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Quality Control Procedure of Different Parameters of X-Rays System and Optimization of Radiation Doses to the Patient

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ABSTRACT

Quality control helps radio-diagnostic facilities achieve appropriate radiological information with little dose and cost. In this study, quality control tests included Kilovoltage kVp accuracy and reproducibility, KVp and timer reproducibility, taking voltage verses radiation doses checking and reproducibility, milliampere(mA) and timer linearity, milliampere second mAs reproducibility and output doses verses mAs, light-radiation collimator integrity, Perpendicularity, and HVL These results were compared to established methods. A certified physicist should do this test. Equipment functionality was determined via the status test. This was done shortly following the acceptance test. The test is repeated after repair that affects functional status, like the acceptance test. A certified physicist performs the status test, which involves absolute measurements. All processes at AECH DINAR D.I. Khan were within acceptable limits.

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Introduction

Radiations are now vital to human health. Medical radiation diagnoses and treats diseases. Medical diagnostic radiology was crucial decades ago. External radiation beams produce diagnostic imaging. Nuclear medicine diagnoses and treats via intravenous and oral radiopharmaceuticals. Both occupations improve lives and health care. Diagnostic radiology includes x-ray, mammography, ultrasound, and CT. CT and SPECT are used in nuclear medicine [1]. X-ray imaging procedures are imparted and have no alternative. Ionizing radiation is used in x-rays, per RSP. Checking quality control program application in diagnostic X-ray services improves image quality and optimizes radiation dose while adjusting patient radiation exposure parameters. Radiologists use image quality techniques to improve patient care [2]. Energy propagation in the medium is radiation. Different kinds of radiation are essential to human life. A body emits energy, which is transmitted via space. Ionizing and non-ionizing radiations exist [3]. Quality guarantees and quality are vital for system performance and machine output satisfaction. Using quality control processes can improve medical diagnosis and optimize radiation doses for patients, caregivers, and staff in radiology. Quality meets regulatory body standards for that machine [4]. Ionizing and non- ionizing radiation are in the electromagnetic spectrum. Many electromagnetic waves come from nature. Example: visible light. The electromagnetic spectrum includes low-frequency, energy, and long- wavelength non-ionizing radiation. Ionizing radiation is often, powerful, and short-wavelength. The most energetic radiation is UV, gamma, and X-rays. Gamma and X-radiation easily ionize and dissociate depending on intensity and peak energy. People gain from radiation beam technology like X-ray imaging. A radiation beam passes through the body, adjusting its range based on structure, to form an image. Exposure and skill determine image quality. Aligned parameters reduce radiation and improve quality [5]. Radiation doses measure human radiation absorption. The amount of ionizing radiation the body absorbs. Energy absorbed by the human body at one joule per kilogram is called absorb dose and is internationally specified as Gray (Gy). Knowing the ambient radiation level makes calculating radiation dose easy. Sievert, measured in millisievert unit, is the total radiation dosage absorbed by the body. International radiation dosage limits for workers and the public. CT imaging produces the best three- dimensional image reconstruction and target image information [6]. X-rays are used for imaging by interacting electrons with matter. Radiation or particle interaction with matter has many medical and industrial applications. Radiation alters or ionizes stuff for additional effects [7]. Photons interact with matter various ways. It can absorb, pass out, or interact and deposit energy, making this study beneficial for radiological needs. Details are [8]. Matter near photoelectric contact stores photons. Bidirectional energy transfer. First one transfers photon energy to electron. Secondary is energy transfer to relevant objects. Strongly attached electrons to atoms with high binding energy interact. This is achievable when binding energy is

