Implementation of exposure index for optimize image quality and patient dose estimation with computed radiography (a clinical study of adult posteroanterior chest and anteroposterior abdomen radiography)

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Abstract. Chest and abdomen Radiographic are most commonly performed and contribute to doses. For this reason, the examination needs to be controlled to obtain image quality with a safe radiation level. This study aims to obtain standardized radiographic exposure index (EI) in Computed Radiography (CR) which is capable of displaying the image quality optimally and to obtain lower radiation dose based on techniques and EI standardized radiographic exposure without reducing the quality of the image information.

This research is a quantitative study with descriptive analysis. Data collected by random sampling technique. The total sample was 61 image editors that have been done by selecting Look Preference Editor (LPE) predetermined. Visual Grading Analysis (VGA) used to analyze quality assessment of the image viewer.

The results showed for the chest’s VGA image quality is best viewed directly on the monitor CR with EI value 1430/220.99, whereas to the abdomen by using CR directly, with the best image has EI 1725/496.7. Good criteria image, with low dose estimation and optimal image quality, both chest and abdominal remain below the required range of Bapeten, which chest with 0.003 mGy and abdomen 0.0069 mGy.

1. Introduction
Most current radiography examinations have been using digital technology, one of them is Computed Radiography (CR). The use of CR is more advantageous than the screen-film system because it has faster acquisition and image processing, wide dynamic range, easy contrast and brightness adjustment, and electronic cropping. Unfortunately, the amount of exposure radiation is difficult to assess when using digital imaging compared to screen-film systems [4].

Optimizing an exposure with diagnostic purposes involves three aspects of the imaging process: (1) selection of radiographic techniques, (2) radiation doses to patients, and (3) radiographic image quality that has diagnostic value [5].

The concept of optimum image quality has undergone a transformation with the ever increasing use of digital radiography. Image quality optimization in radiographic diagnostics should be based on clinical studies or with the patient images and should take into account the capabilities and technology of imaging systems [6].

The pulmonary chest radiographic examination is the most commonly performed in the radiology unit (> 50%), whereas abdominal radiographs also contribute to large doses. For this reason, the population...
of both types of examination needs to be taken care of and controlled in order to meet adequate image quality with a safe dose of radiation for the patient. Based on clinical observations, radiographers tend to ignore the value of Exposure Index (EI) and Deviation Index (DI) that showed in the monitor screen. The success of the radiographic examination is still as the image stigma does not need repetition. Though the image quality factor is not merely a repeated image problem or not, but also that has the breadth of information and also still have to maintain the protection method to the patient, in this case, is acceptance dose due to radiography procedures. The absence of an EI standard corresponding to the condition of the X-ray machine and the object being examined causes the EI range to tend to be too wide, so the patient's dose is not well controlled. Another problem that often occurs is related to the problem of post-processing image is so varied that there is no standard CR quality image processing that can be referred by Radiologist or Radiographer. This study aims to obtain standardization of radiographic exposure techniques with EI capable of optimally displaying non-contrast image quality of chest and abdomen organ with CR and to obtain radiation dose estimation without reducing the quality of CR image.

2. Experimental Methods
This research is a quantitative study with descriptive analysis. The selection of inspection parameters and the Look Preference Editor (LPE) setting performed by the radiographer with the EI value must be within the range required by the manufacturer (Carestream). Processing and data analysis was done with absolute Visual Grading Analysis (VGA) method. Chest and abdomen patient image data were evaluated with three visualization media: (1) via CR monitor screen, (2) via workstation and (3) print out the film. The assessment standards used are: (1) - excellent image quality: minimum limitations for clinical use, (3) - sufficient image quality: moderate limitations for clinical use but no substantial loss of information, (4) - restricted image quality: relevant limitations for clinical use, clear loss of information and (5) - poor image quality: image not usable, loss of information, image must be repeated. The study is also estimated the radiation dose using the exposure index calculation on CR.
The samples analyzed were 61 radiographs, consisting of 37 chest radiographs and 24 abdomen radiographs. A number of samples in each image based on minimum sample unknown population. The criteria for the assessment of the image by the radiologist expert (more than 10 years experience of conventional non-contrast radiographs) based on the Radiograph Criteria Form in accordance with DIMOND III Image Quality and Dose Management For Digital Radiography [2]. To find the difference from 3 (three) reading media is done by Friedman test and continued with Wilcoxon to know how big difference between the three reading media. Furthermore, the image that meets the assessment standards is calculated dose estimation to establish the appropriate examination protocols on both types of examination.

3. Results and Discussion
The preliminary study was conducted by selecting Look Preference Editor (LPE) from 9 options available on Carestream CR as one of the efforts to optimize the image. The images that are categorized are limited to criteria within the range of EI required by the manufacturer or based on the International Electrotechnical Commission (IEC). The preliminary study results show that LPE selection for post-processor radiography of thorax selected LPE with "premium processing with medium latitude (89%)", others chose LPE European mammography (9%) and only 2% chose LPE Premium 2 processing with noise suppression. On abdomen radiography, LPE premium processing with more latitude (about 90%) while others (10%) chose LPE Premium 2 processing with noise suppression.

