Calculation application of patient's dose on fluoroscopy x-ray machine

by Eko Hidayanto

PAPER

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Abstract. Dose recording in patients is not well implemented and so far has not been supported by the dose panel on the X-ray machine. Therefore, it is necessary to develop a dose-record application capable of storing dose data to support the patient's radiation safety. It also refers to the regulation of diagnostic radiology service standards, medical records, and hospital accreditation standards regulated by the Ministry of Health. This study aimed to design an application of patient dosage record for abdominal examination with a Fluoroscopy X-ray machine. The design of dosage record application is done by exposing to radiation output and voltage (kV) variation of X-ray irradiation on 63-94.8 kV, current strength on 0.9-3.1 mA, and phantom thickness on 5-21 cm. The data is processed and multiplied by backscatter factor (BSF) is 1.35 to get entrance surface dose (ESD). ESD formula that can be included in the program script in the XAMPP software application. The dosage record application design can be used to record patient data with the calculated formulation obtained.

1. Introduction

Physics has an important role in the medical field, especially in understanding the work function of body organs, developing diagnostic tools, treatment, and therapy techniques. One of the roles of physics in the medical world is the use of X-rays. In medical science, X-rays are used to look at the condition of the bones, teeth and other organs without performing surgery on the patient's body. One of the benefits of X-rays is that they can detect organ abnormalities quickly through radiodiagnosis.

Since the discovery of W.C Roentgen's X-rays, a graduate of Physics from the German Wurzburg University, many scholars have researched X-rays. This is evidenced by the rapid development of X-rays in various fields, one of which is radiodiagnostics, imaging technology.

Following the machine used, namely fluoroscopic radiography machine, fluoroscopic, radiographic techniques use the ability of X-rays to produce body structure images so that certain radiation doses are needed to image the patient's body structure. Therefore, medical physicists need to examine the radiation dose received by the patient with fluoroscopic radiography. X-rays are considered to provide a large contribution and advancement of the medical world, but X-rays also have a negative impact or effect on X-ray recipients if the radiation dose given is not at the safe limit value. So that it is necessary to monitor the patient's dose at the time of the examination and also test the suitability of the X-ray machine.

Suitability Test for each X-ray Machine Diagnostic and Interventional Radiology has been applied as a permit requirement for the use of ionizing radiation sources which is a mandate of 40 articles of Government Regulation Number 33 of 2007 concerning Safety of Ionizing Radiation and Radioactive Source Safety. Because the X-ray machine is a major component in radiology services, X-ray machines

must be in a state of proper use. In the suitability test, there is a measurement tolerance limit that is allowed to declare X-ray machines safe and suitable for use. If the machine is in an improper condition or does not meet safety standards, the machine can endanger the radiographer, the patient, and the surrounding environment. Radiation exposure, either from radiation accident or medical X-ray examination at the early stage of life usually results in a likelihood of two or three-fold increase in lifetime risk for certain detrimental effects. Patient doses depend on a number of factors such as machine factors; age, size, and body composition of the patient; and user setup, such as collimation and source-to-skin distance. The dose rate to the patient is greatest at the skin where the x-ray beam enters the patient.

Based on Diagnostic X-ray Equipment Compliance Testing from the Radiological Council of Western Australia in 2006, feasibility testing was carried out with quality control activities in the form of measurement of collimation accuracy, measurement of tube voltage accuracy (kV), measurement of exposure time accuracy, measurement of linearisation (mA), measurement of effective focal point, measurement of center grid accuracy, measurement of X-ray machine tube leak and exposure of scattered radiation. By carrying out the X-ray machine suitability test, it is expected to be able to produce high-quality images with the radiation dose given as small as possible within the safe limit of adhering to the ALARA (As Low As Reasonable Achievable) principle.

Protection of patients against radiation exposure is an important concern. 8/2011 states that safety from ionizing radiation in the medical field is an action taken to protect patients, workers, members of society and the environment from radiation hazards. One of the X-ray machine suitability test parameters is the X-ray machine output linearity that can be used to determine the ability of X-ray machine each period and can be used to predict the calculation of surface dose in patients. Linearity test is expected to examine the consistency of the increase in radiation output value (mGy/mAs) on mA or mAs variation.

