International Journal of Allied Medical Sciences and Clinical Research (IJAMSCR)

ISSN:2347-6567

IJAMSCR |Volume 5 | Issue 4 | Oct - Dec - 2017
www.ijamscr.com

Research article | Medical research

Exposure Index and Entrance Surface Dose of ANSI Chest Phantom with Computed Radiography

Agung Nugroho Setiawan[1*], Suryono[2], Suharyo Hadisaputro[1], A. Gunawan Santoso[3], Bedjo Santoso[1], Sugiyanto[1], Gatot Murti Wibowo[1]

[1]*Program Studi Imaging Diagnostik, Magister Terapan Kesehatan, Poltekkes Kemenkes Semarang, Jawa Tengah, Indonesia*

[2]*Program Pascasarjana, Universitas Diponegoro, Semarang, Jawa Tengah, Indonesia*

[3]*Rumah Sakit Dr. Kariadi Semarang, Jawa Tengah, Indonesia*

***Corresponding Author**: **Agung Nugroho Setiawan**

Email id: agung.jtrr@poltekkes-smg.ac.id

ABSTRACT

Background

Radiographer shall ensure the radiation safety of the patient. Posteroanterior chest projection is a frequent examination in the radiology unit. Each radiographic projection must have a safe dose that justifies the dose reference level. One method for estimating the patient dose is using a patient equivalent phantom as an object of radiation exposure. The American National Standards Institute (ANSI) chest phantom was used to simulate chest radiographic examination. Computed Radiography is used for image receptor and provide the exposure index value.

Objective

The objective of this study is to describe the correlation between Exposure Index (EI) and Entrance Surface Dose (ESD) of ANSI chest phantom that mimicking the patient condition using Computed Radiography.

Method

Phantom was irradiated with an X-ray equipment using exposure factors for chest examinations. X-ray equipment, dosimeter, imaging plate and CR programs were well calibrated. EI on the Carestream CR system, as seen on the monitor. ESD measured with calculation method (indirect assessment of incident air kerma). The correlation between EI and ESD is obtained by statistical calculations.

Result

The result showed a positive, very strong and significant correlation between EI and ESD of ANSI chest phantom radiographic examination ($r = 0.819$ and p-value <0.01). Under the controlled conditions used in this study, the EI values were stable.

Conclusions

Entrance Surface Dose can be estimated through Exposure Index value in this Carestream CR. EI can be used as a dose control mechanism on exposure with the same radiation object.

Keywords: ANSI chest phantom, Entrance Surface Dose (ESD), Exposure Index (EI), Computed Radiography.

INTRODUCTION

Radiographer shall ensure the radiation safety of the patient, with a great care of radiation protection principles. The goal of radiation protection is to minimize the probability of stochastic risks and to prevent the occurrence of deterministic effects. To achieve this goal, the ICRP (2007) has developed a framework that is guided by the same three principles described in its 1991 recommendations. These principles relate to justification, optimization, and dose limitation [1]. While justification refers to the fact that every exposure a patient receives must have a positive net benefit associated with it, optimization is intended to ensure that all exposures be kept as low as reasonably achievable (ALARA) without compromising the diagnostic quality of the examination. Dose limits, on the other hand, are outlined in ICRP Publication 60 [2].

Each radiography examination should meet the value of the dose reference level, including chest radiography. This examination still remains the mainstay of chest imaging despite the known diagnostic superiority and increasing availability of cross-sectional techniques. The main advantages of chest radiographs are the speed at which they can be acquired and interpreted, the low cost and the low radiation exposure. Upright chest radiographs still play an important role as a fast tool to rule out various chest diseases and cardiac congestion or to monitor response to therapy. Portable radiographs are the main tools to monitor patients in intensive care units (ICU). Chest radiography is responsible for approximately 30– 40% of all X-ray examinations performed, regardless of the level of health-care delivery [3]. Chest radiography is the most common radiographic procedure performed in medical imaging departments, and one of the most often repeated exams. It is estimated that in the United States 68 million chest radiographs are performed each year. Chest radiography is performed to evaluate the lungs, heart and thoracic viscera [4].

Representation of the patient anatomy can be best characterized by anthropomorphic phantoms. The effects of exposure parameters and the results of the image post-processing techniques can be easily observed on the images. However, their higher cost puts some limitations on the wide range applications of these phantoms in the hospital environment. As for other types of the phantom used in the dosimetry, i.e. the patient equivalent phantom (PEP). Use of patient equivalent phantom intended to represent scattering and attenuation of tissue so it can be applied to the conditions of radiation exposure that is similar to the clinical examination. The high cost of procuring the phantom, becoming an obstacle for the hospital/clinics. Need to replace efficiency efforts that phantom with phantom types, such as the use of simple attenuator slabs or ANSI phantom [5].

