Gravity: Jurnal Ilmiah Penelitian dan Pembelajaran Fisika

http://jurnal.untirta.ac.id/index.php/Gravity

ISSN: 244-515x; e-ISSN: 2528-1976

Vol. 08, No. 02, Aug 2022, Page 70-77

Estimated acceptance of ovarian radiation absorbed dose in abdominal examination using the 10 kV rule method based on Caldose_X Software

Dian Nuramdiani*, Surdiyah Asri Ningrum

Department of Radiology, Politeknik Al Islam Bandung, Indonesia

**E-mail: diannuramdiani@politeknikalislam.ac.id*

(Received: 15 June 2022; Accepted: 18 September 2022; Published: 30 September 2022)

ABSTRACT

Radiation exposure to the ovaries due to abdominal radiology is unavoidable, given its location in the lower abdomen. Ovaries are organs that have a high level of sensitivity to radiation. One of the efforts in applying radiation protection optimization is using the 10 kV rule method. This study aimed to determine the estimated reception of ovarian radiation dose on abdominal radiology examination. The examination was carried out by anteroposterior (AP) projection of the female body phantom (FAX06) using Caldose_X software. The beam variation is set from 60kV/32mAs to 100kV/2mAs. The results of the ovarian radiation dose examination were: 0.484mGy for 60kV/32mAs, 0.402mGy for 70kV/16mAs, 0.309mGy for 80kV/8mAs, 0.227mGy for 90kV/4mAs, and 0.154mGy for 100kV/2mAs. Compared with the radiation dose limit for the abdominal examination set by BAPETEN, the data for this study were much smaller. Likewise, compared with the reference results of previous studies, the data on ovarian radiation dose reception in this study were still within safe limits.

Keywords: abdomen, caldose_X, radiation dose, 10 kV rule method, ovarium

DOI: 10.30870/gravity.v8i2.15734

INTRODUCTION

Within the scope of radiology, many examinations diagnose a disease. One of the radiographic examinations is the abdominal examination. The abdomen is the largest cavity in the body, oval, and extends from above the diaphragm to the lower pelvis. The abdominal cavity consists of two parts, namely the upper abdominal cavity and the lower abdominal cavity. The lower abdominal cavity comprises the bones that make up the pelvic cavity and reproductive organs (Pearce, 2013). The ovary is one of the reproductive organs in women with the size of a walnut that functions to produce hormones and eggs every month from puberty to menopause. The ovary is one of the organs with a high level of sensitivity to radiation. However, radiation exposure to the ovaries due to abdominal radiology is unavoidable, given the position of the ovaries in the lower abdomen. The acceptance of radiation dose for abdominal examination by female reproductive organs (ovaries) is not more than 200mrad (2mSv) (Statkiewicz, Visconti, Ritenour, & Haynes, 2017). Meanwhile, the minimum value for receiving a dose to cause a nonstochastic effect should not exceed 10rad (0.1 mSv) in the reproductive organs (Simon et al., 2006).

Tube tension in X-ray machines is one of the factors that can be controlled to reduce radiation and the dose used in radio diagnostic examinations (Vassileva, 2002). Adjustment of variations in kV values in the examination technique is commonly used for specific projections depending on the size of the patient's body thickness. Bushong (2013) states that engineered systems using the kilo-voltage variation have advantages in various exposures at different body thicknesses. Likewise, the tube current value (mAs) is adjusted for each object examined. Plats (1980) proposed the 10 kV rule method for voltage variations in radio diagnostic studies. This method stipulates that to obtain a relatively equal radio diagnostic image quality, if the kV value is increased by 10 kV, the mAs value must be reduced by half, and if the kV value is decreased by 10 kV, the mAs value must be doubled. The selection of the correct exposure factor can produce optimal radiographic contrast. The tube voltage determines the quality of radiation or the penetrating power of X-rays produced, while the tube current determines the number of electrons that pass through the target so that X-rays are produced with sufficient intensity and energy to penetrate organs.