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less than photon energy. Photoelectric interaction is forbidden when binding energy exceeds photon energy. Only when binding energy exceeds photon energy to remove electrons from atoms. This generates lighter photons from many x-rays. The absorbing substance's binding energy determines whether fluorescent radiation is light or x-rays [9]. When an incoming x-ray photon collides with an orbital electron without losing energy or wavelength, classical scattering occurs. Electron vibration from this interaction scatters x-rays. This contact does not ionize. Under 5% coherent x-ray Dispersion. There are two coherent scattering types. Thomson's scattering elastically scatters unbound electrons. Rayleigh scattering elastically scatters atoms like blue sky light. Unlike large-scale red-blue scattering. Traditional nanoparticle classification uses Rayleigh scattering. Wet biological deposition solgel produces 1–100 nm nanoparticles [10]. Atom nuclei interact with high-energy x-rays. Electron- positron pairs normally annihilate to produce two lower-energy photons. To conserve momentum, electrons and positrons travel oppositely. In 1925, British physicist Paul Adrien Maurice introduced it. Photons become matter and nuclei carry momentum, hence charged particles' K.E is 2mc2. Conserved momentum expels two 0.51 MeV photons in opposite directions [11]. Tissue receives photon energy two ways. First, electron-photon interaction exchanges all energy. Via tissue, energetic electrons carry energy. Energy electrons interact with tissue like photon electrons [12]. This imaging uses specialist X- ray machines for diagnosis and treatment. Specific machine parts do these duties. Generator-type X-rays penetrate the body and distribute visualization software-generated images [13]. Geometry like HVL and focus spot affects beam quality and reduces patient low-energy radiation exposure. The similar procedure is used for mammography [14].

Literature Review

X-rays are essential for diagnosis. Includes power supply, electronic connections, X-ray tube, and target material. This device has quality controls for beam alignment, half cavity layer, KVp precision, dose vs. input voltages, image resolution plate, and image contrast. Radiation must be minimized during the experiment. System quality and radiation safety are assured [15]. X-ray beams incident from a machine on the patient outside the patient are not employed for imaging. This paper discusses them. Noise beams can reduce picture contrast and harm patients in radiation perspective. Beam collimation reduces outer beams [16]. Early radiation concepts were unclear, making body dose measurement difficult. This research focuses on reducing radiation doses and performing fewer exams as doctors urge because many early x-ray beams carry long-term cancer risks from ionizing radiation. Most nations use radiation- reduction measures [17]. Compared to X-rays, computed radiography has the most radiation. CT has the most radiation compared to x-ray. Ct dosages vary for spine, pelvis, hips, etc. [18]. The x-ray is one of the greatest hospital radiological procedures. One of the best ways to give the body's inside structure

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and body parts including hips, skull, bones, and others as prescribed by the doctor. Imaging with X-rays is simpler than CT, MRI, ultrasound, and other radiological methods. Fracture and soft tissue static examinations provide useful information [19]. Quality control is needed in diagnostic x-ray facilities to produce accurate images with less radiation. This study used quality control to examine diagnostic radiology performance in Bangladesh and found acceptable parameters. This study measured concentrated spot, field coincidence, and HVL for diagnostic x-ray equipment in different facilities using quality control test tools [20]. The patient prepares before the surgery. The technician next instructs the patient to recline or sit on the x-ray room machine plate facing the film or sensor. Sitting or standing on the plate, the patient adjusts the x-ray machine arm to receive an image to test a new portion [21]. Image processing creates it. This research uses digital software-based technologies to get gray scale photos and accurate methods to get high-quality images [22]. WHO quality assurance in diagnostic radiology Requires facility staff to give patients with high-quality images, diagnostic information, low-cost imaging, and reduced radiation exposure. Program sets service quality and procedure improvements. X-ray system quality assurance includes administrative and machine-to-end operations. Manufacturer criteria govern acceptance and commissioning under these programs. Purchase specifications include QA program operations to monitor and maintain system setup for picture quality evaluation and final record. To increase quality, an expert committee reviews all quality tests while assuring radiation safety and output efficiency [23].

Method and Materials

The research study, titled "Quality Control Procedures for X-ray Systems to Optimize Patient Radiation Doses and Ensure Best Clinical Use in Radiology," is planned at AECH, DINAR Cancer Hospital, and Dera Ismail Khan. The available services at the research location related to the study are outlined. The SHIMADZU X-ray machine at DINAR Cancer Hospital, Dera Ismail Khan, is used daily for accurate patient diagnosis, Key Equipment, X-ray unit tests, X-ray unit-film processing unit, Control console, The ray safe xi dosimeter, Quality control test, Time accuracy, Leakage test, The reproducibility tests It indicates the test method result must be constant under the same situation, yet when other parameters are fixed at the machine console, the x-ray machine timer and kVp change. The optimal machine configuration provides optimal patient dosages and image. The kVp and time fluctuation coefficients must be below 2% and 5%, respectively. Reproducibility checks output continuity after several X-ray exposures. Peak Kilovoltage kVp reproducibility was measured with the ray safe dosimeter S/N 181559). the equation is given.

