Evaluation of dose radiation on x-ray radiography

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Abstract. Evaluated radiation dose and output of general radiographic machine on the thorax and abdomen examination. Radiation output testing on 53 radiographic machine produced 1985-2017 in East Java, Indonesia. For thorax examination, 45-89 kV, 100-200 mA, exposure time 0.01-100 s and abdominal examination, 50-89 kV, 18-320 mA, exposure time is 0.02-100 s. Tests are carried out with the Piranha X-Ray Multimeter. There are reportedly 3 of 53 radiographic machine in the thorax examination as follows: the incident air kerma (INAK), tube output, and entrance surface air kerma (ESAK) rates ranged between 0.019 - 1.604 mGy, 0.0004 - 0.0057 mGy/mAs, and 0.024 - 2.101 mGy. While on abdominal examination, the INAK, tube output, and ESAK rates ranged between 0.009 - 2.710 mGy, 0.014 - 0.072 mGy/mAs, and 0.013 - 3.660 mGy. From data with various brands, general radiographic machine in East Java, for Thorax and Abdomen examination INAK values are below 1.604 mGy, 2,710 mGy, values are below 0.0057 mGy / mAs, 0.072 mGy / mAs, and ESAK values are below 2,101 mGy, 2,710 mGy and still within the limits permitted by the BAPETEN regulation in Indonesia.

1. Introduction
The output of general radiographic x-ray machine which are currently used in hospitals, needs to be evaluated to ensure safety for patients, workers and the community. Based on BAPETEN regulation No. 8 of 2011, one of the parameters that directly affects the patient's radiation dose and determines the feasibility of an x-ray machine operation on a patient is the dose information received by the patient and general radiographic X-ray output. Until now circulating x-ray machine throughout Indonesia around 7,000 general radiographic x-ray machine with various brands and years of installation in each hospital. Until now there is no data related to the evaluation of the output and dose of radiation that the patient will receive. For this reason, it is necessary to evaluate general radiographic machine radiation doses and conditions to pass the test in accordance with existing regulations.

2. Theory
Exposure is proportional to the energy fluids in the X-ray beam which is affected by the quality and quantity of X-rays. X-ray quality is the ability of X-rays to penetrate objects, the greater the energy the greater the HVL value, the greater the ability of X-rays to penetrate. The quantity of X-rays is the number of photons contained in the irradiation. X-ray exposure, quality, quantity and efficiency of X-
ray production are influenced by six main factors, namely target material, voltage, electric current, irradiation time, filtration and generator waveforms.

Kerma is the sum of all the initial kinetic energy transferred from uncharged particles (photons) to charged particles (electrons) in a material with a certain mass. Energy absorption due to ionizing radiation in a material can be measured using the calculation of the absorbed dose. Incident Kerma Water (INAK) is the dose on the central axis of the X-rays at the point where X-rays enter the skin, this dose does not include backscatter factor. Entrance Surface Kerma Water (ESAK) is the air that is in the middle of the axis of the X-ray beam at the point where X-rays enter the phantom. This includes the effect of backscatter factor. This ESAK was recommended by the International Commission on Radiation Units and Measurements (ICRU) for dosimetry in medical imaging.

Measurement of entrance surface charcoal water can be determined by indirect measurement by using incident water and backscatter factors or can take measurements directly using TLD. ESAK measurements use incident value of charcoal water and backscatter factor in the air, the selection of backscatter factors is based on HVL and the size of the field used during inspection. In addition to INAK and ESAK there are also other parameters on the X-ray machine, Tube output at distances d (Y (d)) is a kV function and the relationship is approximated by the power function, power regression is usually used to display increased experimental results with a specific rate of increase.

3. Materials and methods
Radiation output testing on 53 radiographic machines produced 1985-2017 in East Java was carried out with the following settings: For thorax examination, SSD 100 cm distance, voltage variation 45-89 kV, current strength 100-200 mA, exposure time 0.01-100s and whereas for abdominal examination, SSD distance is 100 cm, voltage variation is 51-89 kV, current strength is 18-320 mA, exposure time is 0.02-100 s. Tests are carried out with the Piranha X-Ray Multimeter.

4. Results and Discussion
To find out the voltage accuracy voltage measurement is performed. Voltage obtained the voltage on the panel tool and the measurement result is the difference of 0-28%. There are 3 of 53 radiographic machine that have exceeded 10% a voltage difference, the voltage difference affects the radiation output on X-ray machine, which will affect the dose of INAK, tube output and ESAK

![Graph](image)

**Figure 1.** The relationship between the INAK (mGy) and the tube voltage (kV) in the abdominal examination

From the graph, it can be seen that the variation in the machine tube voltage ranging from 50 kV-89 kV on the X-axis and the output on the Y-axis is the incident value of kerma water or incident dose.
(mGy) which is the measurement result to get the dose distribution parameter incident between the tube voltage (kV). Based on data and graphs, the value of INAK from various x-ray machines is 0.009 - 2.710 mGy and the INAK value exceeds 1.5 mGy, namely the tube voltage of 81.302 kV INAK value of 1.721 mGy, at tube voltage 72.658 kV INAK value of 2.315 mGy, at tube voltage 79.955 kV INAK value 2.710 mGy, at tube voltage 72.672 kV INAK value 2.678 mGy, tube voltage 79.955 kV INAK value 2.710 mGy, and tube voltage 94.36 kV INAK value 1.750 mGy, INAK value exceeding the value of 1.5 mGy this shows that there is an INAK value that exceeds the average which needs to be recommended for a review of the radiation output for the x-ray machine.

