Relation between body mass index and position of chest examination as a function of entrance surface dose

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Abstract. X-ray is ionic radiation which is now a necessity in the health sector as a tool in establishing diagnosis. Calculation of exposure doses in patients generally only considers gender and age, but from a theoretical point of view, energy absorption will be greater with increasing thickness of material. The thickness of the material in terms of chest examination using X-rays is indicated by position of the examination where the lateral examination makes the material exposed to radiation thicker than the posterioranterior or anteriorposterior examination position, as well as the patient's body mass index. Therefore, the relationship between the position of examination and body mass index to the entrance surface dose is the topic of this study. Analysis of chest examination data in several patients with various examination positions and different body mass indices showed an increase in entrance surface dose with increasing body mass index and examination position. The highest entrance surface dose was observed in patients with lateral examination positions, as well as in patients with large body mass indexes.

1. Introduction

X-rays are a type of electromagnetic radiation that can ionize atoms and molecules. The nature of ionization can have a negative impact on the tissues of the human body exposed to X-rays, for example cancer, because there are genetic changes. Conversely, X-ray which is electromagnetic radiation has a large penetrating power. The ability to penetrate the material causes X-rays to be used in several sectors, for example in the industrial sector, X-rays are used to examine the quality of materials, and in the medical field, to see abnormalities or disturbances in organs inside the body without surgery.

Especially in the medical field, the use of X-rays began in 1900, five years since it was discovered by William Conrad Roentgen to detect fractures and abnormalities in the body [1,2]. The use of X-ray radiation continued to develop, until in 1920, X-rays began to be used in fluoroscopy devices that can detect abnormalities or infections that cause ulcers in the stomach, intestines, esophagus to cancer [2]. In 1940, the use of X-ray radiation was no longer single, but several sources of X-ray radiation were used, known as CT scan. As a result, the use of single X-ray radiation is said to be a conventional X-ray device until now [2].

Because the use of X-ray radiation in medicine is very broad, and has become a necessity, various studies have been conducted that are related to the effects of X-ray radiation exposure on the human body. For example the effect of exposure to X-ray radiation in pregnant women [3,4], in blood cells [5], on cells and chromosomes of living things [6], and so on. As a result, many studies have been carried out to minimize the negative effects of X-ray radiation exposure on the human body through...
determination of irradiation doses, absorption doses, equivalent doses, and effective doses. The purpose of determining the dose is to prevent or minimize the effects of X-ray exposure to the body, but can still produce good radiological photographs.

Radiological photo itself is two-dimensional image of the inside of an object that is irradiated with X-rays. This radiological photo is formed because there is a portion of the radiation energy absorbed and transmitted by the material, if no radiation energy is absorbed or all transmitted, no image will be formed. The amount of energy absorbed by the material can be known through the blackness of radiological film. That is why the degree of blackness of radiological film can be associated with irradiation doses that fall on the film, so the film is used as a material to measure the radiation dose received by radiation workers [7, 8].

Until now, many studies conducted only discussed the amount of dose received by the material caused by radiation exposure, and absorbing doses of medium. Common dosage measurements do not take into account the patient's position at the time of examination. Consideration of the patient's position is only used to determine the amount of voltage or current to be used. This is reasonable, because the results obtained are only to be used to clarify the image and predict the effects that can be detected. On the other hand, the thickness of the material will affect the amount of energy absorbed, as expressed in the Beer-Lambert law [9]. Therefore, it is necessary to review the effect of the position of the chest examination using X-rays on the quality of radiological photographs. This is because the position of the patient can represent the thickness of the material that must be passed by X-ray radiation, which in turn will determine the dose received by the body, for example on the skin. In this research that has been done, we measured the dose that arrived at the skin or entrance surface dose (ESD) during the thorax examination using a conventional X-ray device with various examination positions and differences body mass index.

2. Material and Method
This research was carried out in the radiology department of Hasanuddin University Hospital - Makassar - Indonesia. Samples were patients who experienced thorax examinations using X-rays, both those who performed routine medical examinations, and those who had organs dysfunction in the thorax area.

Data on body weight and height were taken before chest X-ray examination, while for patients who could not stand, data on body weight and height were taken from medical records. For electrical voltage data and electric current of the X-ray tube were seen directly from the X-ray machine.

Entrance surface dose (ESD) is calculated using the following equation [10,11]:

\[
ESD \text{ (mGy)} = a \times (kV)^b \times \text{mAs} \times \left(\frac{100}{\text{FSD}}\right)^2 \times \text{BSF} \times \left(1 - \frac{1}{1000}\right)
\]

with a and b are numbers obtained from the graph of the output of the X-ray tube radiation used. The FSD or distance of the focus point to the patient's skin used is 120 cm for PA and AP, and 100 cm for lateral and RLD, while the BSF used is 1.4 [11,12]

3. Result and Discussion
Various positions of examination are carried out on the chest examination using X-ray radiation. This is done in order to obtain good radiological photo quality, which can be used as supporting data to establish the diagnosis, and still maintain patient comfort. These positions are posterioranterior (PA), anteriorposterior (AP) position, left or right lateral from posterioranterior (PA), left or right lateral to anteriorposterior (AP), right lateral decubitus (RLD), and left lateral decubitus (LLD) [13].