Coefficient of Variation: $\frac{Standard\ Deviation}{Average} X\ 100$ 1

kVp accuracy test Each X-ray exposure has an optimal tube potential; errors beyond ±5% kVp

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may compromise image quality, increasing patient dose. The equation is given below.

Percentage kVp error: $Vo - Vs/Vs \times 100$ 2

time accuracy test is short times increase patient doses, affect image quality; errors should remain within ±5%.so this relation is given by.

Percentage time error: $To - Ts/Ts \times 100$ 3

And Calculation of HVL is the Half-value layer (HVL) is the material thickness reducing incident energy by

50%, inversely related to attenuation coefficient (μ).

HVL= $\frac{0.693}{u}$ 4

Since HVL decreases with absorbing material atomic number, it is significantly dependent on it. A study found that attenuators made of aluminum (Al) have a thickness of 3 mm at 50 kVp, 4 mm at 60 kVp, 5 mm at 70 kVp, 5.6 mm at 81 kVp, and 6.1 mm at 90 kVp. BAPETEN No. 09 Year 2011 and Western Australia Standard state that the HVL for each voltage on the X-ray plane for general radiography examined in this study is within the allowable minimum range. Use the correction factors for the measured data to eliminate any rough values. Compare your data with a calculated date to get the results.

Results and discussion

The experiments have been performed in radiology department at DINAR cancer hospital Dera Ismail khan to assess the image quality. The multiple factors of X-ray machine (SHIMADZU-Japan Company) have been verified. During the experiment the SHIMADZU X-ray machine and computed radiographic system of dinar have been used. To enhance the image quality, different data have been and were graphically analyzed.

Assessment of tube voltage kVp versus exposure/ radiation doses:

Increased electron counts result in more x-ray emission in the tube, including both distinctive and continuous radiation. Increasing x-ray tube voltage accelerates electrons, which emits more x-rays in the target element. Increasing tube voltage increases exposures. Multiple voltages were used for optimal use and outcomes. The table shows exposure averages against applied voltage. Data was acquired at SSD=100 (source to surface distance) and demonstrates increasing applied

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voltages vs exposures. Exposure values were averaged three times. Results show that the equipment performs well against voltage by delivering optimal exposure for patient use. Heavy patients require high voltage and current for exposure. Therefore, patients will gain. High input voltage precision and machine adjustment for radiation dose-induced voltage increase yield positive outcomes.

Table 4.1 Assessment of Tube Voltage kVp Versus Exposure/ Radiation Doses

Machine Name SHIMADZU JAPAN				**Model Collimator Type R-20J**		**Tube Current 100mA**		**Timer Setting 100ms**		**SSD 100cm**	**Field Size 10x15**	
S. N	**Set Value KVp**		**Reading (R) 1**	**R2**	**R3**	**R4**	**R5**	**R6**	**R7**	**R8**	**R9**	**R10**
1	**50**	KVp	50.11	50.17	50.34	50.34	50.20	50.26	50.26	50.05	50.27	50.85
		Dose(uGy)	340.2	339.5	337.6	338.5	341.8	337.4	338.8	337.8	338.2	331.9
		Time	3.433	3.422	3.403	3.412	3.449	3.401	3.415	3.405	3.405	3.346
2	**60**	KVp	60.44	60.10	60.01	60.31	60.05	59.93	60.01	60.26	60.36	60.28
		Dose	526.0	520.8	517.3	503.4	521.7	524.1	523.3	521.9	501.9	520.4
		Time	5.266	5.202	5.180	5.035	5.212	5.241	5.233	5.219	5.014	5.205
3	**70**	KVp	70.11	70.28	70.15	70.27	70.29	70.39	70.03	70.08	69.91	70.06
		Dose	710.4	681.1	706.8	681.9	690.6	709.3	707.1	708.2	718.2	715.5
		Time	7.096	6.804	7.668	6.812	6.899	7.094	7.064	7.075	7.175	7.148
4	**80**	KVp	81.17	81.23	81.16	81.44	81.03	81.10	80.97	81.08	81.12	81.13
		Dose	965.3	896.9	891.6	885.3	851.0	888.3	894.3	889.2	888.6	853.0
		Time	8.635	8.949	8.857	8.824	8.491	8.863	8.923	8.873	8.867	8.521
5	**90**	KVp	90.92	91.01	91.07	90.87	90.97	90.97	91.10	90.68	91.18	90.35
		Dose	1107	1.112	1.076	1.132	1.117	1.131	1.135	1.112	1.119	1.065
		Time	11.04	11.09	11.72	11.29	11.13	11.28	11.31	11.09	11.16	10.61
6	**100**	KVp	101.3	101.6	101.6	101.4	101.4	101.8	101.6	101.7	101.3	101.8
		Dose	1358	1.302	1.343	1.342	1.340	1.287	1.338	1.335	1.339	1.349
		Time	13.53	12.97	13.39	13.37	13.35	13.38	12.82	13.34	13.30	13.44
7	**110**	KVp	111.8	112.7	111.8	112.0	112.3	11.6	112.0	111.8	111.9	112.2
		Dose	1556	1.629	1.611	1.571	1.619	1.628	1.610	1.559	1.610	1.563
		Time	15.49	16.23	16.04	15.63	16.11	16.22	16.08	15.53	16.04	15.56