3.1. Absolute Visual Grading Analysis for Chest and Abdomen Images
The chest images were evaluated based on VGA score of 37 total number of radiographs. Five radiographs were rejected due to error positioning (14%), meaning that the radiographs will be analyzed next only 32 images (86%). The best result on the image in the sample is the lowest score. From the data processing obtained VGA score with media read on the smallest CR monitor is 0.09, the largest 0.16
with the average chest VGA score is 0.11. From the sample images, the image has the smallest score of 0.09 as many as 15 images (47%), 0.13 as many as 16 images (50%) and only 1 image gets a score of 0.16 (1%).

Table 1. Descriptive Statistics of VGA score from three reading methods

| Visual Grading of Reading Methods | N  | Mean  | Std. Deviation | Minimum | Maximum |
|----------------------------------|----|-------|----------------|---------|---------|
| CR Monitor - thorax              | 32 | .1122 | .02181         | .09     | .16     |
| Workstation – thorax             | 32 | .1241 | .02722         | .09     | .19     |
| Film- thorax                    | 32 | .1153 | .02423         | .09     | .16     |
| CR Monitor - Abdomen             | 23 | .4761 | .07709         | .35     | .57     |
| Workstation - Abdomen            | 23 | .4970 | .08143         | .39     | .65     |
| Film - Abdomen                   | 23 | .4583 | .07272         | .30     | .61     |

Friedman test shows the significance value of 0.18, means there is a significant difference of mean VGA value between viewing media of chest image display (CR, workstation, and film), in other say there is a difference of image quality when the three display media are applied. Reading chest image directly to the display on monitor CR has the best image quality compared to reading from a workstation or by the film.

In the abdomen radiographs, from 24 samples, one radiograph was rejected due to positioning factor (4%), meaning the radiograph to be further analyzed was 23 images (96%) of all samples. The result of this study showed that the VGA score of the abdomen with reading media of film has the smallest score is 0.30 with the average score 0.4583 is recommended as the best reading media, followed by CR monitor which has minimum value 0.35 with average 0.4761. While the VGA score on the workstation has a value of at least 0.39 with an average value of 0.4970.

The difference in quality when reading images with 3 (three) media is possible because of auto image compress when delivering from CR modality to workstation. Similarly, when printed out, providing different quality, so should be considered the quality of the printer used. It is a consideration for hospitals to read chest images directly on CR monitors, which will make it difficult for large patient flow, so the possibility of using CR for film processing will also be more frequent, so alternative media should be sought.

3.2. Estimation of Optimal Dose in Chest and Abdomen Radiography using Computed Radiography

The exposure index (EI) and the deviation index (DI) are not directly related to the patient's dose, but an evaluation of the value of EI is necessary to ensure that x-ray equipment is used appropriately and for optimizing the radiation dose for each radiographic examination, since patient care is cannot be underestimated [7].

The manufacturer of digital imaging equipment provides several methods for connecting the exposure to the receptor image. In Carestream CR and DR System, we found a formula to find out the amount of exposure on the plate with the equation: [8]

$$EI = 1000 \log (E) +2000$$ (1)

so that,

$$E = 10^{(EI-2000)/1000}$$ (2)

where E is the exposure in mR. Because 1 Roentgen is equal to 0.877 rad dose in the air, so to estimate the absorption dose received by the plate by multiplying the dose of radiation exposure by 8.77 rad [9].
Subsequently, the dose on the plate is converted to ESD (Entrance Skin Dose) with the inverse square law formula, by the equation:

\[ I_{(ESD)} = \frac{FFD^2 \times I_D}{FOD^2} \]  \hspace{1cm} (3)

with \( I_D \) is dose in imaging plate.

Previous research has shown a very strong and significant relationship between EI and ESD, such as Setiawan et al [10], Warren-Forward et al [11], Butler, et al [12] as well as the Silva and Yoshimura [13].

Estimated dose chest radiography in this study, the entire image accepted in the dose category permitted by Bapeten, where the entrance surface dose (ESD) per radiography for thorax (chest PA) was ≤0.4 mGy [3]. The minimum dose estimate in patients was 0.0030 mGy, the maximal dose was 0.0078 mGy and the mean dose was 0.0046 mGy. Therefore, all data both the category of image quality and the doses allowed into the range in reference, then look for the minimum dose. Whereas in the entire image of the abdomen confirm with the dose category permitted by Bapeten, where the entrance surface dose (ESD) per radiograph for the abdomen AP is ≤10 mGy [3]. The minimum dose was 0.0069 mGy, the maximum dose was 0.0080 mGy and the average dose was 0.0073.

| Objects    | N  | Mean | Minimum | Maximum |
|------------|----|------|---------|---------|
| Thorax     | 32 | 0.003| 0.0046  | 0.0078  |
| Abdomen    | 23 | 0.0073| 0.0069  | 0.008   |