In addition to producing optimal radiographs, the selection of the correct exposure factors will indirectly provide radiation protection for patients from repeated exposure. Optimizing radiation protection and safety should be pursued to obtain an optimal radiographic image with the lowest possible patient radiation dose. This study examined the absorption of ovarian radiation dose on abdominal examination using the 10kV rule method. The data presented in the form of the indicated dose values are expressed in the entrance surface air kerma (ESAK), incident air kerma (INAK), and organ absorption dose. The data obtained were compared with the dose limit values set by BAPETEN and the results of previous studies.

RESEARCH METHODS

Abdominal examination in this study was carried out through a simulation of X-ray examination using Caldose_X software. Caldose_X is a software that can be used to calculate INAK and ESAK based on the output parameters of the X-ray tube used using the Monte Carlo method (Kramer, Khoury, & Vieira, 2008). In Caldose_X, the tube potential is 50-120 kVp with a total filtration of 2.0 – 5.0 mmAl. The generator potential defaults to a constant value, and the X-ray irradiation angle is 17°. This value is frequently used and represents a frequently encountered X-ray field.

The exposure was carried out on a 1.2 mm FAX06 phantom voxel with organ and soft tissue mass according to the reference data from ICRP89, which is available virtually and integrated. An abdominal examination was performed on a female phantom patient, 35 years old, 60 kg mass and 163 cm high. The examination position was performed in a supine position with an anteroposterior (AP) projection. The area was 35 x 40 cm, with a Focus to Detector Distance (FDD) of 110 cm.

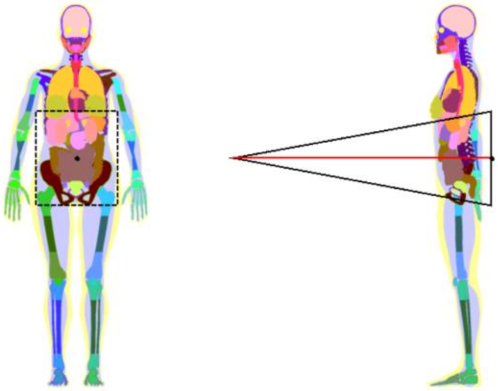

Figure 1. The abdominal examination irradiation position

The determination of the kV value was adjusted to the software's default setting for abdominal examination, which was between 60-100 kV, and also adjusted to the standard kV value commonly used in clinical examinations, which was in the 70-80 kV range with mAs between 20-30 mAs (Handoko, Nurfathoni, & Sulistiyadi, 2019) and in the 66-74 kV range with mAs between 16-25 mAs (Indrati, Sumala, Sudiyono, & Daryati, 2017). Furthermore, the kV variation in this study followed the 10 kV rule based on the theory of G.J Van der Plats (1980), where if the kV value is increased by 10 kV, then the mAs value will be reduced by half, as well as if the kV value is decreased by 10 kV, then the mAs value will increase twice.

Radiation examination started from 60 kV and 32 mAs, and then the voltage values were increased to 70 kV and 16 mAs, 80 kV and 8 mAs, 90 kV and 4 mAs, and 100 kV and 2 mAs. Each simulation for each kV and mAs produced the exact value of the X-ray machine output factor. Furthermore, this output value was used in calculating the estimated value of the radiation dose received by the patient, including details of each organ exposed. The variation of kV and mAs values used in this study is shown in Table 1. below.

Table 1. Variation of kV and mAs values used in the abdominal examination

No	kV Value	mAs Value
1	60	32
2	70	16
3	80	8
4	90	4
5	100	2

The data analysis phase carried out a thorough recap of all the simulation data with various variations in the values of kV and mAs. In a more focused manner, the radiation dose received to the ovaries was reviewed for each variation of its value to obtain the most minimal dose data. Similarly, any data obtained were compared with the dose limit value set by BAPETEN and the results of previous studies.