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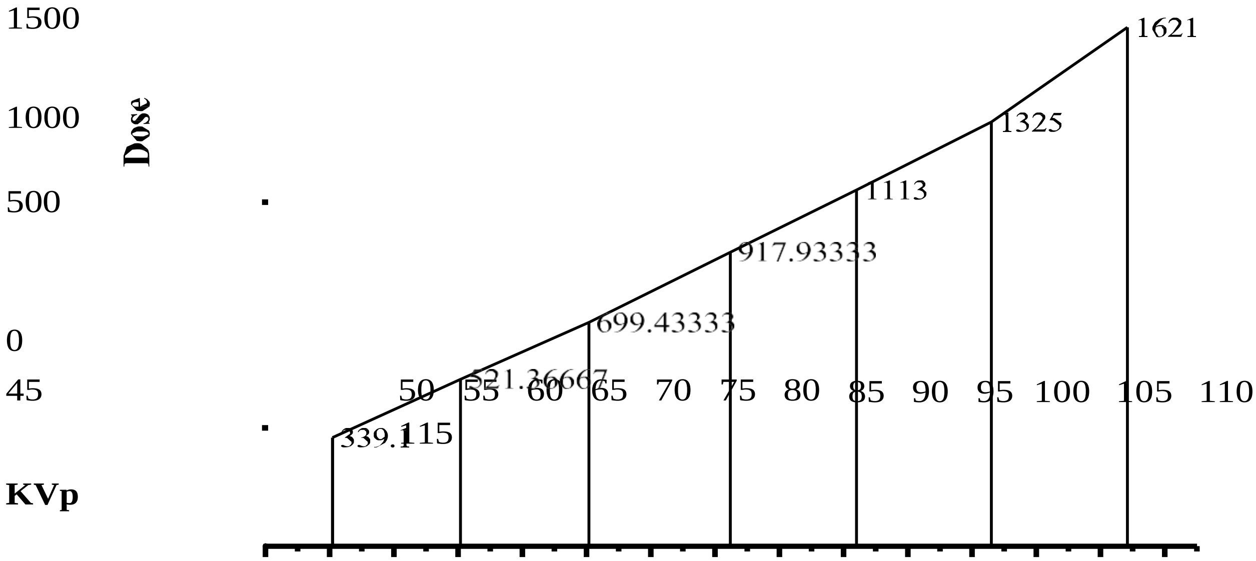

Figure 4.1 Assessment of tube voltage kVp versus exposure/ radiation doses

Calculation of voltage kVp accuracy and reproducibility

The x- ray of different patients is performing at same voltage and its reproducibility is necessary. The experiment has been performed at fixed mA (100) at x ray machine and its multiple data have been taken during experiment. The experiment is repeated for each value at three times and then average kVp have been found. The detail experimental data taken is below. The set voltage in data shows the given voltage set down at the console of machine.

