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Original Article

Assessment of X-Ray Tube Technical Factors: Tube Voltage and Exposure Time in Erbil Medical Imaging Centers

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Abstract

Background: An evaluation of certain radiographic factors affecting patient exposure during medical imaging was carried out. Factors considered included selection of tube kilovoltage and time exposure combination. An increase in X-ray tube voltage increases the amount of radiation coming out of the X-ray tube, as well as the amount of skin dose in the image. This study aimed to assess the possibility of reducing the voltage and exposure time in medical imaging centers. The study indeed intended to protect patients from the risk of developing cancer with excessive radiation dose.

Materials and Methods: This study was performed in Erbil hospitals, Iraq. NOMEX multimeter (Finland, PTW) was used to measure radiation dose (mGy), total voltage, current (mA), exposure time (s), and total filtration in 150 patients undergoing different X-ray examinations.

Results: The results showed that the highest output was obtained in the age group of 42-70 years (dose range: 52.43–19.46 mGy), followed by the age group of 50-70 years (dose range: 39.9–25.63 mGy) and the age group of 10–40 years (dose range: 30.35–10.55 mGy).

Conclusion: The high voltage (kVp) and high exposure time to be important factors to increase patient doses via increasing the exposure dose. Thus, optimization of exposure time and voltage is recommended for all cancer patients undergoing medical imaging with high voltage and long exposure time.

Keywords: X-ray output, Voltage (Kvp), Exposure time, Radiographic projection

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Introduction

A conventional X-ray examination is particularly useful in diagnosing conditions or diseases that affect the bone and chest. The dose of radiation from an X-ray tube depends on the voltage of X- ray tube (kVp, peak kilo voltage) and exposure time. These parameters define the radiation dose. It is important to limit the level of exposure parameters because it helps radiographers to create the best quality images as safely as possible. The current study was conducted on 150 patients in three different age groups (age range: 10-70 years). X-ray parameters such as the tube voltage, tube current, and exposure time were presented in the tables according to the age of patients.

X-rays are ionizing radiation waves emitted as a result of differences in energy levels of electrons in atoms of X-ray anode. X-ray with high energy beam is used for medical diagnostic and therapeutic purposes. Nowadays, modern and digital medical imaging equipment improve the quality of images and reduce patient's radiation dose. To protect the patient from unnecessary radiation dose, several technical factors should be considered (1, 2). ALARA (as low as reasonably achievable) is a principle of radioprotection that is based on minimizing radiation doses as the application of X-ray in medicine for diagnosis purposes represents the highest amount of exposure to ionizing radiation. The main technical factors are measured by applying high voltage X-ray tube, tube current, and duration of diagnoses. These factors can impact the level of radiation dose delivered to the patient (3-5).

In addition, these factors can lead to the accumulation of doses and are important parameters to evaluate the quality of imaging at hospitals for subjects undergoing medical X-ray examinations. The optimization of radiation dose depends on the tube voltage (kVp), tube current (mA) of X-ray tube, exposure time of the patient to the radiation (s), and focus to detector distance (cm). The voltage of X-ray tube is an important factor which controls the amount of energy differences of electrons emitted from the X-ray tube (6, 7). The greater voltage and current increase the penetration of radiation inside the organs. The number of electrons at cathode coil is also high. While the kVp controls the quality of the

beam, current of the tube (mA) controls the quantitative character of exposure factor (8, 9). These technical parameters are considered as a part of medical diagnosis of patient (8-10). High voltage reduces skin dose and increases electrons intensities that strike on the film. Therefore, high voltage results in a low contrast to many different components of tissues in the organ that is exposed to radiation, though it produces more scattering radiations (11, 12). In this case, the radiation dose can be evaluated in terms of entrance skin dose (ESD) in each radiograph, which is considered an important parameter in evaluating the amount of dose received by the patient during the X-ray examination. Final dose (system dose) that is passed through the patient and receives to detector or film, it always less than original dose which is automatically controlled by the system via change the value of voltage which determined skin dose and may increase or decrease electrons intensities that strike on the film (13, 14).

