Bull Acad Natl Med .1996 Jan . Wilhelm Conrad Rontgen and the discovery of X-ray .
[2] J. Radon, "On the determination of functions from their integral values along certain manifolds," IEEE Transactions on Medical Imaging, vol. 5, no. 4, pp. 170-176, Dec. 1986, doi: 10.1109/TMI.1986.4307775.
[3] S.R. Deans, "The Radon Transform and Some of Its applications," New York, USA: John Wiley& Sons, Inc,1983
[4] M. Hjouj J. Lavee J, D.Last , D. Guez , D. Daniels , S. Sharabi S, B.Rubinsky B, Y. Mardor, "The effect of blood flow on magnetic resonance imaging of non-thermal irreversible electroporation," Sci Rep. 2013 Oct 30;3:3088. doi: 10.1038/srep03088. PMID: 24169528; PMCID: PMC3812656.2013
[5] [F. Hjouj, "Towards tomography with random orientation", ACM International Conference Proceeding Series, 2019, pp. 49–53, https://doi.org/10.1145/3379299.3379309
[6] F. Hjouj, MS. Jouini, "On the Radon transform and linear transformations of images,"ACM International Conference Proceeding Series, pp.26– 31, 2019. doi.org/10.1145/3379299.3379306
[7] F. Hjouj, MS. Jouini, "On Image Registration using The Radon Transform: Review-and-Improvement,"DMIP'21,20214thInternational Conference on Digital Medicine and Image Processing, pp. 17–23, 2021, doi.org/10.1145/3506651.3506654
[8] F.Hjouj, M.S Jouini, "On Orthogonal Polynomials and Finite Moment Problem ", Open Chemical Engineering Journal, to appear
[9] F. Hjouj, M.S. Jouini, "Review and improvement of the finite moment problem," Open Chemical Engineering Journal, vol.14, pp.17–24, 2020, DOI:10.2174/1874123102014010017
[10] M. S. Jouini, F. Bouchaala, M. K. Riahi, M. Sassi, H. Abderrahmane and F. Hjouj, "Multifractal Analysis of Reservoir Rock Samples using 3D X-ray Micro Computed Tomography Images," in IEEE Access, 2022, doi: 10.1109/ACCESS.2022.3186476
[11] M.S. Jouini, F. Bouchaala1, E. Ibrahim, F. Hjouj, " Permeability and Porosity Upscaling Method Using Machine Learning and Digital Rock Physics," Conference Proceedings, 83rd EAGE Annual Conference & Exhibition, vol. 2022, pp.1 – 5, 2022, DOI: https://doi.org/10.3997/2214-4609.202210016
[12] H. Arjah, M. Hjouj, F. Hjouj, "Low dose brain CT, comparative study with brain post processing algorithm," 2nd International Conference on Digital Medicine and Image Processing, DMIP 2019. pp.1-7, 2019, https://doi.org/10.1145/3379299.3379308
[13] Agency pNaI. Hospitals in Palestine 2020 [cited 2022 22-3]. Available from: https://info.wafa.ps/ar_page.aspx?id=14977.
[14] Rasuli B, Pashazadeh A, Javad M, Tahmasebi Birgani MJ, Ghorbani M, Naserpour M, *et al.* Quality Control of Conventional Radiology Devices in Selected Hospitals of Khuzestan Province, Iran. Iranian journal of medical physics. 2015; 12:101-8. doi: 10.22038/ijmp.2015.4773.
[15] Farzaneh MJK, Shandiz M, Vardian M, Deevband M, Kardan M. Evaluation of image quality and patient dose in conventional radiography examinations in radiology centers in Sistan and Baluchestan, Iran and comparing with that of international guidelines levels. 2011; 4:1429-33. doi: 10.17485/ijst/2011/v4i11/30264.
[16] Delis H, Christaki K, Healy B, Loreti G, Poli GL, Toroi P, *et al.* Moving beyond quality control in diagnostic radiology and the role of the clinically qualified medical physicist. Phys Med. 2017;41:104-8. Epub 2017/04/17. doi: 10.1016/j.ejmp.2017.04.007. PubMed PMID: 28412135.
[17] Khiyani N, Singh V. X-ray Image Production Equipment Operation. StatPearls. Treasure Island (FL): Stat Pearls Publishing Copyright ©2022, StatPearls Publishing LLC.; 2022.
[18] Baorong Y, Kramer HM, Selbach HJ, Lange B. Experimental determination of practical peak voltage. Br J Radiol. 2000;73(870):641-9. Epub 2000/07/27. doi: 10.1259/bjr.73.870.10911788. PubMed PMID: 10911788.
[19] Goel A, Feger,J. Kilovoltage peak Refrence article , Radiopaediaorg. doi: https://doi.org/10.53347/rID-29650.
[20] [20] IOWA STATE UNIVERSITY CfNE. Nondestructive Evaluation Techniques , Radiography testing , X ray generators. Available from: https://www.nde-ed.org/NDETechniques/Radiography/developingfilm.xhtml.
[21] Murphy A. Radiographic contrast . Refrence article doi: https://doi.org/10.53347/rID-58718.
[22] Njiki C, Manyol E, Yigbedeck Y, Beyala Ateba JF, Abou'ou D, Ndah Thierry N. Quality Control of Conventional Radiology Devices in Selected Hospitals of the Republic of Cameroon. 2018.
[23] Omojola A, Akpochafor MO, Adeneye S, Soyebi K, Moses A, Bolanle A. Assessment of peak tube kilovoltage accuracy in ten selected X-ray centres in Lagos metropolis, South-Western Nigeria: A quality control test to determine energy output accuracy of an X-ray generator2016.
[24] (AAPM) AAopiM. Basic Quality control in Diagnostic Radiology AAPMReport No 74Madison: Medical Physics Publishing :2002.
[25] Akpochafor M, Adeneye S, Daniel F, Omojola A, Moses A. Evaluation of kilovoltage failure in conventional X-ray machines among selected X-ray Centers in Jos North Local government area of Plateau State, Nigeria. Nigerian quarterly journal of hospital medicine. 2018; 27:768-75.
[26] Jomehzadeh Z, Jomehzadeh A, Tavakoli MB. Quality Control Assessment of Radiology Devices in Kerman Province, Iran. Iranian Journal of Medical Physics. 2016;13. doi: 10.22038/ijmp.2016.7142.
[27] Asadinezhad M, Bahreyni Toossi MT, Ebrahiminia A, Giahi M. Quality Control Assessment of Conventional Radiology Devices in Iran. Iranian journal of medical physics. 2017;14:1-7. doi: 10.22038/ijmp.2017.19052.1173.