Table 4.2. Calculation of voltage kVp accuracy and reproducibility

kVp	R1	R2	R3	Average
40	36.91	38	36.82	37.93
45	42.29	43.07	43.9	43.57
50	48.12	48.06	49.3	48.87
55	52.88	52.98	52.02	53.22
60	52.02	52.09	53.1	54.30
65	65.45	65.34	65.09	65.22
70	66.59	67.6	68.58	68.44
80	72.43	72.4	72.5	74.33

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90	88.38	88.38	88.5	88.82
100	94.94	94.94	94.99	96.22
110	108.1	108.1	108.29	108.63
120	112.2	112.2	116.6	115.53
130	124.4	126.02	128.6	127.26
140	132.5	132.9	134.12	134.88
150	140.4	140.9	141.01	143.08

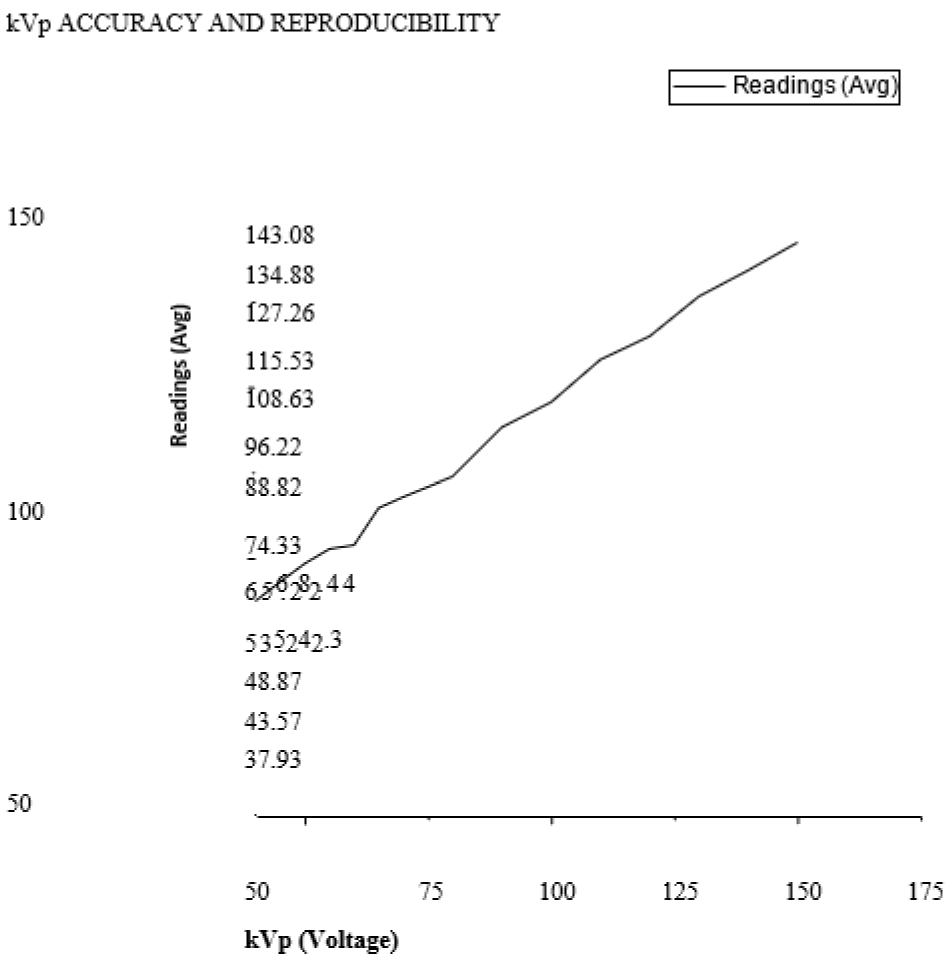

Figure 4.2 Calculation of voltage kVp accuracy and reproducibility

Assessment of time accuracy

Radiographic contact times are generally kept as minimum as likely. The time of exposure has the central parameters playing role for imaging an x ray of different patients. It is the time of

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exposure of concerned site of performing imaging of body. Against each site of exposure (like knee, chest x ray), the automatically selectable time has been taking by machine for exposures also have option of changing its time against study. When the exposures time increase or decrease the numbers of emitted electrons increasing or decreasing or respectively. The different exposures times have taken at fixed voltage. The data is given below.