Materials and Methods

This study was conducted on 150 patients referred to medical imaging centers of both governmental and private hospitals in Erbil, Iraq with different age groups (age range: 10-70 years). The NOMEX multimeter device (PTW, Finland) was used to calculate radiation doses and X-ray technical parameters, including total voltage, exposure time (s), current (mA), and total filtration. During performing the examinations, the data were arranged in tables according to the age of the patients. The tube voltage range was between 60-120 kVp. This study focused on using voltage (kVp) technique to reduce radiation exposure dose for patients undergoing a radiological examination by conventional X-ray. Absorption of X-ray dose increases with increasing mAs and high voltage. High-voltage grid (above 100 kV) must be used to reduce the scattering radiation on film.

The data was obtained during the projections of X–ray on patients. Anterior-posterior (AP) of patient chest, abdomen, hand, forearm, pelvis, and knee joint were examined. The images of all patients in our study had a good quality. The first step of this work started with recording the following information for each patient: age, weight, length, and gender. For each X-ray machine in each of the medical imaging centers, specific data model, manufacture, year of installation, wave form, added filtration, and other parameters were recorded.

Results

The results of this study showed the main exposure parameters in medical imaging centers in Erbil city. The tube potential (tube voltage) of X–ray range was between 60–120 kVp. Increasing the tube voltage leads to the emission of more electrons from the filament (cathode); then, more X-ray is produced as a result of increasing the interaction between electrons and anode of the X-ray tube. The adjustment of technical factor, that is the effect of kVp value on exposure dose when high voltage is increased, led to an increase in energy of X–ray beam. High voltage produced more electrons inside the X–ray tube around the cathode and could result in passing through patient body. In addition, mAs is a measure of radiation produced over a set amount of time.

Table 1 shows the X-ray tube voltages and exposure time in 10 different X-ray tube projections in the age group of 10–40 years. As can be seen, there are 10 different amounts of radiation absorbed dose, and the value of absorbed dose depends on patient's age (10-40 years). The final dose of radiation varies from one type of examination to another and the amount of radiation dose is inversely proportional with exposure time.

Table 2 shows the exposure time from different radiographic projections with age groups of 42–70 years. The exposure time is inversely proportional with the radiation dose.

Table 3 shows four of the chest X–ray radiographic projections, and six abdomen (PA) X–ray radiographic projections. As can be seen, the age group of patients

Table 1. The Technical Parameters of X-ray Tube for Age Group of 10-40 Years

Radiograph Projection	Voltage (kVp)	Current Milliamp (mA)	Time (s)	Average Dose (mGy)	mAs
Chest PA	60	100	35	10.55	2.81
Chest PA	80	200	25	20.64	1.00
Abdomen	120	400	7	30.35	2.8
Chest PA	80	400	25	14.28	6
Hand	75	200	20	12.49	4
Pelvis	80	300	10	27.31	3
Abdomen	60	200	24	16.39	4.8
Knee joint	80	400	20	29.93	8
Forearm AP	70	200	30	11.35	6
Chest PA	88	380	7	31.56	2.66

Table 2. The Technical Parameters of X-ray Tube for Age Group of 42-70 Years

Radiograph Projection	Voltage (kVp)	Current (mA)	Exposure Time (s)	Average Dose (mGy)	mAs
Chest (PA)	80	355	26	25.32	9.23
Chest (PA)	90	351	4	52.43	1.40
Abdomen	70	300	14	19.16	4.2
Pelvis	90	500	11	32.39	5.5
Hand	100	438	16	32.28	7
Abdomen	120	385	17	35.04	6.54
Forearm AP	90	500	20	29.85	10
Knee joint	120	368	6	38.72	2.2
Chest(PA)	88	380	12	31.56	4.56
Chest(PA)	100	370	8	33.63	2.96

Table 3. The Technical Parameters of X-ray Tube for Age Group of 50-70 Years

Radiograph Projection	Voltage (kVp)	Current (mA)	Exposure Time (s)	Average Dose (mGy)	mAs
Abdomen (PA)	100	360	8	30.84	2.88
Chest (PA)	120	350	5	39.9	2.1
Chest (PA)	95	370	20	28.27	7.4
Abdomen (PA)	90	375	23	26.33	8.6
Abdomen (PA)	88	380	7	31.56	2.66
Abdomen (PA)	85	350	6	23.42	2.1
Chest (PA)	80	355	30	26.35	10.6
Abdomen (PA)	100	365	22	29.59	8.03
Chest (PA)	120	360	5	28.55	1.8
Abdomen (PA)	95	375	19	25.63	7.12

was between 50–70 years. In general, radiation doses increased with voltage and inversely with exposure time in many patients.