ANSI phantom can become an object of radiation exposure as one of the methods in the estimation of radiation dose patients. Researchers utilizing ANSI chest phantom, as a representation of the difference in attenuation and scattering, on chest radiographic examination using Computed Radiography (CR). The exposure factors were kV and mAs, commonly used for chest radiography that produce radiation dose profiles (Entrance Surface Dose), in accordance with the report of AAPM number 31 [6]. The reason for using Computed Radiography (CR) as the image receptor is to get accurate information related with Exposure Index on the use of CR, in particular, to know the relationship with patient dose. Another reason is the CR that widely used in Indonesia, thus optimizing the use of EI parameter, the radiographer will be helped in keeping the patient dose remains at the safe level.

METHOD

This research was conducted with x-ray exposure to ANSI chest phantom with some variation exposure factors (kV and mAs) to find out the value of the Entrance Surface Dose (ESD) and an Exposure Index (EI) on Computed Radiography.

X-ray machine which used in this study (GE medical system, model E7843X) declared pass the compliance test, that required in Perka Bapeten, 2011 includes: a) kVp accuracy; b) timer accuracy; c) exposure linearity; and exposure reproducibility [7]. Carestream Directview Classic CR System under normal circumstances, and declared pass the accuracy of exposure indicators test, as well as in the report of AAPM's number 93 [8]. Patient equivalent phantom, created in accordance with the ANSI specification of chest phantom in the AAPM Report number 31 [9]. Dosimeter RaysafeX2 (serial number: 214331) is well calibrated.

Figure 1. ANSI chest phantom according to AAPM report number 31

The research samples were 45 (forty-five) ESD and EI values resulted from the 15 (fifteen) combination of exposure factors (kV and mAs) with ANSI chest phantom as radiation object. Radiation exposure performed on ranges of 50-110 kV, mAs 1-10 and completed as many as 3 times on every combination of kV-mAs. The resulted radiation exposure should meet the range of exposure as in the AAPM Report number 31.

EI on the Carestream CR system, as seen on the monitor. The scheme of EI data collecting as in the figure below.

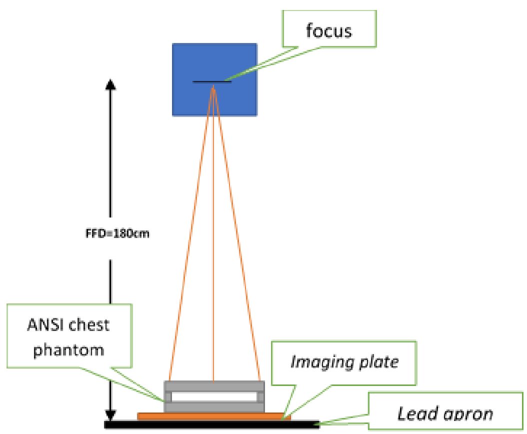


Figure 2. Geometric scheme of the EI ANSI chest phantom data collecting with CR

Measurement of exposure radiation on ANSI chest phantom has been done with a scheme in figure 3.

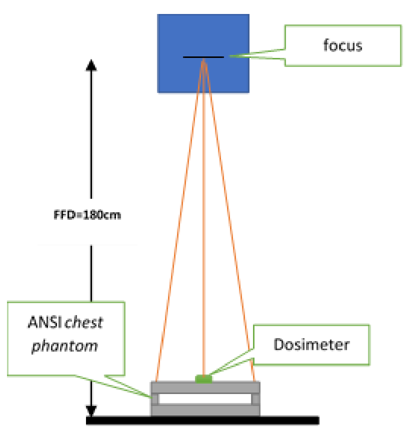


Figure 3. Geometric scheme measurement of ESD on ANSI chest phantom use RaySafe dosimeter

ESD measurement conducted with calculation method (indirect assessment of incident air kerma equation) as stated on IAEA Technical Report Series No. 457, on the following equation 1 and 2 [1]:

K_e=B. K_i (Eq. 1)

$$K_i = Y(d)P_{It}\left(\frac{d}{d_{FTD}-t_P}\right)^2 \quad \text{(Eq. 2)}$$

Ke: ESD or entrance surface air kerma (mGy)
B: backscatter factor
K_i: Incident air kerma (mGy)
Y(d): The X-ray tube output measured at a distance (mGy/mAs)
P_{It} : Tube loading during the exposure of the patient (mAs)
d: Distance from tube focus
t_P : The patient thickness
d_{FTD}: Focus to image receptor distance

The analysis of the correlation between EI and ESD conducted with statistical analysis.