Table 4.3. Timer Accuracy and Reproducibility

Timer Accuracy and Reproducibility					
KV=70					
Set Time (mSec)	**Measured Time (mSec)**			**Avg. Exp. Time**	**% Age Accuracy**
	R1	**R2**	**R3**		
5	4.75	4.76	4.78	4.76	4.73
5.6	5.4	5.5	5.59	5.50	1.85
6.3	6.2	6.15	6.25	6.20	1.59
7.1	6.9	6.98	7	6.96	1.97
16	15.7	15.92	15.88	15.83	1.04
32	31.92	31.88	31.72	31.84	0.50
40	39.9	39.93	39.79	39.87	0.32
50	49.9	49.75	50.05	49.90	0.20
63	62.85	62.72	63.11	62.89	0.17
71	70.5	70.06	71	70.52	0.68
100	99.5	99.7	99.99	99.73	0.27
125	125.1	124.7	124.8	124.87	0.11
140	139.9	139.5	140.1	139.83	0.12

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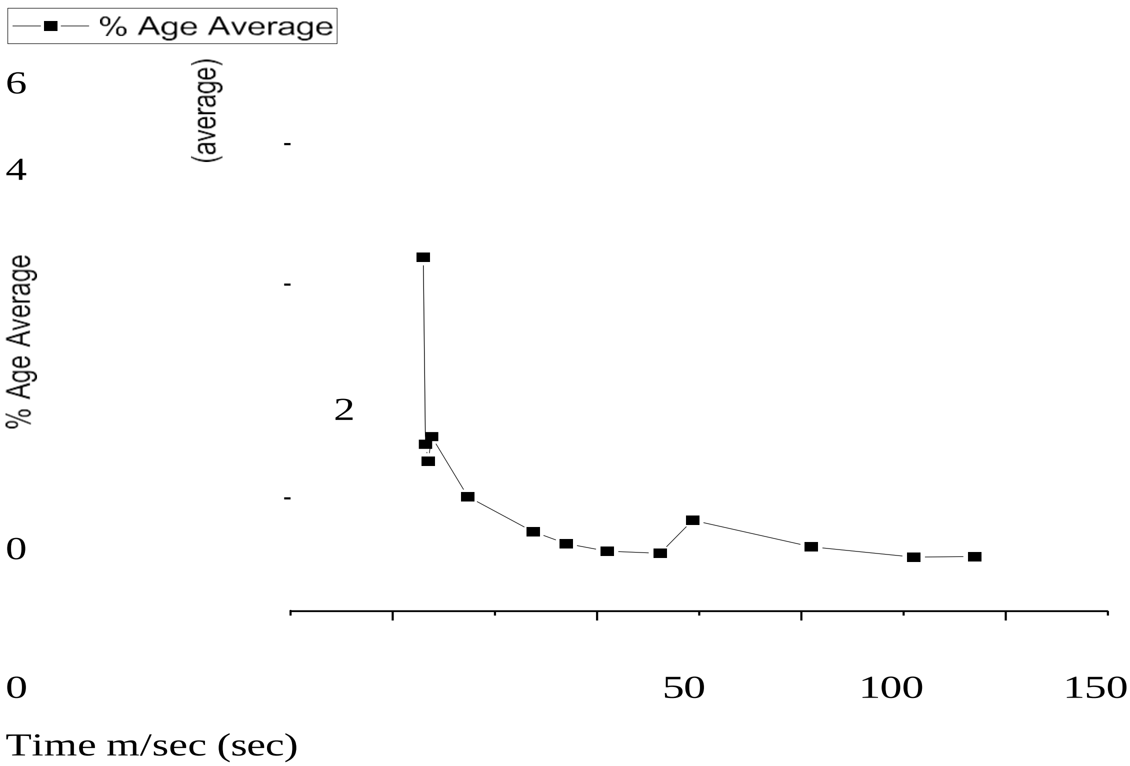

Figure 4.3 Timer Accuracy and Reproducibility

The time accuracy has been shown above in the table and result has been drawn which shows that the value is within acceptable range of 5% most of the value are near exactly to the input time thus these values shows that X-ray machine of a good results for patient exposure at selected time which is great benefits for treated patients at diagnostic radiology.

Assessment of exposure time accuracy

A high range of contact periods has been taken in this experiment at the fixed voltage of 70 kVp has taken the data has been tabulated below. For contact time more than 20 msec, and less than 20 msec exactness must be within ± 5 % and ± 10 %, correspondingly.

