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# Optimization of Radiation Dose Exposition in Medical Imaging via Variation of X-Ray Tube Outputs Parameters

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***Abstract:*** *-* This paper's goal is to shield the patient from needless radiation exposure. To do this, a number of observations and actions have been made to establish the physical components, which are based on the standard methodology for X-ray human diagnostic techniques. Initially, the several parts of the X-ray circuit that deal with the X-ray tube is made to change the input voltage from low-voltage AC to high-voltage DC. Next, we discussed the creation of X-rays via the bremsstrahlung process, which is a unique X-ray process. To ensure that patients receive a low dose and the best possible outcomes, both quality and quantity of X-rays are needed. After that, a variety of criteria determine how much radiation is administered to a patient undergoing a medical X-ray. Several X-ray projections have been examined in this work, and the variables influencing radiography have been identified and recorded. In summary, the relationships between the tube voltages (kVp), tube currents (mAs), and exposure times (s) were carefully observed and analyzed. The outcome shows that a high kVp and low mAs are required to provide the lowest radiation exposure.

***Keywords:*** Medical Imaging, Tube Voltages, Radiation Dose, X-ray Beam, Optimization.

## I. INTRODUCTION

Medical imaging is crucial in precise illness diagnosis and improved patient treatment, and it has shown to be useful throughout the process [1]. Its use is critical at all levels of health care, including preventative medicine, curative medicine, and palliative care. Throughout the last 50 years, the medical community has witnessed a technological evolution that has increased the use of ionizing radiation from X-ray equipment[2], transitioning progressively from analogue to digital detectors and platforms, from single to multiple detectors and platforms [3]. Growing use patterns have emerged from the increased use of medical imaging. The UNSCEAR 2008 Report contains survey findings from 1997 to 2007 and shows rising trends in all levels of health care, mostly due to increased usage of CT [4].The newly published National Council on Radiation Protection and Measurements (NCRP) report 184 [5] verified a rise in usage in radiological procedures in the United States of America (USA) through 2016, but less pronounced than the quick and dramatic growth from the early 1980s to 2006 [6]. According to a recent study that examined data from more than 135 million imaging exams performed in the United States and Ontario, Canada between 2000 and 2016, the annual increase in CT, MRI, and ultrasound exams was highest in the earlier years (i.e. between 2000 and 2016), but continued to rise by 1-5% annually for most age groups between 2012 and 2016 [7].

Due to the importance of the matter, many measurements were carried out to study the factors affecting the quality and quantity of the image, as there are several factors that affect the level of radiation dose provided to the person undergoing medical X-ray examinations in order to take a satisfactory medical image with minimum dose absorption.

## II. RELATED WORK

A Medical imaging is an important part of health care and contributes to accurate disease diagnosis and treatment, but it also can lead to patient harms such as incidental findings, over diagnosis, anxiety and radiation exposure that is associated with an increased risk of cancer [8].

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The National Council for Radiation Protection has emphasized that the use of ionizing the use of ionizing radiation in medical imaging is connected with a risk of cancer and should thus be subject to safety regulations and optimized [9]. According to the International Atomic Energy Agency (IAEA) Radiation Protection and Safety in Medical Uses of Ionizing Radiation, Safety Standards Series No. SSG-46, optimization in diagnostic and interventional medical exposure is "keeping patient exposure to the minimum necessary to achieve the required diagnostic or interventional objective"[10].

The risk of X-rays comes from the radiation they produce, which can harm living tissues [11]. This risk is relatively small, but it increases with cumulative exposure. That is, the more you are exposed to radiation over your lifetime, the higher your risk of harm from the radiation. Things that are risk factors for X-ray damage include [12]:

- A greater number of X-ray tests;
- X-rays at a younger age;
- Being a woman (women are somewhat more likely than males to get radiation-associated cancer in their lifetime). Actions you can do to lower your risk of radiation exposure from X-rays:
- Maintain a record of your X-ray history and ensure that your physicians are aware of it;
- Consult a healthcare provider about testing other than X-ray exams
- Inform the X-ray technician or radiologist if you are pregnant or suspect you may be pregnant [13].

## III. EXPERIMENT DETAILS

The experiments for this study were done on stationary X-ray units in hospitals. Various images were captured by taking many X-ray radiographic projections for different age. Several exposures time and absorption dose will be taken for every projection and a data of different X-ray radiographic projections will be taken. A technologist in radiology must decide on the best parameters, which include exposure time, mAs, and kVp before any examination. Several considerations are important to determine these optimum values. It is crucial to have an acceptable image quality and the shortest exposure time feasible. One of the reasons why three phase and high frequency generators are better than single phase generators is that shorter exposure times are possible with the former. Many statements will be made with kVp or mA selected. The choice of kVp and mA as well as the resulting mAs value should be taken into consideration because time needs to be reduced to a minimum. In order to achieve the best possible radiographic contrast and Optical Density (OD), the radiographer must ensure that the patient is exposed to the right amount and type of X radiation.