RESULTS AND DISCUSSION

The estimated radiation dose received by the ovaries from abdominal radiology has been calculated by varying the values of kV and mAs following the 10 kV rule. This study expresses the radiation dose produced in INAK, ESAK, and organ absorption doses. The INAK value was obtained from the air kerma of X-ray irradiation in the mid-phantom position without considering the excellent scattering factor (BSF). The amount of INAK was obtained from the radiation output equation of the X-ray machine used in the examination. Each X-ray machine had a radiation output graph that was different from other X-ray machines. This is unique because each X-ray machine can have a different filtration, HVL, kVp, and mAs. Radiation output data were obtained from the results of the suitability test. In the suitability test for X-ray aircraft, one of the test parameters was voltage accuracy. In voltage accuracy testing, radiation output is measured for each voltage value variation, from the lowest to the highest voltage, according to the conditions of clinical use. The results of the voltage accuracy measurement were then analyzed to obtain radiation output data. The radiation output in this study was obtained, as shown in Figure 2 below.

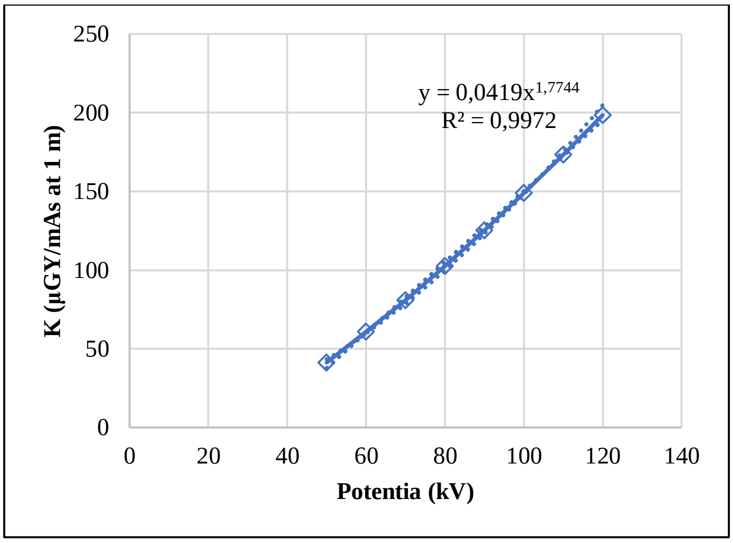

Figure 2. X-ray radiation output graph

The X-ray radiation output represents the radiation exposure value or air kerma (K) of the main X-ray beam measured in free air at a certain distance (usually 100 cm from the focal point) without any backscattering contribution. From Figure 2. above, the radiation output equation is obtained as follows.

$$y = 0.0419x^{1.7744} \quad (1)$$

Alternatively, it can be written:

$$K = INAK\left(\frac{\mu Gy}{mAs} at 1m\right) = 0.0419x^{1.7744} \quad (2)$$

This equation is not much different from Bushberg's (2002), which states that radiation exposure in diagnostics is proportional to the square of the kV value. Furthermore, the obtained INAK equation (µGy/mAs @1 m) can be used if the parameters in the equation are met, namely the value of kVp, mAs, and the distance from the patient to the focus of the X-ray plane. With the correlation coefficient is $R^2 = 0.9978$, and tube current-time (mAs), which tend to be constant, it strengthens the linearity of the relationship between the voltage (potential) of the tube and the output X-ray radiation dose.

The equations obtained from the data analysis in Figure 2 were then used to calculate the estimated dose received by the patient and the radiation dose absorbed by the ovaries. The quantity used to express the radiation dose received by an object is ESAK. ESAK is the radiation dose on the surface of the radiation object, including backscattered radiation or BSF measured at the center of the radiation beam on the patient surface or phantom. The difference between ESAK and INAK is that ESAK includes the dose of scattered radiation, while the incident dose does not include the dose of scattered radiation. So, ESAK will always be greater than the dose of INAK. The following estimates the radiation dose for abdominal examination in this study.