This research aims to obtain the X-ray machine linearity coefficient on fluoroscopic radiography, to obtain the X-rayradiographic radioscopy machine's output formula and to make an application for calculating and recording radiation doses for patients.

2. Research Methods
The study was started by a literature study on researches that have been conducted previously related to this research. After obtaining the appropriate problem formulation and theory, continued with research with the following procedures:

2.1 Data retrieval of X-ray machine exposure data
Data collection on radiation exposure begins by preparing a radiographic device fluoroscopy then positions the patient's table horizontally with the X-ray tube, so that radiation beam irregularities must fall perpendicular to the patient's table. Next, put MPD (Multi-Purpose Detector) in a horizontal position with the water pass so that the radiation beam can fall perpendicularly. The detector is placed in a position facing the primary beam and placed at a distance of 100 cm from the focal point of the irradiation or X-ray tube.

Furthermore, voltage regulation will be measured on fluoroscopy radiography devices with a voltage variation of 63-94.8 kV, current strength of 0.9 to 3.1 mA and phantom thickness of 5- 21 cm. This research was carried out using fluoroscopic radiography machine. The machine used was Siemens x3-ray machine model 03345233, serial 504341282 series option tube 150/40 / 80HC having a large focus 1, small focus 0.6 voltage 150 kVp and current strength 800 mA.

2.2 Calculate the coefficient of linearity
The value of the radiation output such as tube voltage (kV), exposure time current (mAs), and dose rate (mGy) will be measured in the Multi-Purpose Detector (MPD) inside the Piranha measuring instrument. The measured variable in the Piranha is recorded and calculated for its linearity coefficient using the formula:

$$linearity = \frac{X_2 - X_1}{X_2 + X_1} \times 100\% \qquad (1)$$

where X_2 is the maximum radiation output, and X_1 is the minimum radiation output. The dose measurement results in mGy/mAs.

The resulting value must not exceed 0.1, and if it exceeds, then there is no compatibility between the tools measured on fluoroscopic radiography.

2.3 Designing web-based data using XAMPP software

The data obtained from the results of research using Piranha is the measured voltage (kV), the measured time current (mAs), the radiation dose (mGy) produced. The data is then processed using a Microsoft Excel program so that the linearity coefficient and dose received by the patient (mGy) are obtained. The data will later be displayed on the estimated radiation dose on the web.

Web-based databases are designed using the XAMPP program with the PHP (Personal Home Page) programming language which is used as a programming language server-side script designed to develop the web. In the medical field, XAMPP is used to support dose formula calculation on INAK that will be inputted in the application, useful for medical records. Processed data on Microsoft Excel is the data that will be entered into the web service which then can be used by a database useful for consistency in output linearity, can be used for patient doses by adding back scattering factors.

3. Discussion and results

3.1 Measurement of linearity of the output

X-ray machine output linearity measurement to test the consistency of the increase in the value of radiation output (mGy/mAs) in the variation of mAs. The voltage setting is set at 62 kVp, the current strength is 0.9 mA and the exposure time is 2999 - 4203 ms with five times the exposure obtained a linear coefficient value of 0.000045. This value indicates that the X-ray machine output is still linear. So that it can be used for inspection and the data of the family can be used to calculate the dose received by the patient. The linearity coefficient value also still passes the test on the X-ray machine suitability test parameters referring to BAPETEN No. 9 of 2011 Head Regulation.

3.2 Data processing and formulas

Voltage data, strong time flow, thick phantom, distance measurement, the radiation dose from measuring instrument is the initial data to be processed for data processing which will be obtained dose calculation formula. Dose calculation formula in the form of power regression relationship between the output of radiation output (mGy/mAs) and voltage variation (kVp) on certain phantom thickness (cm).