### *A.* ***Case1***

X-ray tube potential and mAs was varied for each projection. A numerous X-ray radiographic projections obtained for varying age ranges in Table I .For every projection, the exposure duration and absorption dose are recorded.

Table I. Different X-ray examinations

| Radiograph Projection | KVp | mAs | Exposure time (ms) | Absorption dose µGray |
|---|---|---|---|---|
| Hand | 50 | 3 | 11.1 | 6.47 |
| Hand | 52 | 2 | 6.8 | 4.69 |
| Hand | 55 | 5.12 | 20 | 28.40 |
| Hand | 57 | 3.1 | 9.6 | 9.42 |
| Chest | 120 | 1.12 | 3 | 5.9 |
| Chest | 125 | 1.2 | 5.3 | 13.39 |
| Chest | 125 | 2.4 | 10.9 | 25.9 |
| Abdomen | 70 | 5.65 | 27.3 | 150 |

| | | | | |
|---|---|---|---|---|
| Abdomen | 85 | 11.5 | 34.2 | 202.18 |
| Abdomen | 85 | 6.8 | 6.2 | 59.84 |

Table I shows how the various absorbed doses obtained by the projections and the exposure times that we looked at vary in relation to one another. Table I suggests that there is a direct relationship between the amount of absorption and the exposure time. The absorption dosage increases with exposure duration. The Changes in the KVp change the average energy and the maximum energy of the X-ray beam. The quantity also changes with kVp because bremsstrahlung production increases with increasing projectile electron energy.

*B.* ***Case 2***

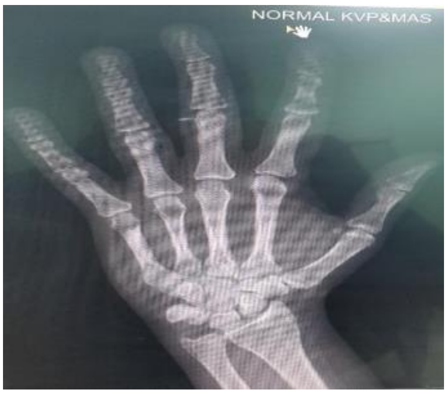
A several chest examination is taken for a fixed KVp with different value of mAs.

Table II. X-ray examinations for Chest

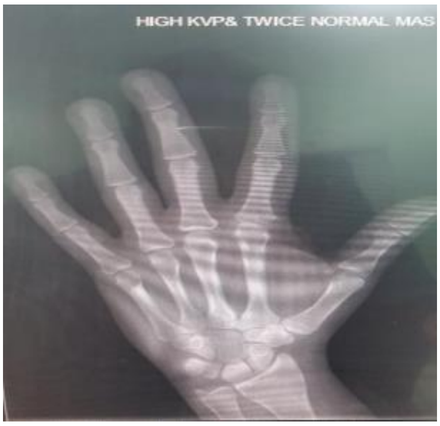
| Radiograph projection | KVp | mAs | Exposure time (ms) | Absorption dose µGray |
|---|---|---|---|---|
| Chest | 125 | 0.7 | 3.3 | 5.43 |
| Chest | 125 | 4 | 2.1 | 2.56 |
| Chest | 125 | 5.3 | 20.5 | 50.94 |
| Chest | 125 | 1.2 | 5.3 | 13.39 |
| Chest | 125 | 2.4 | 10.9 | 25.9 |

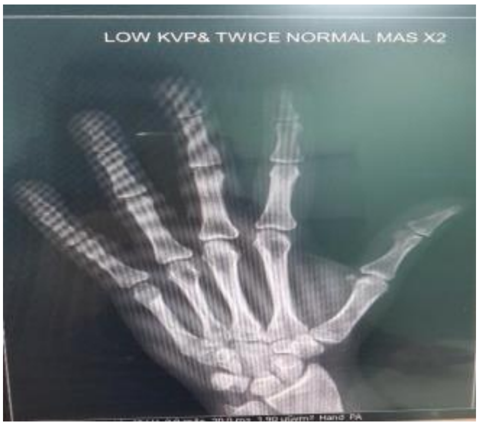
*C.* ***Case 3***

In this part, many combinations of kVp and mAs are adjusted, and the observations are in Fig. 1, in order to give a comparable radiographic image and with a subject dose being minimized.