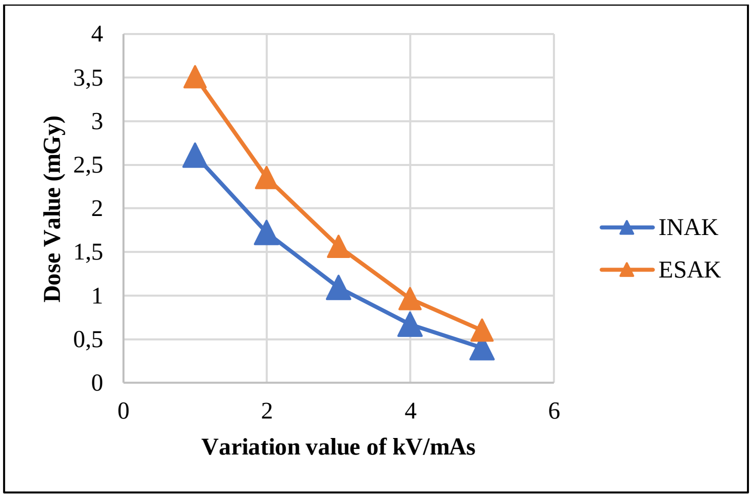

Figure 3. INAK and ESAK values from AP projection abdominal examination

An increase in the kV value, accompanied by a decrease in the mAs value, will affect the patient's dose value. Tube current (mAs) regulates the number of X-rays, while tube voltage (kV) regulates X-ray quality. When the mAs value is lowered, it will be followed by a decrease in the number of electrons hitting the anode per unit time so that fewer X-rays are produced. An increased kV value will cause a large penetrating power to the body, so a low absorption dose is obtained. In other words, the radiation dose can be reduced by increasing the kV because the higher the kV, the higher the penetrating power of X-rays produced so that more X-rays are transmitted than absorbed by the body. This fact can be seen from INAK and ESAK numbers obtained in this study, as shown in Figure 3. above.

Regarding scattering radiation, the increasing kV value will increase scatter radiation production due to the interaction of X-rays with more objects. The relationship between variations in the value of kV on the backscatter factor (BSF) in this study can be seen in Figure 4, and the radiation dose received by the ovaries can be seen in Figure 5 below.

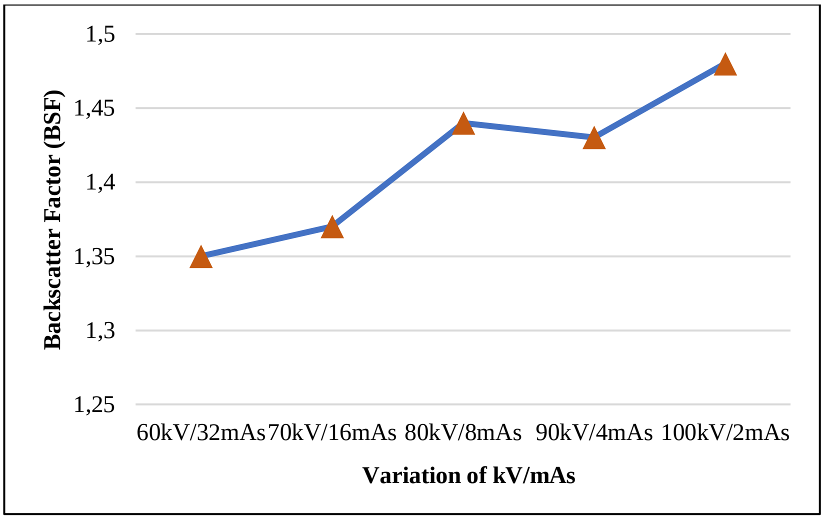

Figure 4. The relationship between variations in the value of kV on the backscatter factor