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Table 4.4. mAs Versus Dose Linearity

mAs and Dose Linearity						
KV=70						
Set mAs	**Dose absorbed (mGy)**					**Avg. value (mGy)**
	R1	**R2**	**R3**	**R4**	**R5**	
20	1.004	0.995	1.001	1.007	1.006	1.003
40	1.997	2	1.978	2.014	2.007	1.999
63	3.256	3.196	3.193	3.225	3.221	3.218
80	4.05	4.083	4.03	4.171	4.021	4.071
100	5.221	5.288	5.285	5.264	5.387	5.289
125	6.774	6.781	6.586	6.591	6.603	6.667
140	7.3	7.369	7.302	7.51	7.362	7.369
180	9.393	9.651	9.45	9.426	9.606	9.505
220	12.09	12.09	12.12	12.11	12.12	12.106
280	15.35	15.32	15.37	15.1	15.13	15.254
400	20.9	21.39	21.1	21.38	19.93	20.940
500	23.96	22.4	26.26	26.36	28.22	25.44

The graph shows the accuracy of mAs and also gradually increase of dose with exposure time the value is within acceptable limit of $\pm$5%

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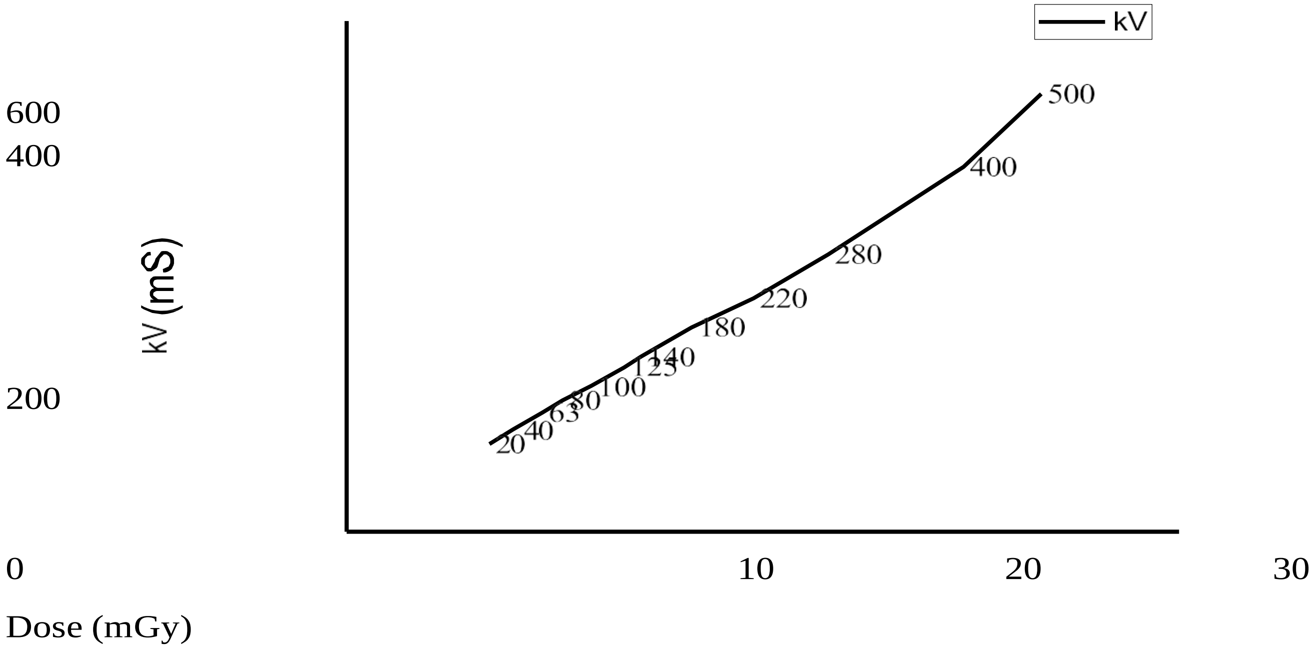

Figure 4.4. mAs Versus Dose Linearity

Assessment of half-value layer

The Dosimeter was placed at 100 cm distance from tube the kVp and mAs was fixed at the focal spot which is set down for this experiment. The experiment has been performed without aluminum filter and the reading was noted at this setup. The aluminum sheet was added which ranges from 0mm thickness to 4mm thickness one by one and multiple reading was taken at each thickness and also taken average values for each thickness. These doses were graphed at multiple thickness and find out within the acceptable range as variation with thickness as shown in Figure 4.5