3.3. Determination of Chest and Abdomen Radiography Protocols with Carestream CR

Image evaluation is based on CR image quality which observed with three reading methods and also achieved lowest dose estimation on both examinations. The research concluded the protocol of chest and abdomen radiography examination on Carestream CR as shown in table 3.

| Parameter                          | Chest Protocol                  | Abdomen Protocol               |
|------------------------------------|---------------------------------|---------------------------------|
| Patient position                   | Erect-PA                        | Supine-AP                       |
| Radiography mode                   | Fixed Radiography system;       | Radiography/Fluorography        |
|                                   | Vertical stand with moving grid | system; Bucky-table             |
| Nominal focal spot                 | ≤1,3                            | ≤1,3                            |
| Additional filter                  | 2,5 mm Al                       | 2,5 mm Al                       |
| Anti-scatter grid                  | R =12; 36/cm                    | R = 12; 40/cm                   |
| FFD                                | 200 cm                          | 115 cm                          |
| Patient thickness                  | 24 cm                           | 21 cm                           |
| Collimation                        | 35 x 43 cm                      | 35 x 43 cm                      |
| kV                                 | 102 kV                          | 83 kV                           |
| mA                                 | N/A                             | N/A                             |
| ms                                 | N/A                             | N/A                             |
| mAs                                | 10 mAs                          | 30,6 mAs                        |
| Exposure Index Indicator           | Green (Carestream & IEC Index Exposure References) | Green (Carestream & IEC Index Exposure References) |
| AEC                                | Not-used                        | Central or lateral chamber      |
| X-ray cassette+IP                  | Carestream CR cassette; 250     | Carestream CR cassette; 250     |
| Quality Class                      | Premium processing with medium latitude | Premium processing with more latitude |
The results showed for the chest’s VGA image quality is best viewed directly on the monitor CR with EI/DI value 1430/220.99, whereas to the abdomen by using CR directly, with the best image has EI/DI value 1725/496.7.

![Figure 1. Best images based on VGA score and lowest dose estimation](image1)

4. Conclusions and Suggestions
Standardization of radiographic exposure techniques based on EI to perform an optimal image quality of chest and abdomen in clinical condition has been obtained. LPE standard for chest image is "Premium processing with medium latitude" while for abdomen image is "Premium processing with more latitude". The chest image with EI 1430 / 220.99 is the best image, while for abdomen is EI 1725 / 496.7.

The patient's dose in this study is still below the required reference dose by Bapeten. Estimated dose of patients on the lowest chest radiography examination is 0.003 mGy, that still obtained an image with optimum quality. While estimation of the lowest patient dose in abdomen image is 0.0069 mGy with optimum image quality.

For reading media, we recommend using directly from CR monitors, although this is quite a hassle if the workflow is busy or the number of patients is quite a lot, or radiographer can provide a printed radiograph directly performed from the CR modality instead of the workstation.

5. References

[1] A. C. Oliveira, A. P. Martins, R. T. Avelãs, M. S. C. D. Santos, P. M. Martins, S. De Francesco, P. Sá-Couto, C. Ferreira; Visual Grading Analysis of image quality in pediatric abdominal images acquired by Direct Digital Radiography and Computed Radiography Systems, European Society of Radiology, ECR 2013
[2] Busch H.P. & Trier, EC, (2004), DIMOND III Image Quality and Dose Management For Digital Radiography; Final Report.
[3] Perka Bapeten No 8 tahun 2011 tentang keselamatan radiasi dalam penggunaan pesawat sinar-X radiologi diagnostic dan intervensional.
[4] L. Lanca and A Silva (2007), Evaluation of Exposure Index (IgM) in Orthopaedic Radiography, Sentinel Workshop, Delft.
[5] Mervyn D. Cohen, Matt L. Cooper, Kelly Piersal, Bruce K. Apgar (2010), Quality assurance: using the exposure index and the deviation index to monitor radiation exposure for portable chest
radiographs in neonates, Pediatric Radiology DOI 10.1007/s00247-010-1951-9. © Springer-Verlag 2010
[6] Nadzri, M. M. Y (2011), Radiographic Image Evaluation, © University Publication Centre (UPENA), UiTM
[7] J. Anthony Seibert, Richard L. Morin (2011), The standardized exposure index for digital radiography: an opportunity for optimization of radiation dose to the pediatric population. Pediatric Radiology 41:573-581. © Springerlink.com
[8] Jacqueline G.,(2010). The Concept of Exposure Index For Carestream Directview Systems. © Carestream Health, Inc 2010
[9] Bayuadi, I. (2011), Optimasi Kualitas Citra dan Dosis Pada Pemeriksaan Thorak Menggunakan Computed Radiografi. Universitas Indonesia.
[10] 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.
[11] 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.
[12] 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 2009;7263:726302-726302–8. doi:10.1117/12.810748.
[13] Silva TR, Yoshimura EM. Patient dose, gray level and exposure index with a computed radiography system. Radiat Phys Chem 2014;95:271–3. doi:10.1016/j.radphyschem.2012.12.043.