RESULTS

The results showed that the range of ESD is 0,155 until 0,415 mGy. The range of EI is 2.001,33 until 2.733,33. When we plot it into the graph, showed that EI is directly proportional to the exposure; hence, a high exposure will result in a high EI, and a low exposure will generate a low EI.

The resume of results shown in Table 1 and Figure 4 the following.

Table 1. The results of the measurement ESD and EI on ANSI chest phantom

No.	kV	mAs	ESD (mGy)	*Exp. Index* (EI)
1	60	10	0,219±0,000	2096,67±12,70
2	60	8	0,172±0,001	2001,33±8,96
3	70	10	0,311±0,001	2389,00±3,00
4	70	8	0,244±0,000	2290,00±4,00
5	70	6,25	0,193±0,000	2193,33±5,51
6	80	10	0,415±0,002	2613,67±7,57
7	80	8	0,326±0,002	2517,33±7,64
8	80	6,25	0,256±0,001	2414,00±2,00
9	80	4	0,162±0,000	2210,33±8,32
10	90	6,25	0,330±0,003	2582,33±2,31
11	90	4	0,209±0,002	2389,00±2,00
12	100	6,4	0,411±0,001	2733,33±2,89
13	100	4	0,257±0,000	2534,00±3,00
14	110	4	0,311±0,000	2650,33±6,02
15	110	2	0,155±0,000	2344,67±8,39

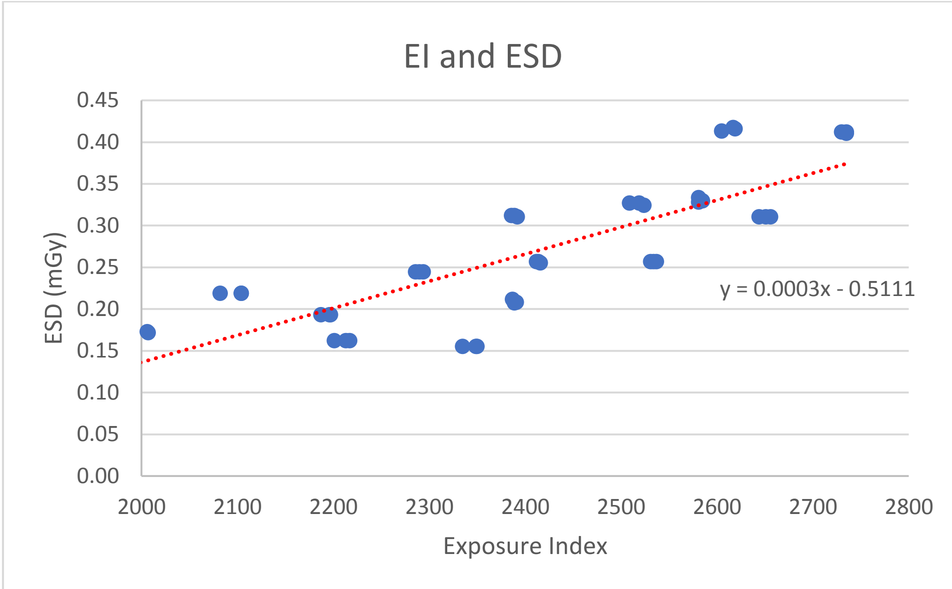


Figure 4. Correlation of Exposure Index and ESD

Statistical analysis with Pearson correlation test found that Exposure Index and ESD have a linear relation as expected. Correlation has the r value = 0.819 and p-value < 0.01, this means Exposure Index and ESD have a positive, very strong relationship and significant. Higher EI will increase ESD, vice versa.