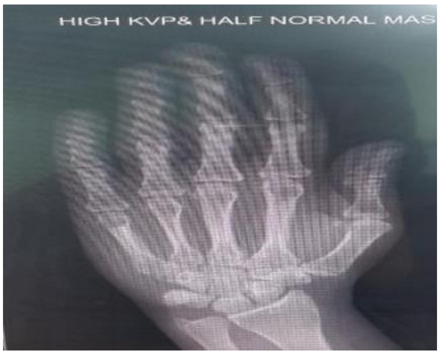


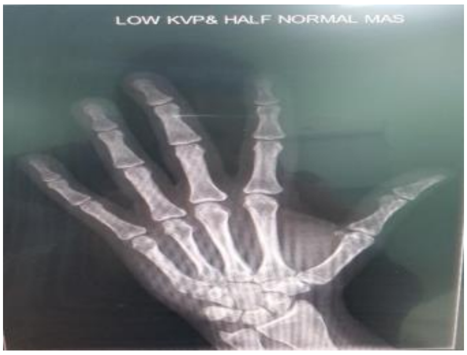

(a) Normal KVp and normal mAs



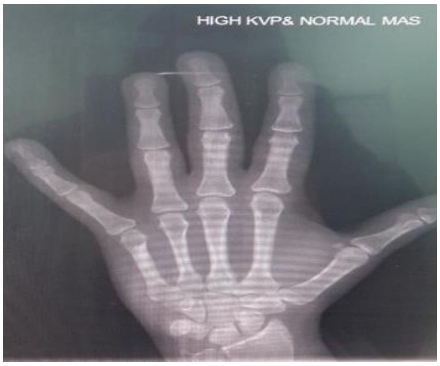



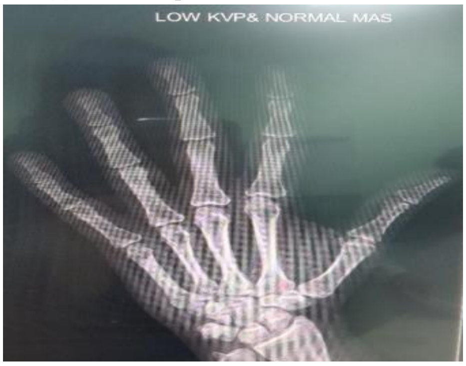

(b) High KVp and twice normal mAs (c) Low KVp and twice normal mAs




(d) High KVp and half normal mAs (e) Low KVp and half normal mAs




(f) High KVp and normal mAs (g) Low KVp and normal mAs

Figure. 1 *Real hand radiographs demonstrating the choice of Kvp and mAs*

The value of kVp governs the penetration of the X-rays in the tissues body .It depends on the kVp setting controlled the contrast of the radio graphic image. An Optimum value of kVp resulted in a sufficient medical image with a minimum absorbed dose.

Figure 1 shows a series of a real hand radiographs demonstrating resulting from many combination of KVp and mAs technique. These factors are indicated on each radiograph image.

As KVp grew, more x-rays were passed through the patient, increasing both the quantity and quality of X radiation for all projections. This also led to an increase in dose absorption.

## IV. Results and discussion

All the combination of KVp and mAs results of a real hand radiographs demonstrating are grouped on the table below:

Table III. Results of combination of KVp and mAs

| Radiograph examination | KVp | mAs | Exposure time (ms) | µGray |
|---|---|---|---|---|
| **Hand ( Normal KVp and Normal mAs)** | 52 | 1.9 | 6.8 | 4.12 |
| **Hand (High KVp and half normal mAs)** | 75 | 0.8 | 2.5 | 2.40 |
| **Hand ( High KVp and normal mAs)** | 75 | 1.9 | 5 | 4.88 |
| **Hand (High KVp and twice normal mAs)** | 75 | 3.8 | 10 | 9.73 |
| **Hand (Low KVp and half normal mAs)** | 40 | 0.8 | 5 | 4.7 |
| **Hand (Low KVp and normal mAs)** | 40 | 1.9 | 10 | 9.4 |
| **Hand (Low KVp and twice normal mAs)** | 40 | 3.8 | 20 | 19 |

From this Table III, when kVp is increased and mAs is twice the normal value of mAs although the exposure time was proportionally increased and the absorbed dose was increased.

We get to the conclusion that a high KVp mostly benefits from a lower absorption dose. In a secondary manner, as the mAs grow and the kVp decreases, the absorption dose rises as well. As a result, there are more X-rays arriving at the image receptor, but the radiation dose to the patient is increased.

The mAs value also influences contrast. To produce a satisfactory quality for a medical image with a minimum radiation dose, the radiographer must choose a high kVp with a compensating reduction in mAs.