![Graph](image1.png)

**Figure 2.** Output tube (mGy / mAs) at tube voltage (kV) on abdominal examination

The value of the tube output between 0.014 - 0.072 mGy / mAs, from the above graphs can be found that the tube voltage variation ranging from 50 kV- 89 kV yields the output value of the output which varies the graph shows that the tube output exceeds the average 0.05 mGy / mAs) at 72.672 kv, 72, 682kv, 77, 555 kv, 79.955 kv, and 82, 035 kv tube output values of 0.063 mGy / mAs, 0.074 mGy / mAs, 0.061 mGy / mAs, 0.067 mGy / mAs and 0.063 mGy / mAs.

![Graph](image2.png)

**Figure 3.** Entrance Surface Air Kerma (ESAK) (mGy) with tube voltage (kV) on abdominal examination
From the graph, we can know that by varying the tube voltage starting from 50kv-89kv to produce ESAK (mGy) entrance surface water kerma, the ESAK value obtained by calculating backscatter factor (BSF) on the tube voltage of each machine, the BSF value used is 1.26, 1.35, 1.38 and 1.41 referring to the voltage value with the source of TRS 457 in 2007. ESAK values obtained were between 0.013 - 3.660 mGy. The average obtained is still in the range of 2 mGy, but at tube voltage 72,685 kV ESAK value is 3.125 mGy, 79,9551kv ESAK value is 3.660 mGy and at tube voltage 81,302 kV the ESAK value is 2.375 mGy. This shows that the ESAK value is still at the recommended dose by Safety Series N0115 which is for abdominal radiography examination of 10 mGy.

**Figure 4.** The graph between the INAK (mGy) with the tube voltage (kV) on the thorax examination

From this graph, it can be seen that the variation in the tube voltage from 45 kV-89 kV on the X-axis and the output on the Y-axis is the incident value of kerma water or incident dose (mGy) which is the measurement result to get the dose distribution parameter between the tube voltage (kV) on each machine. Based on data and graphs, it can be seen that the INAK is between 0.019 - 1.604 mGy and that exceeds 1.5 mGy, ie at 64.92kv voltage is 1.604 mGy, the INAK value which exceeds the 1.5 mGy value indicates that the INAK value exceeds the average need to be reviewed for the output of the x-ray tube.
Figure 5. The output tube graph (mGy / mAs) with tube voltage (kV) in the thorax examination.

Tube voltage (kV) From figure 5 it can be seen that the tube voltage variation ranging from 45kV-89 kV produces tube output value between 0.0004 - 0.057 mGy and the data and graph shows that there is a tube output exceeding the average of 0.04 mGy / mAs at tube voltage 58.7 kV tube output equal to 0.0493 mGy / mAs, at tube voltage 71.9 kV tube output value is 0.053 mGy / mAs, and at tube voltage 88.47 kV tube output value is 0.057 mGy / mAs.

Figure 6. Entrance Surface Air Kerma (ESAK) (mGy) with tube voltage (kV) on thorax examination

From figure 6 we can know that by varying the tube voltage starting from 45kV - 89kV to produce ESK (mGy) entrance surface water, the ESK value obtained by calculating the backscatter factor (BSF) on the tube voltage of each, the BSF value used between others are 1.26, 1.35, 1.38 and 1.41 referring to the voltage value with the source of TRS 457 in 2007. The average ESK value obtained is still in the range of 0.4 mGy, but at tube voltage 57, 42kV ESK value is 0.509 mGy, 58.26 kV ESK value is 0.664mGy and at tube voltage 58.705kv the value of ESK is 0.745 mGy at tube voltage 58.888kv ESK value is 0.465 mGy, 60.26kv ESK value is 0.464mGy and at tube voltage 64.924kv ESK value of 02.101mGy, tube voltage of 71.1 kV ESK value of 0.698 mGy, and
at tube voltage 71.96 kV ESAK value of 1.82 mGy, this shows that the ESAK value is above the recommended dose by Safety Series N0115 that is for radiographic examination of the chest of 0.4 mGy.

5. Conclusion
Radiation dose on the radiographic x-ray radiographic output of the thorax examination was with a value of incident air kerma INAK between 0.019 - 1.604 mGy, the value of the tube output between 0.0004 - 0.0057 mGy / mAs and the value of entrance surface air kerma (ESAK) between 0.024 - 2.101 mGy. For abdominal examination with incident air kerma INAK value between 0.009 - 2.710 mGy, the value of the tube output between 0.014 - 0.072 mGy / mAs and the value of entrance surface air kerma ESAK between 0.013 - 3.660 mGy.

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