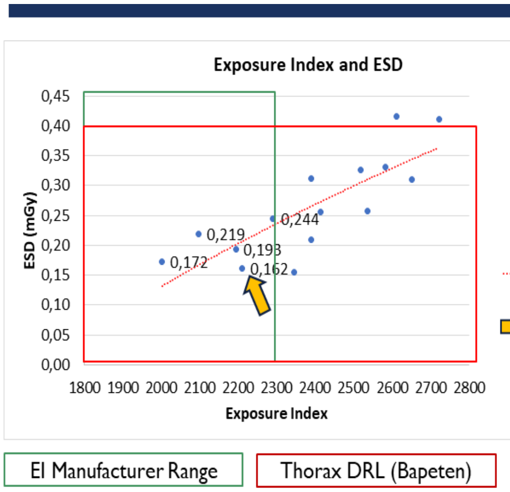
DISCUSSION

The dose to the patient is determined by the X-ray technique factors (kV, mAs, grid, SID, filtration, beam collimation), X-ray beam penetrability and quality, the amount of energy imparted to the body, and the size and area of the body irradiated. The exposure incident on the detector is determined by the remnant radiation (primary radiation transmitted through the patient and scattered radiation transmitted from the patient) that is absorbed, converted to electronic signals, and formatted into a digital radiographic image with a given detective quantum efficiency (DQE). The DQE is a measure of information transfer efficiency that is dependent not only on the efficient absorption of X-rays but also on the conversion into a useful signal with minimum corruption by other detector noise sources (such as electronic and artifact noise). The exposure index is a measure of the signal level produced by a digital detector for a given incident exposure transmitted through the patient, is proportional to the signal-to-noise ratio squared (SNR^2), and is related to image quality [10].

Entrance Surface Dose in this study was obtained by the method of calculation, using the solid-state dosimeter to acquire tube output of x-rays, which are used to calculate the incident air kerma. ESD exposure on the phantom shows a value between 0.6-15, 77 (10-6 C/kg). Fifteen exposure factors that meet the AAPM Report Number 31 range, can be applied to be the parameter in chest radiography patients because it has a smaller value than the dose of Bapeten's guide (< 0.4 mGy) [11].

Carestream's CR Exposure Index (EI) using the equation, EI = 1000. log (E) + 2000. E is an acceptable dose detector on imaging plate (mR). The image with the exact recommended exposure expected at the range of EI between 1700-2300 [12].

This research obtained the EI range values on the phantom: 2001-2733. So, then we could say that only five exposure factors combination that approved with the manufacturer's recommendations, i.e. 60 kV-8 mAs, 60 kV-10 mAs, 70 kV-6,25 mAs, 70 kV-8 mAs and 80 kV-4 mAs. The ideal combination or chosen exposure factor for chest radiography study is a combination of the values that meet the ESD condition of Bapeten's guide and the EI value that fulfill manufacturer recommendation.



No.	kV	mAs	mGy	Exp. Index (EI)	SD
1	60	10	0,219	2096,67	4,68
2	60	8	0,172	2001,33	3,62
3	70	10	0,311	2389,00	1,41
4	70	8	0,244	2290,00	3,10
5	70	6,25	0,193	2193,33	1,73
6	80	10	0,415	2613,67	2,34
7	80	8	0,326	2517,33	2,52
8	80	6,25	0,256	2414,00	2,20
9	80	4	0,162	2210,33	4,08
10	90	6,25	0,330	2582,33	0,58
11	90	4	0,209	2389,00	8,33
12	100	6,4	0,411	2733,33	2,08
13	100	4	0,257	2534,00	4,85
14	110	4	0,311	2650,33	4,15
15	110	2	0,155	2344,67	4,83

Figure 5. The ideal combination of exposure factors in this study

Ideal exposure factor that resulted from this study, is 80 kV and 4 mAs. This value could be a parameter for evaluating the consistency of the EI value with a phantom object. The reason for using this value is because have a low dose (0,162 mGy), and EI=2.210 still on the accepted range of EI manufacturer recommendation (between 1,700-2,300).

The result of this study shows the same conclusion with Warren-Forward, et al [9], Butler, et al [10] as well as the Silva and Yoshimura [11]. The research showed the very strong and significant correlation between EI and ESD. Under the controlled conditions used in this study, the EI values were stable. This means that the higher EI indicated the increasing ESD, or in another word, Entrance Surface Dose can be estimated through Exposure Index value in this Carestream CR system.

But, ANSI phantom study has limitation due to their responses to beam quality, scatter and photon transmission. Furthermore, need a clinical adjustment with using anthropomorphic phantom for next study.

CONCLUSION

EI can be used as a dose control mechanism on exposure with the same radiation object. Radiographer can do the dose optimization with Exposure Index information from the CR system, to keep the lowest dose but in acceptable image quality range.