Doubling the mAs is equal to increasing kVp. This method works because the X-ray beam is more penetrable, which allows more radiation to reach the image receptor and less radiation to be absorbed by the patient The X-ray beam's amount, but not its energy or quality, is affected by changes in mA. The mA directly determines the amount of the x-ray beam; so, doubling the mA also doubles the x-ray beam's intensity and quantity. Time and mA have the same impact on the generation of X-rays. The amount of x-rays that reach the patient and the image receptor rises as the duration is extended, but this does not alter the x-ray beam's quality or penetrating characteristic. The study concludes that the decrease human dose while producing a good radiography image, it is recommended to use combinations of high kVp and low mAs. It demonstrates how the radiation dose on various radiographic projections is impacted by the decision to change the kVp, which in turn impacts the mAs.

## V. Conclusion

For a very long time, X-ray technology has been an essential component of medical care. It can be used for a wide range of purposes, including as determining the nature of a lung tumor, assessing digestive issues, and diagnosing bone injuries during ER visits. X-rays are generally safe, but if you need several over your lifetime, you may be more likely to develop cancer. Because of this, it's crucial to see your doctor before getting an X-ray so that you have all the information you need to make an educated choice. That's why a good radiographer who can take a satisfactory medical image with a minimum dose absorption. There are many factors that affect the medical image to minimize the dose of absorption. The kVp, which is entirely dependent on the kVp setting, controls how deeply the rays penetrate into the body. The contrast of the radio graphic image is controlled by this voltage peak setting. Optimum kVp resulted in consistent scattering of the beam resulting in sufficient output image. We inferred that there is adequate inverse proportionality between the kVp and mAs, as the kVp is increased the mAs is decreased irrespective. The parameters kVp and mAs are drastically fluctuated irrespective of the projections. Our findings and observations lead us to the conclusion that, in order to provide a decent radiography image while minimizing subject dose, it is preferable to combine combinations of high kVp and low mAs. Our findings lead to the decision to change the kVp, which in turn changes the mAs and, consequently, the subject's radiation exposure on various radiographic projections.

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## REFERENCES

[1] *G*.Frija, I.Blažić, D.P. Frush, M. Hierath, M.Kawooya, L. D.Bach, B. Brkljačić, How to improve access to medical imaging in low- and middle-income countries ?, eClinicalMedicine,Vol38,July 2021

[2] J.Youk and Y. Kwon, Quantitative and qualitative mutational impact of ionizing radiation , Cell Genomics, vol. 4, no. 2, pp. 1-13, Feb, 2024.

[3] M. Rehani, O. Ciraj-Bjelac, E. Vañó, D. L. Miller, S. Walsh, B. D. Giordano., Radiological Protection in Fluoroscopically Guided Procedures Performed Outside the Imaging Department, Annals of the ICRP, vol. 40, no. 6, pp. 1-102, 2010,

[4] S. Hussain and all, Modern Diagnostic Imaging Technique Applications and Risk Factors in the Medical Field: A Review , BioMed Research International , vol. 22, no. 5, pp. 1-19, Jun 2022, https://doi.org/10.1155/2022/5164970

[5] Medical Radiation Exposure of Patients , United States Report, National Council on Radiation Protection and Measurements (NCRP), No 184, Bethesda, Md, 2019

[6] J.Aldrich and all, Optimization of dose and image quality for computed radiography and digital radiography,Journal of Digital Imaging,Vol.19, No.2, pp. 126-131, Jun 2006,

[7] M.S. Huq, The report of Task Group 100 of the AAPM:Application of the risk analysis methods to radiation ther -apy quality management,Med Phys,vol. 43, no.7,pp.42104262,Jul2016, https://doi.org/10.1118/1.4947547

[8] T.Kumar and R. Ponnusamy, Robust Medical X-Ray Image Classification by Deep Learning with Multi-Versus Optimizer, Eng. Technol. Appl. Sci. Res., vol. 13, no. 4, pp. 111406–11411, Aug. 2023

[9] A. Kerr,C. K. Chekar,E. Ross,J. Swallowand S. C.-Burley, Personalised CancerMedicine : Future Crafting in the Genomic Era, 1st Ed, Manchester University, 2021.

[10] F.Bouzar jomehri, Patient dose in routine X-ray examinations, Yazd state. Iran., Vol.1, No.4, pp. 199-215,2004.

[11] K. Naeem, A. Hussain, and S. Abbas, A Review of Shaped Charge Variables for its Optimum Performance, Eng. Technol. Appl. Sci. Res., vol. 9, no. 6, pp. 4917–4924, Dec. 2019.

[12] R. F. A. Marar, D. M. Uliyan, and H. A. Al-Sewadi, Mandible Bone Osteoporosis Detection using Cone-beam Computed Tomography, Eng. Technol. Appl. Sci. Res., vol. 10, no. 4, pp. 6027–6033, Aug. 2020.

[13] F. A. Cavalcanti, L. A. P. Santos, A MOSFET-Based Method for Measuring Peak Kilovoltage (kVp) in Diagnostic X-Ray Beams, in IEEE Open Journal of Instrumentation and Measurement, vol. 1, pp. 1-7, 2022.