Table 4.5. HVL for Different thickness of Sheet

kVp = 50, mAs = 20, Distance = 100cm

S. No	**Thickness (mm Al)**	**Dose (µGy)**
1	**0**	**735**
2	**1**	**525**
3	**2**	**453**
4	**3**	**370**
5	**4**	**344**

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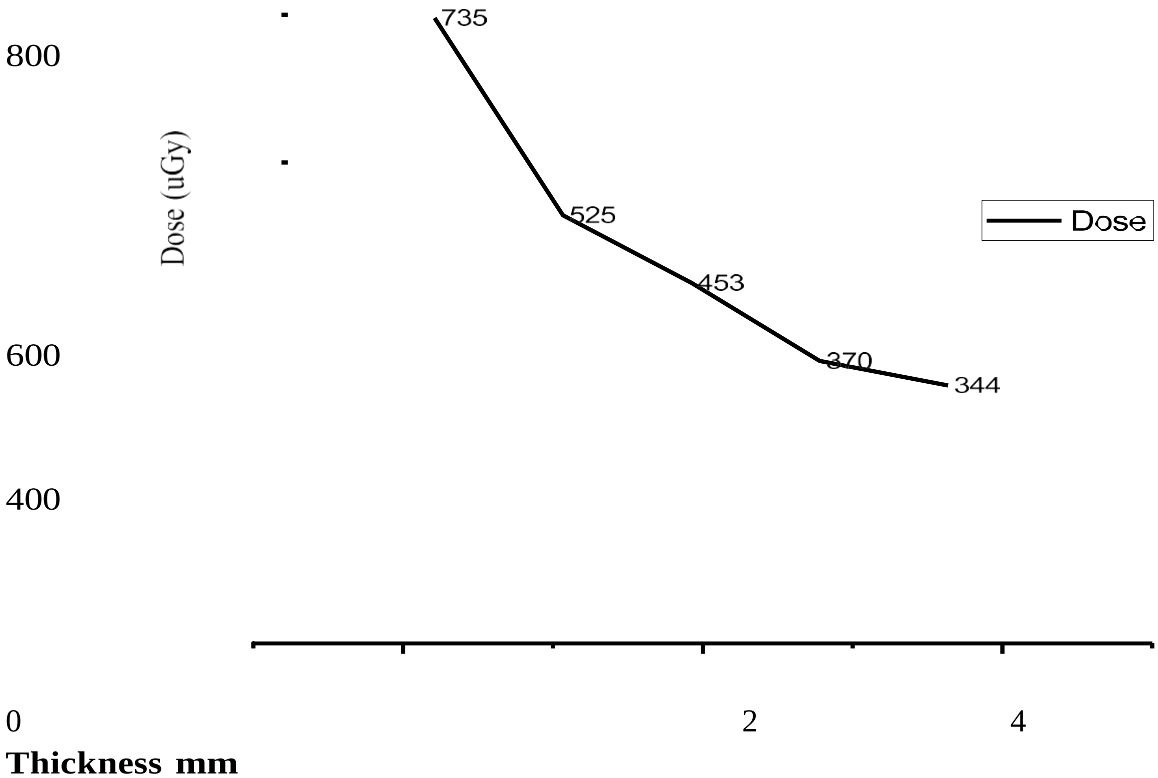

Figure 4.5 HVL for Different thickness of Sheet

The HVL has been calculated and found within acceptable limits, these HVL will be helpful in performing the x ray imaging of light and heavy-weight patients at DINAR Cancer Hospital Dera Ismail Khan.

Conclusions:

The DINAR Cancer Hospital D. I. Khan radiology department conducted the experiments. The study tested machine functionality for patient use. Radiation exposures against applied voltages were tolerable. Installation settings for X-ray machines were examined. Routine X-ray parameters, such as tube current, voltage, time precision, and image quality (contrast, beam alignment), have been confirmed. The trials were done 100cm from tube to dosimeter. The experiment setting is done. The results were decent and image quality was excellent. Also, x-ray settings were altered for numerous values and obtained optimum results on ray-safe dosimeters. The investigation found that this centre's X-ray machine is functional and useable. The results showed that the equipment is excellent for patient use with high-quality images and low radiation. The image was taken at the lowest voltage and mAs and adjusted at the console for optimal results. The radiation doses for each voltage and current were within acceptable limits and finalized for patient use. The trial examined DIINAR patient protection visits and radiology

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department x-ray equipment administration.

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