Acknowledgment

This article has been extracted from the M.App.Sc. Student thesis that was approved by the Examiner Board in *Program Studi Imaging Diagnostik, Magister Terapan Kesehatan, Poltekkes Kemenkes Semarang* dated 21st March 2017. We appreciate the sincere cooperation and assistance of those who helped us in the implementation of this research. Special appreciation and thanks to *Badan Pengembangan dan Pemberdayaan Sumber Daya Manusia Kesehatan Kementerian Kesehatan RI*, with student scholarship which mandated to us.

REFERENCES

[1]. IAEA. IAEA Technical Report Series No. 457 Dosimetry in Diagnostic Radiology: an International Code of Practice. 2007.

[2]. Seeram E, Davidson R, Bushong S, Swan H. Radiation dose optimization research: Exposure technique approaches in CR imaging – A literature review. Radiography 19, 2013, 331–8. doi:10.1016/j.radi.2013.07.005.

[3]. Schaefer-Prokop C, Neitzel U, Venema HW, Uffmann M, Prokop M. Digital chest radiography: an

update on modern technology, dose containment and control of image quality. Eur Radiol 18, 2008, 1818–30. doi:10.1007/s00330-008-0948-3.

[4]. Hobbs DL. Chest radiography for radiologic technologists. Radiol Technol 78, 2007, 494–9.

[5]. Bor D, Unal E, Uslu A. Comparison of different phantoms used in digital diagnostic imaging. Nucl Instruments Methods Phys Res Sect A Accel Spectrometers, Detect Assoc Equip 795, 2015, 160–6. doi:10.1016/j.nima. 2015.05.013.

[6]. Glaze S, Gray JE. AAPM Report No. 31 Standardized Methods for Measuring Diagnostic X-Ray Exposures Published for the American Association of Physicists in Medicine by the American Institute of Physics. Physics (College Park Md) 20,

[7]. Bapeten. Perka Bapeten Nomor 9 Tahun 2011 tentang Uji Kesesuaian Pesawat Sinar-X Radiologi Diagnostik dan Intervensional. Jakarta: 2011.

[8]. Group AT. Acceptance Testing and Quality Control of Photostimulable Storage Phosphor Imaging Systems Report of AAPM Task Group 10 October 2006. 2006.

[9]. Setiawan AN, Suryono, Hadisaputro S, Santoso AG, Wibowo GM. Profil Dosis Radiasi, Exposure Index dan Nilai Piksel Citra Radiografi Toraks Proyeksi Posteroanterior pada Variasi Ketebalan Modifikasi "ANSI Chest Phantom." M.App.Sc Thesis. Magister Terapan Kesehatan, Prodi Imaging Diagnostik, Poltekkes Kemenkes Semarang, Semarang, Indonesia, 2017.

[10]. Seibert JA, Morin RL. The standardized exposure index for digital radiography: an opportunity for optimization of radiation dose to the pediatric population. Pediatr Radiol 41, 2011, 573–81. doi:10.1007/s00247-010-1954-6.

[11]. Bapeten. Perka Bapeten Nomor 8 Tahun 2011 tentang Keselamatan Radiasi dalam Penggunaan Pesawat Sinar-X Radiologi Diagnostik dan Intervensional. Jakarta: 2011.

[12]. Kathy McQuillen Martensen. Radiographic Image Analysis. 4th ed. St. Louis, Mo.: Elsevier Inc.; 2015.

[13]. Warren-Forward HM, Arthur L, Hobson L, Skinner R, Watts A, Clapham K, et al. An assessment of exposure indices in computed radiography for the posterior-anterior chest and the lateral lumbar spine. Br J Radiol 2007;80:26–31. doi:10.1259/bjr/59538862.

[14]. Butler ML, Rainford L, Last J, Brennan PC. Optimization of exposure index values for the antero-posterior pelvis and antero-posterior knee examination. Proc SPIE 7263, 2009, 726302-726302–8. doi:10.1117/12.810748.

[15]. Silva TR, Yoshimura EM. Patient dose, gray level and exposure index with a computed radiography system. Radiat Phys Chem 95, 2014, 271–3. doi:10.1016/j.radphyschem. 2012.12.043.

How to cite this article: Agung Nugroho Setiawan, Suryono, Suharyo Hadisaputro, A. Gunawan Santoso, Bedjo Santoso, Sugiyanto, Gatot Murti Wibowo. Exposure Index and Entrance Surface Dose of ANSI Chest Phantom with Computed Radiography. Int J of Allied Med Sci and Clin Res 2017; 5(4): 947-953.

Source of Support: Nil. **Conflict of Interest:** None declared.