The results of X-ray output voltage showed that tube voltages kVp varied between different age groups. In Table 1, the tube voltage ranged between 60-120 kVp; in Table 2, the tube voltage ranged between 70-120 kVp; and in Table 3, the tube voltage ranged between 80-120 kVp. Most X-ray radiographic projections were focused on the PA type of examination. In all tables, the tube voltage of X-ray kVp was below 120 kVp. The mAs shows the value of X-ray tube current per second (mAs (current)× S (time seconds)). We can obtain different mAs values with various combinations of mA and s. The mAs monitors the number of electrons produced at the cathode and then the number of X-rays produced at the anode. Our results recommended that using high tube voltage (kVp), low current (mAs), and minimized exposure dose of X-ray can result in clear and a high-quality images.

The amount of (mAs) has a direct proportional relationship with quantity of X-ray produced. If the amount of (current * time) is doubled the quantity of X-ray is doubled and if the amount of (current * time) is decreased to halve led to the quantity of X-ray is reduced to half.

Discussion

Continuous use of X-ray examinations may induce cancers in future due to overexposure to radiation. In the present study, the calculated average dose was different between different age groups. Operators should take a special care regarding overexposure caused by inappropriate high radiographic techniques, which cause unnecessary patient doses (1).

Source surface distance should keep suitable distance between the tube of X-Ray (source of radiation) and the skin of patient during examination. Operators should never forget ALARA principle when using doses. The increases in X-ray tube voltage increase the amount of radiation output, as well as the average photon energy, which increases penetration (2).

Modern X-ray equipment operators may use the manual or automatic control mode. In the manual mode, the operators will determine the factors set, including kVp, milliamps (mAs), and exposure time to the radiation. In general, the rate of exposure time is inversely correlated with the peak kilovoltage of X-ray tube (kVp) and directly correlated with tube current (mAs) (8). Automatic X-ray

machines with high kVp and mAs could expose the patients to more serious risks by increasing the exposure dose (7). X-rays transmitted from the patient are called final intensity of X-ray or termed scatter of radiation. Scatter radiation is directly correlated with an increase in voltage and current. These factors are responsible for the radiation doses between the patients undergoing the same medical X-ray examinations (14).

The selection of appropriate tube voltage (kVp) based on patient age, body mass index, and low exposure time (s) reduce radiation exposure and protect patients from risk of radiation injury. Lowering tube voltage decreases photon energy causing greater absorption by body tissue, and increases image noise (9). Technical factors and dose estimation showed that unnecessary patient doses are being used in Erbil hospitals without any diagnostic benefits (6). The main technical factors that are not considered in our medical imaging radiation centers, they measured by applying high voltage X-ray tube this is meaning the highest amount of exposure to ionizing radiation and unnecessary radiation to patients lead to Poor image quality in our hospitals and without any diagnostic benefit (10).

Conclusion

Many factors can affect the amount of radiation exposure during X-ray examinations. The operators who perform the medical imaging must be aware of the role of these factors on the patient safety (such as exposure time) and the methods for reducing exposure time. Patients should be informed about the risk of radiation, particularly when repeated radiologic procedures are required. The current (mAs) is typically reduced to compensate the increasing voltage (kV). Absorbed dose can be reduced by choosing a high kVp and lower mAs. X-ray voltage tube is one of the primary technical factors that can be adjusted in X-ray tube with tube current and exposure time to protect patient from over-radiation dose. The first parameter to be considered is the amount of peak kilovoltage of X-ray tube (kVp), which ensures adequate penetration and exposure and depends on photon energy and tissue attenuation.

Conflict of Interest Disclosures

The author declare that they have no conflict of interests.

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Ethical Statement

The present study was approved by the Ethical Committee of College of Medicine at Hawler Medical University (KR, meeting code: 9, paper code: 1, date: 11/10/2020)

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Not applicable.

Informed Consent

All patients in the study gave their consent and agreed to participate in counseling sessions.

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