Table 4: : The accuracy and reproducibility of tube voltages measured in the evaluated X-ray units.

Hospital -Number of the device	Selected Tube voltage (kVp)	measured Tube voltage (kVp)			kVp average	kVp accuracy	kVp reproducibility
A-1	60	61.9	61.9	61.9	61.9	3.1%	0%
	80	82.6	82.4	82.6	82.5	3.1%	0.1%
	100	102	102	102	102	2%	0%
	120	121	120.9	120.9	120.9	0.72%	0.04%
A-2	60	61.7	61.5	61.7	61.6	2.6%	0.1%
	80	82.2	82.1	82.1	82.1	2.6%	0.06%
	100	101.2	101.1	101.1	101.1	1.1%	0.04%
	120	120.5	120.6	120.7	120.6	0.5%	0.08%
A-3	60	62.6	62.5	62.6	62.5	4.1%	0.07%
	80	83.6	83.6	83.3	83.6	4.5%	0.1%
	100	103.4	103.4	103.4	103.4	3.4%	0%
	120	124.3	124.4	124.3	124.2	3.5%	0.04%
B-1	60	61.5	61.6	61.5	61.5	2.5%	0.08%
	80	82.3	82.3	82.3	82.3	2.8%	0%
	100	101.5	101.6	101.7	101.6	1.6%	0.09%
	120	120.3	120.3	120.4	120.3	0.25%	0.04%
B-2	60	60.3	60.2	60.2	60.2	0.3%	0.08%
	80	79.8	79.8	80	79.8	0.3%	0.12%
	100	98.8	99.7	98.8	99.1	0.4%	0.4%
	120	119.6	120.5	119.6	119.9	0.04%	0.04%
C-1	60	61.5	61.6	61.6	61.6	2.6%	0.08%
	80	82.3	82.4	82.3	82.3	2.87%	0.06%
	100	103	103	103.2	103	3%	0.09%
	120	122.5	122.6	122.5	122.5	2.08%	0.08%
C-2	60	60.4	60.4	60.5	60.4	0.6%	0.08%
	80	78.8	78.5	78.6	78.7	1.5%	0.12%
	100	98.8	98.5	98.5	98.5	1.5%	0%
	120	117.1	117.1	117.2	117.1	2.4%	0.04%
D-1	60	61.9	61.8	61.9	61.9	1.5%	0.08%
	80	82	82	81.9	82	2.5%	0.06%
	100	101.6	101.7	101.6	101.6	1.6%	0.04%
	120	120.1	120.2	120.2	120.2	0.1%	0.04%
E-1	60	60.4	60.4	60.4	60.4	0.6%	0%
	80	81.2	81.1	81.2	81.1	1.3%	0.06%
	100	100.1	100.1	100.1	100.1	0.1%	0%
	120	119.4	119.4	119.4	119.4	0.5%	0%
F-1	60	61.8	61.7	61.7	61.7	2.8%	0.08%
	80	81.9	81.9	82	81.9	2.3%	0.06%
	100	101.6	101.6	101.6	101.6	1.6%	0%
	120	121.9	122	122	121.9	1.5%	0.04%
G-1	60	57.5	57.5	57.5	57.5	4.1%	0%
	80	76.6	76.4	76.4	76.5	4.3%	0.1%
	100	95.8	95.5	95.7	95.6	4.4%	0.1%
	120	116.6	116.5	116.6	116.5	2.9%	0.04%
H-1	60	58.7	59.6	58.8	59	1.6%	0.7%
	80	77.6	77.6	77.1	77.4	3.2%	0.3%
	100	113.3	113.1	113	113.1	13.1%	0.1%
	120	123.1	123.3	123.1	123.1	2.5%	0.08%

[28] Ijabor B, Nzotta C, Omojola A. Quality control test of conventional X-Ray systems in Delta State, South-South, Nigeria. 2021; 157:140-53.
[29] [Gholami M, Nemati F, Karami V. The Evaluation of Conventional X-ray Exposure Parameters Including Tube Voltage and Exposure Time in Private and Governmental Hospitals of Lorestan Province, Iran. Iranian Journal of Medical Physics. 2015;12:85-92. doi: 10.22038/ijmp.2015.4770.