Using the power function chart is a reference from the IAEA provisions to get the equation of the formula for the radiation output of the X-machine-machine against the voltage (kV) of the machine. For each different type of machine, the different line values depend on the data obtained. The equation obtained then becomes the main equation in dose prediction. Here is a chartical picture of the relationship between radiation output (mGy/mAs) and voltage (kV) of X-ray machines on irradiation without using phantom:
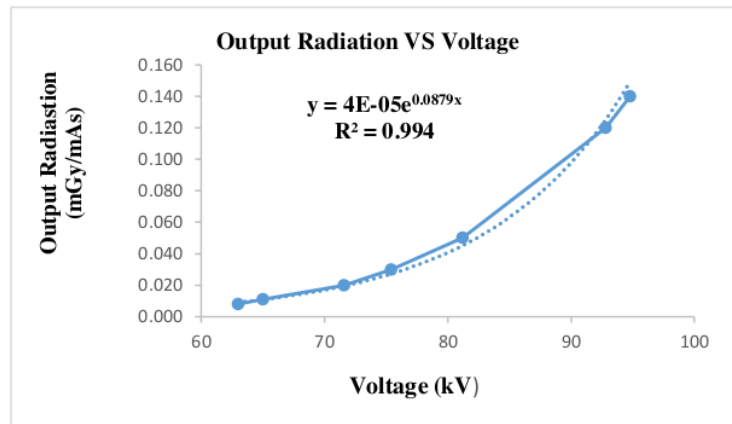
Output Radiation VS Voltage

$y = 4E\text{-}05e^{0.0879x}$
$R^2 = 0.994$

Output Radiastion (mGy/mAs)

Voltage (kV)

Figure 1. Chart of voltage and radiation output relationships.

From the chart above (Fig. 1) obtained the equation $y = 3E\text{-}15x^{6.8945}$ with the resulting radiation output value has linearity with an R^2 value of 0.999, rising specifically to the increase in tube voltage (kV). The chart of the relationship between the radiation output (mGy/mAs) and the voltage (kV) of the X-ray machine on the irradiation of the voltage variation is 63-94.8 kV, the current strength is 0.9 - 3.1 mA and the phantom thickness is 5- 21 cm.

From the above equation (Eq. 1), it can be used to calculate the output value of the dose (output) at a distance of d *[Y(d)]* with x as the tube voltage value (kV) when examining the patient with fluoroscopy machine. As a predictive dose received by the patient. The higher the tube voltage is given, the higher the output of the X-ray machine

3.3 Making calculation applications and recording doses

The design of web-based dose prediction application is done using the XAMPP program which is a stand-alone server (localhost) with the JavaScript programming language, HTML (Hypertext Markup Language), and PHP (Personal Home Page). XAMPP is chosen as an application program that is used to create websites because of its ease of use and functions as an offline server with interesting features.

Web applications can be accessed using the address HTTP: // localhost / phpmyadmin. The following program code is used for translate commands in the PHP programming language in notepad ++:
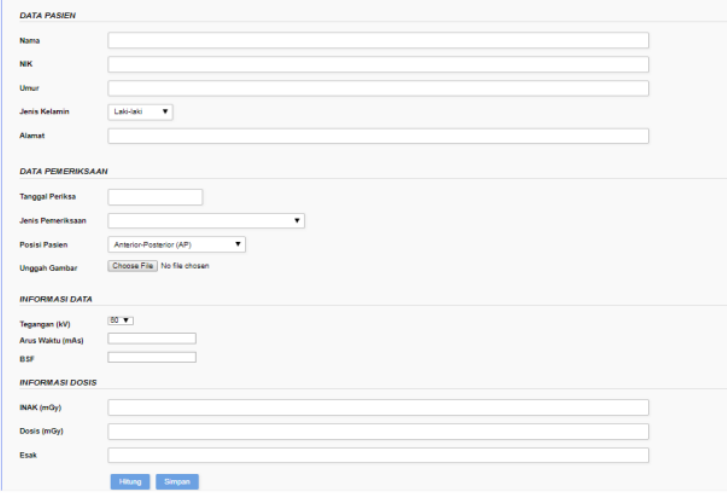
The results of research on fluoroscopic X-ray machine obtained several components of values that will be used in the calculation to predict patient dose values using Microsoft Excel programs.

