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Literature study of the influence of exposure factors on receiving radiation doses in radiographic examinations

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ABSTRACT

High tube voltage with reduced tube current and exposure time can reduce the dose received by the patient. Based on the principle of optimizing radiation protection and safety, efforts are needed to minimize patient doses in such a way that it still allows for obtaining the necessary diagnostic information. The aim of this study is to investigate whether high tube voltage and lower exposure time can minimize the radiation dose received by patients. This study used a literature review method as the basis for research planning. Literature review involves searching and analyzing various sources of information such as books, journals, and relevant publications to understand the research topic. The research findings indicate that high tube voltage and lower exposure time can minimize the radiation dose received by patients. Therefore, understanding the role of technical factors in radiation dose settings is crucial for medical operators performing X-ray examinations. By selecting the appropriate kVp and mAs settings, it is possible to ensure minimal exposure dose.

Keywords: Dose; literature review; kVp; mAs; X-rays

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INTRODUCTION

X-rays are a type of electromagnetic radiation similar to visible light. However, X-rays have higher energy and can penetrate most objects, including the human body. The use of X-rays in the medical field is to create images of structures and tissues in the body. When X-rays pass through the body and reach the detector on the other side, a “shadow” image of the objects inside the body is formed [1].

In diagnostic procedures, good quality is essential. Exposure factors can influence the quality of radiography. Exposure factor settings must be carried out carefully to produce optimal-quality radiographs and ensure that the patient receives the smallest possible radiation dose, in line with the ALARA (as low as reasonably achievable) principle. The use of radiation sources is carried out by paying attention to minimizing the radiation dose received by patients, medical workers, and the general public as much as possible. The exposure factor consists of tube current (mA), tube voltage (kV), and exposure duration (s). Tube voltage is one of the important factors for X-ray tubes which regulates the amount of energy emitted and controls the quality of the beam, the tube current. The tube current regulates the total number of electrons that can pass through the target, producing X-rays with the energy and intensity used to penetrate specific organs. Meanwhile, the duration of exposure is determined by the exposure time, thus influencing the number of X-rays produced [2].

Radio diagnostic examination is a diagnostic process that uses X-ray technology or other ionizing radiation to produce an internal image of the human body. Its main purpose is to detect, diagnose, and monitor medical conditions or injuries in the body. To improve the optimization of radiation dose in patients undergoing radio diagnostic examinations, it is essential to have detailed knowledge of the dose the patient receives during the procedure. This ensures that radiation protection is met without compromising the image quality required for diagnosis. In contrast to the doses received by radiation workers and the public, medical radiation doses cannot have a set limit value because they must be adjusted to specific diagnostic needs. Thus, protecting patients from excessive doses can be done by limiting radiation doses as a guide used for radio diagnostic techniques.

Thus, it is important to pay attention to the radiation dose received by the patient during diagnostic imaging procedures, both in terms of the technique to be used and in terms of equipment. The total radiation dose received can be a topic of interest for radiation dosimetry. Because it can indicate a potential risk of biological tissue damage to the patient. The biological impacts of radiation are categorized into stochastic and deterministic effects. As regulated in Regulation Number 8 of 2011 by the Head of the Nuclear Energy Regulatory Agency, the radiation dose received by the public must not exceed 1 mSv per year. The guideline value for skin surface radiation dose per radiograph on PA projection chest x-ray examination for patients is 0.4 mGy. This study aims to determine whether a lower exposure time with a high tube voltage can minimize the radiation dose received by the patient.

RESEARCH METHODS

The method used in this research is the literature study method which is used as a basis for planning in research. Literature studies involve searching and analyzing various sources of information such as journals, publications, and related books to understand the research topic. The goal is to introduce new knowledge on a topic and increase researchers' understanding of the topic. In this case, researchers analyzed scientific papers published in national journals and published between 2014 and 2023 to support the research being carried out [4]. The steps in carrying out this research were carried out as follows [5], determining the research topic, collect relevant information, determine the research focus, collect data sources, present the collected data, and prepare reports.

This research uses a data analysis method that refers to the approaches of Krippendorff (1993) and Sabarguna (2005) [6,7]. This approach involves four steps, namely the process of selecting, comparing, combining, and sorting data to find relevant information.

RESULTS AND DISCUSSION

Based on the results of a literature review from several journals, it was found that the X-ray tube voltage was between 60-120 kVp. Increasing the tube voltage produces more electrons from the filament (cathode); as a result, there is an increase in the production of X-rays due to greater interaction between the electrons and the anode of the X-ray tube. When the kVp value is increased in technical factors, this results in an increase in the X-ray energy produced. High voltage increases the number of electrons in the X-ray tube around the cathode and can cause penetration into the patient's body. In addition, mAs is a measure of the radiation produced over a certain period. Data obtained from several journals are:

Table 1. Results of skin surface radiation dose measurements in postero anterior projection thorax examination using high tube voltage [2].

Exposure factor				TLD	Radiation dose (mGy)
kV	mA	Ms	mAs		
100	100	20	2	86	0.029
100	100	8	0.8	88	0.023
100	100	6	0.6	87	0.006
100	100	8	0.8	89	0.023

Based on the research journal in Table 1, it is known that the use of a higher kV in radiographic examinations, such as 100 kV with 2 mAs, produces a radiation dose of 0.029 mGy, proven safe and by the guidelines in Regulation Number 8 of 2011 by the Head of the Nuclear Energy Regulatory Agency. This is because high kV produces greater X-ray penetrating power, thus allowing the use of lower radiation doses to achieve optimal results. The use of high kV is in line with the ALARA principle which prioritizes the use of the minimum possible radiation dose [2].