The commonly used position or standard position on the thorax examination using an X-ray machine is the posterioranterior (PA) where the patient stands up straight and hugs the film cassette. This position is used for healthy patients who only do the examination as a routine medical check-up, or patients who are sick but can still stand.
Figure 1: Chest examination of posterioranterior (PA) and anteriorposterior (AP) positions

The other position used by the chest X-ray examination is the anteriorposterior position (AP). This position is intended for patients who are sick and unable to stand, so the film cassette is placed under the back of the patient who is in a supine sleeping position. Radiological photographs produced in this position are not as good as in the PA position, so to obtain good radiological photo quality, the voltage and electric current of the X-ray tube must be increased (table 1 and figure 1) [14].

Table 1: Variations in the magnitude of voltage and electric current of X-ray tubes for various thorax examination positions.

| Voltage (kV) | Electric Current Second (mAs) | Thorax Examination Position          |
|-------------|------------------------------|--------------------------------------|
| 52          | 20                           | Posterioranterior (PA)               |
| 58          | 78                           | Anteriorposterior (AP)               |
| 78          | 90                           | Lateral                              |
| 48          | 5                            | Right Lateral Decubitus (RLD)        |

Lateral position is the examination of the thorax sideways, the position of the film cassette is located on the left arm for the left lateral position, and the position of the film cassette is located on the right arm for the right lateral position (figure 2). Generally the left lateral is used to show the right heart and left lung, and lateral lung to show the picture of the right lung. The average human thorax width for men is 46.5 cm, and women are 39.5 cm, and human thorax thickness is between 25 - 35 cm [15], so the thickness of the material X-ray radiation which can be indicated in the position lateral examination is greater than in the PA or AP examination position. As a result, the voltage and electric current of the X-ray tube are highest (Table 1).
If the patient is suspected to have some fluid in the lungs or a permanent or mobile pleural effusion, then the thorax is examined with the right lateral decubitus (RLD) position for the right lung and left lateral decubitus (LLD) for the left lung. The position of the patient can be in position of PA or AP. Especially this position is often used in pediatric patients, therefore, absorbing doses of X-ray radiation are low (table 1).

In the four types of thorax examination positions, it was observed that there was an increase in the use of X-ray tube voltage and electric current second with increasing patient weight, which in this case was indicated by the parameters of body mass index (table 2). The increase in body mass index can be interpreted as increasing body fat or in other words will increase the thickness of the body's thorax. In accordance with the theory of radiation absorption in materials proposed by Lambert and Beer, who said that the thicker the material [16], the intensity of the radiation that is transmitted will decrease, the same thing happened in this study. The increase in body mass index increases the energy of X-ray radiation absorbed by the body, which is shown by the increased use of the operating voltage and electric current second of the X-ray tube.

Entrance Surface Dose (ESD) which describes the radiation dose received by the patient on examination with PA position, in this study had the lowest value of 0.44 mGy for the patients who have the body mass index which was in the underweight category, and increased with increasing body weight, which was 0.88 mGy for those who were in the overweight category. We found the same tendency in the AP examination position, the ESD value has the lowest value of 1.57 mGy for those in the underweight category, and increases with an increase in the body mass index value of 4.67 mGy.
for those in the overweight category. A high ESD was also observed in a lateral position examination for those who were in the overweight group, it was 7.63 mGy. For the right lateral decubitus (RLD) position which is a thorax examination carried out on children, the size of ESD is very low at 0.13 mGy. Overall, the ESD value received by the samples in this research is still lower than the Indonesia Nuclear Energy Regulator Agency (INERA) standard value [17].

| Body mass index | Entrance Surface Dose (mGy) |
|-----------------|-----------------------------|
|                 | PA  | AP  | Lateral | RLD | (AP – PA) | lateral – PA | (RLD – PA) |
| Underweight     | 0.44| 1.57| -       | 0.13| 1.13      | -            | -          |
| Normal weight   | 0.59| 3.47| 5.49    | -   | 2.87      | 4.89         | -          |
| Overweight      | 0.88| 4.67| 7.63    | -   | 3.79      | 6.75         | -          |

The difference in entrance surface dose (ESD) caused by the increase in body weight appeared to be significant, for example from underweight to normal weight for PA position was 0.16 mGy or about 27%, and 1.89 mGy or about 54% for AP position. From normal weight to overweight, ESD increases were 0.29 mGy or about 48% for PA examination positions, 1.21 mGy or about 34% for AP examination positions, and 2.14 mGy or about 39% for lateral positions.

On the other hand, changes in the position of the examination also increased the ESD significantly, such as from the PA position to the AP position, the dose increase was 3 times greater, and from the PA position to the lateral the ESD increment reaches 8 times. Therefore, the thorax examination using an X-ray plane is always or wherever possible in the PA position.

4. Conclusions.

From the discussion above, it can be concluded that body weight and examination position determine the dose that the patient will receive. Increasing body weight and changing the position of examination from PA to another will increase the radiation dose received by the patient.

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