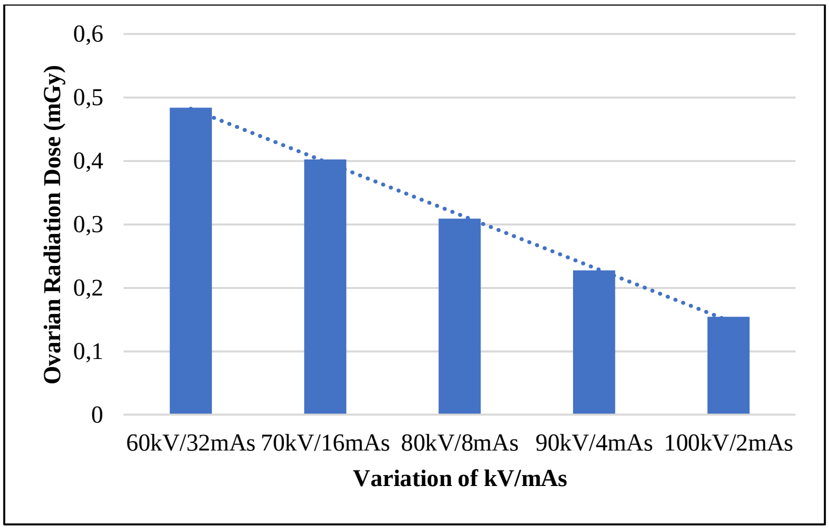

Figure 5. Graph of Ovarian Radiation Dosage Acceptance Value on AP Projection Abdominal Radiography Examination

Figure 5 shows that the absorbed dose received by the female reproductive organs (ovaries) on abdominal examination using various kV values based on the 10 kV rule method tends to decrease along with the increase in kV value and decrease in mAs value. It is also seen in Figure 5 that the radiation dose received by the ovaries is 0.484 mGy for 60kV/32mAs, 0.402 mGy for 70kV/16mAs, 0.309 mGy for 80kV/8mAs, 0.227 mGy for 90kV/4mAs, and 0.154 mGy for 100kV/2mAs. The radiation absorption dose received by the ovary for various kV values is still below the safe limit, even though the ovary is included in the irradiation field. Acceptance of this dose does not exceed the prescribed dose because, according to Statkiwiecz, the dose received for the ovaries on abdominal examination is a maximum of 2 mSv (Statkiewicz, Visconti, Ritenour, & Haynes, 2017).

The radiation dose value in this study can also be evaluated through comparison with several existing references. Table 2 below compares the estimated radiation dose values for abdominal examination and ovarian absorption doses obtained in this study compared to the results of several previous studies regarding radiological examinations.

Table 2. Acceptance Value of Radiation Doses in the Reproductive Organs (Ovaries) from several previous research results

References	Dose
(Statkiewicz, Visconti, Ritenour, & Haynes, 2017)	2 mSv
(Indrati, Sumala, Sudiyono, & Daryati, 2017)	1.46602 mSv for low kV 0.59928 mSv for High kV
(Bima, Maslebu, & Munenggar, 2016)	3,5093mGy
(Darmini, Masrochah, & Daryati, 2013)	1,706 mGy for right ovary 1,774 mGy for left ovary
(Achuka, Aweda, Usikalu, & Aborisade, 2020)	3,705 mGy
(Yousef, Tambul, & Sulieman, 2014)	3,53 mGy

Compared with the reference results of previous studies in Table 2, the data on ovarian radiation dose reception on abdominal examination in this study were still in the safe range. Similarly, compared with the limit value set by BAPETEN for radiation dose for the abdominal examination, which is set at 10 mGy, the data for this study is much smaller.

CONCLUSION

Ovarian radiation exposure during abdominal examination is difficult to avoid the given position of the ovaries in the lower abdomen. As an organ with a high sensitivity to radiation, radiation dose reception must be considered to prevent stochastic and nonstochastic effects on female organs. This study decreased the dose of ovarian radiation received by increasing the kV value and decreasing the mAs value according to the 10 kV rule method proposed by Plats (1980). Abdominal examination with various kV and mAs revealed ovarian radiation doses of: 0.484 mGy for 60kV/32mAs, 0.402 mGy for 70kV/16mAs, 0.309 mGy for 80kV/8mAs, 0.227 mGy for 90kV/4mAs, and 0.154 mGy for 100kV/2mAs. Compared with the reference results of previous studies and the threshold value set by BAPETEN for radiation dose for abdominal examination, the value of receiving radiation dose to the ovaries on abdominal examination in this study was still within the safe range.