Table 2. Estimated radiation dose values [8].

Sample	kVp	mAs	Radiation dose
1	55	8	0.194
2	58.5	8	0.225
3	60	10	0.298
4	60	12.5	0.373
5	70	3.2	0.131
6	121	0.9	0.087
7	121	1	0.097
8	125	1	0.101
9	125	0.9	0.091

From the data presented in Table 2, it is evident that radiography number 9 shows the lowest estimated radiation dose of 0.091 mGy, while radiography number 4 shows the highest estimated radiation dose of 0.373 mGy. The total radiation dose received by the patient is directly influenced by various exposure factors, with an important emphasis on increasing the mAs value which is an indicator of the amount of radiation produced, so that the higher the value, the greater the radiation dose received by the patient. From this research, it appears that the results of setting X-ray exposure parameters such as lower exposure time and higher tube voltage can minimize the radiation dose received by the patient by the guidelines of Regulation Number 8 of 2011 by the Head of the Nuclear Energy Regulatory Agency [3-4].

Table 3. Ovarian dose acceptance at low kV and high kV [9].

No	Low kV		High kV	
	kV	Ovaries (mSv)	kV	Ovaries (mSv)
1	66	1.63664 ± 0.03412	100	0.67662 ± 0.01504
2	68	1.50899 ± 0.02524	102	0.65728 ± 0.03177
3	70	1.49071 ± 0.01054	104	0.62369 ± 0.04854
4	72	1.45497 ± 0.04186	106	0.53602 ± 0.01100
5	74	1.25449 ± 0.02957	108	0.52863 ± 0.02031
6	66	1.60063 ± 0.02003	100	0.62483 ± 0.03443
7	68	1.51047 ± 0.00529	102	0.64397 ± 0.02261
8	70	1.48841 ± 0.02386	104	0.60195 ± 0.00416
9	72	1.35912 ± 0.01222	106	0.55765 ± 0.01069
10	74	1.35573 ± 0.03430	108	0.54213 ± 0.01017
Average		1.46602 ± 0.02370		0.59928 ± 0.02087

In Table 3, each phantom model is used for two exposures, using a high kV technique and a low kV technique. For the low kV technique, the exposure factor setting uses tube voltage and tube current at certain values (68 kV 22 mAs, 74 kV 16 mAs, 66 kV 25 mAs, and 72 kV 18 mAs) which are usually used in routine abdominal examinations in clinics. The goal of this setup is to produce abdominal radiographs that meet good quality criteria. Meanwhile, for the high kV technique, the tube current and tube voltage are set at higher values (102 kV 4.4 mAs, 108 kV 3.6 mAs, 100 kV 5 mAs, 106 kV 3.8 mAs, and 104 kV 4.0 mAs) [5].

The results of measuring the dose absorbed by the reproductive organs, measured using a TLD dosimeter, are reported in mSv. Based on Table 3, on abdominal examination with AP projection, the radiation dose received by the ovaries at the high kV setting is 0.599277 ± 0.02087 mSv, and at the low kV setting is 1.466017 ± 0.02370 mSv. In the paired t-test there was a significant difference in the results in the dose received by the ovaries for the high kV and low kV settings, with a p-value <0.001 at the 95% significance level. The average dose difference was 0.86673 (95% CI: 0.81295 – 0.92051), indicating that the number of radiation doses received by patients in the low kV setting resulted in a higher dose than the high kV setting [5].

For abdominal examination with AP projection and using low kV techniques (66 – 74 kV), on the surface of the ovarian skin, the average absorbed dose received is 1.46602 mSv. Meanwhile, with the use of high kV techniques, the dose received by the ovaries is 0.59928 mSv. According to Statkiwieckz, the permitted dose limit is by the guidelines of Regulation Number 4 of 2014 by the Head of the Nuclear Energy Regulatory Agency. The ovarian dose for abdominal examination is a maximum of 2 mSv. Therefore, the dose received in both techniques does not exceed the established dose limit [5]. Previous studies have shown that the use of high kV techniques tends to produce lower radiation doses to the ovarian skin surface compared with the use of low kV techniques. The effects caused by the radiation dose received by the body can be non-stochastic or stochastic. Therefore, choosing the right exposure factor is very important to minimize the possibility of stochastic effects and reduce the risk of non-stochastic effects [5].

Tube voltage (kV) also plays an important role in determining the level of radiation dose obtained. There is a negative correlation between kV and the dose obtained by an individual. As the applied tube voltage (kV) increases, the amount of radiation dose received by the patient decreases. Therefore, increasing the kV value can be used to reduce the radiation dose. X-rays are produced with increased penetration capacity, allowing more X-rays to be transmitted while minimizing the dose absorbed by the body [10,11]. Many factors influence radiation exposure during X-ray examinations, and medical operators need to be aware of the role these factors play in patient safety. Repeated exposure time may increase the risk of radiation, therefore, it is important to reduce exposure time. The use of low mAs and high kVp can reduce the radiation dose absorbed by the patient. Adjustment of kVp and mAs is the main technical factor that can be done to protect patients from excess radiation exposure. Optimal kVp determination ensures adequate penetrating power and exposure, according to photon energy and tissue absorption [6].

CONCLUSION

Based on a literature review from three journals, it was concluded that setting a high kVp and a lower mAs can reduce the radiation dose. Technical factors such as kVp and mAs are important parameters that can be adjusted to protect patients from excessive radiation exposure during X-ray examinations. Thus, understanding the role of technical factors in setting radiation doses is very important for medical operators performing X-ray examinations. By selecting the correct kVp and mAs settings, a minimal exposure dose can be provided.

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