The formulation used to predict the patient's dose value is to use the equation on the chart of the radiation output / linearity output (mGy/mAs) with voltage (kV) where the equation $y = 3E\text{-}15x^{6.8945}$ is obtained, then put into the equation to get INAK (Incident Air Kerma) namely INAK = α (kVp) ^ β × mAs. With α = 3E-15, x = Voltage, β = 6.8945 and mAs = time flow.

The chart above shows the radiation output linearity of the relationship between voltage (kVp) to the radiation output / output (mGy/mAs) using the power function calculation on fluoroscopic X-ray machine at FDD = 100 cm, indicated by the value of $y = 3E\text{-}15x^{6.8945}$ with a value of $R^2 = 0.999$ with y is the value of the radiation output (mGy/mAs) and x is the voltage value (kVp) used.

This equation is then used to estimate the INAK (Incident Air Kerma) and ESD (Entrance Surface Dose) doses. So that to obtain the ESD value, the INAK value must be corrected by a backscatter factor (BSF). The equation used to predict the patient's dose value is ESD = INAK × BSF. According to the IAEA Technical Report Series No. 457 of 2007, the backscattering factor for radiography has a value ranging from 1.24 - 1.67. The backscattering factor of the patients used was ~ 1.35.

The results of the calculations to predict the calculation of the patient's dose are then entered into a web-based dose recording application. This application is divided into three parts, namely: patient data: inspection data, and data information. The application is then implemented in the form of an interface display as shown in the picture below. The following are the parameters needed to fulfill the completeness of the dose prediction application:

Figure 2. Input of Information on the application

In Fig. 2, web pages are designed using HTML. Information on this web page is divided into four parts of information, namely information on patient data, information on examination data, information on patient radiation data, and dose information. Inpatient data information, information that needs to be included is general patient information such as name, NIK (National Citizenship Number), age, gender, and home address. In the examination data information and irradiation, data must be following what is done in fact. Information on irradiation data has important parameters that will determine the results of the dose value obtained by the patient. The type of machine will determine the formula for calculating the dose, which previously discussed for different types of the machine will produce different line equations as well as the results of the dose obtained. Irradiation parameters such as patient thickness (cm), voltage (kV), and time flow (mAs) must be following the control panel settings. Whereas for programming in the formulation of doses is included using the Javascript programming language.

The data that will be filled in the form of patient information until the irradiation parameter is the input variable which is then processed by the program that has been set to be the output in the form of air kerma value and surface dose. For information on patient data, examination data, and radiation data will then be saved into a database in the MySQL program, while for input voltage (kV), time flow (mAs), and patient thickness (cm) the program will automatically calculate the dose predictions obtained by the patient then stores the data in the database in the MySQL program. The following shows the calculation application and records the patient dose containing the patient's self-filled information stored and processed by koding.process.php and stored as a database in MySQL.

The dose prediction web page can be operated using an HTML program, where the operation does not require an internet connection or offline, so the confidentiality of the patient data that is checked is only for devices that have complete software and certain XAMPP program data. The following is image results of the patient dose prediction database display :

Figure 3. Display of calculation results and record the patient dose database.

Figure 3 shows the display of patient dose record data that has been saved in the web application. The results table of the data will be following the data input that is performed when filling in the inspection information data. It can be seen that by entering the same voltage value (kV) and time flow (mAs) but with different phantom thickness will get a different surface dose value, depending on the results of the equation in certain photoperiod conditions. This proves that the formula used in the calculation of Excel with the formula used in the web application is accurate. This dose prediction application is still in the scope of the local server and can be implemented further by hosting online.

4. Conclusion

The results of the study can be summarized as follows: The linearity value of the radiation output is in accordance with the exposure factor, namely the linearity coefficient of 0.000054. By using the calculation shown in the chart the linearity relationship between output (mGy/mAs) to voltage (kV) is obtained by the equation $y = 3E\text{-}15x^{6.8945}$ with a value of $R^2 = 0.999$. The chart equation of linearity relationship between output and voltage becomes the formula for calculating the dose/value of INAK so that it can predict the dose value (ESD) received by the patient.

The calculation formula is embedded into a web service-based application that can already be run the application for predicting dose value calculation and dose recording for patients. Currently, the method used in this research is categorized as new when research on this field is still rare and therefore it is more difficult to find previous sources deemed compatible.

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