REFERENCES

Achuka, J. A., Aweda, M. A., Usikalu, M. R., & Aborisade, C. A. (2020). Assessment of Patient Absorbed Radiation Dose during Hysterosalpingography: A Pilot Study in Southwest Nigeria. *Journal Biomed Physics Engineering, 10*(2), 131-140.

Akhadi, M. (2000). *Dasar-dasar Proteksi Radiasi.* Jakarta: Rineka Cipta.

Ball, J., & Price. (1989). *Chesney's Radiography Imagin.* Oxford: Blackwell Scientific.

Bima, E. A., Maslebu, G., & Munenggar, J. (2016). Estimasi Dosis Radiasi Janin pada Pemeriksaan Anterior-Posterior (AP) Abdomen dengan X-ray Konvensional. *Seminar Nasional Masif II Tahun 2016* (pp. 189-194). Semarang: Universitas PGRI Semarang.

Bushberg, J. T., Siebert, J. A., Leidholth, E. M., & Boone, J. M. (2002). *The Essential Physics of Medical Imaging.* Philadelphia: Lippincott Williams & Wilkins.

Bushong, S. C. (2013). *Radiologic Science for Technologists (10th Edition).* United state of America: Mosby Company.

Darmini, Masrochah, S., & Daryati, S. (2013). Analisis Dosis Radiasi pada Organ Reproduksi Wanita pada Pemeriksaan Histerosalfingografi sebagai Penunjang Keselamatan Radiasi pada Unit Pelayanan Radiologi. *LINK*, 427-436.

Handoko, B. D., Nurfathoni, M. A., & Sulistiyadi, A. H. (2019). Analisa Dosis radiasi Organ Reproduksi pada Pemeriksaan Radiografi Abdomen Proyeksi Anteroposterior dengan Penggunaan Metode 10 kV Rule. *JImeD, 5*(1), 43-49.

Indrati, R., Sumala, R., Sudiyono, & Daryati, S. (2017). *Analisa Penerimaan Dosis Serap Organ Reproduksi pada Pemeriksaan Radiografi Abdomen Antara Penggunaan Teknik kV Rendah dan Teknik kV Tinggi.* Jakarta: Bapeten.

Kramer, R., Khoury, H. J., & Vieira, J. W. (2008). CALDose_X - A Software Tool for the Assessment of Organ and Tissue Absorbed Doses, Effective Dose and Cancer Risks in Diagnostic Radiology. *Physics in Medicine and Biology*, 6437.

Kumar, A., & Kumar, P. (2011). *Evaluation On X-Ray Exposure Parameter Considering Tube Voltage and Exposure Time.*

Pearce, E. C. (2013). *Anatomi dan Fisiologi Untuk Paramedis.* Jakarta: Gramedia.

Plats, V. D. (1980). *Medical X-Ray Techniques In Diagnostic Radiology.* Netherland: Martinus Nijhoff Publisher.

Simon, S. L., Weinstock, R. M., Doody, M. M., Neton, J., Wenzl, T., Stewart, P., Linet, M. (2006). Estimating historical radiation doses to a cohort of U.S. radiologic technologists. *Radiation Research*, 174-192.

Statkiewicz, M. A., Visconti, P. J., Ritenour, E. R., & Haynes, K. (2017). *Radiation Protection In Medical Radiography.* Canada: Mosby.

Vassileva, J. (2002). A Phantom for Dose Image Quality Optimization in Chest Radiography. *The British Journal of Radiology*, 837-842.

Yousef, M., Tambul, J. Y., & Sulieman, A. (2014). Radiation dose measurements during hysterosalpingography. *Sudan Medical Monitor*, 15-18.