Quantitative Analysis of the Additional Radiation Burden due to Electronic Collimation in Digital Radiography

DM Satharasinghe[1,2#], WMNMB Wanninayake[2], AS Pallewatte[3] and J Jeyasugiththan[1]

[1]*Department of Nuclear Science, Faculty of Science, University of Colombo, Sri Lanka.*
[2]*Horizon Campus, Malabe, Sri Lanka.*
[3]*Department of Radiology, National Hospital of Sri Lanka*

[#] duminda92ms@gmail.com

Abstract: In recent years, the conventional film-screen radiography technique is replaced with the novel invention of digital radiography. This digital technology provides prompt image readout with reduced radiation exposure. The image can be post processed to adjust the spatial resolution and contrast. However, the inappropriate use of the background masking tool during post processing degrades the outcomes of the digital technology. Although this tool is intended to eliminate the ambient light around an image to improve the quality of the displayed image, contrary it is used as a substitute for insufficient pre-exposure collimation of the irradiated field resulting in unnecessary overexposure. The present study aimed at evaluating additional radiation dose due to electronic cropping in digital radiography facility for the first time in Sri Lanka. A sample of 194 X-ray images under nine different projections was evaluated and the average areas of pre and post-exposure collimation were measured. The difference of the mean areas was calculated and presented as a percentage of the area of the whole radiation field. The percentage of overexposed area due to improper collimation was found to be over 50% in cervical spine, shoulder and sinus projections (in 44.4% of study sample). The lateral projection of cervical spine showed the highest overexposed percentage (55%). Therefore, it is within the scope of practice of a radiologic technologist to use appropriate pre-exposure collimation. The electronic masking should be only utilized to eliminate the interfering brightness in the image and the technologists should be clinically competent to adopt the above concept.

Keywords: Electronic collimation, Digital Radiography, Background masking, Radiation exposure.

Introduction:

Almost after 90 years of the invention of X-rays by Roentgen, a new era of radiography began with the transition of film-screen to digital radiography in 1987. Following this enormous invention of Computed Radiography (CR) by Fuji, film-screen system became obsolete. Almost two decades after the introduction of CR, a new technology launched with the label “Digital Radiography

(DR)”. This technique facilitates the digital achieving of the radiographic image with enhanced image quality. Moreover, the radiation dose can reduced without compromising the image quality due to its digital detector system [1].

However, DR also has potential drawbacks where the operator should pay extreme attention to avoid unnecessary over exposure. Although the dynamic range provides benefits during under exposure to provide a viewable image, with over exposures the amount of radiation delivered to the patient will be ten or more times higher before the occurrence of signal saturation and loss of information. This would happen without the knowledge of the operator [2]. Moreover, the capability of electronic post processing and collimation of under collimated images are another potential pitfall. Accordingly, the electronic collimation may restrict the area appearing on the final radiograph thereby overriding the right of the patient to receive the full information obtained during the acquisition [3]. Furthermore, proper collimation of the anatomy is always important since it influences the image quality. When the exposed volume of tissue increases, the tube voltage (kVp) should also be increased in order to produce a quality image. This would, more likely result in increased compton interactions, or scatter production and produce a negative impact on image quality [3]. Moreover, these scatter would increase the patient dose remarkably, hence proper collimation of the required anatomy would be essential [4]. However, electronic collimation could be used to mask the unexposed boarders around the collimation edges since these edges would allow excess light to enter in to the eye. This extra light would result in over sensitization of a chemical within the eye called rhodopsin that results in temporary white light blindness or veil glare [5]. Although viewer eye quickly recovers from this, the distraction caused would interfere with image evaluation by the eye. In screen-film radiography, special view boxes were sometimes used to avoid the effects of veil glare, but no technique has ever been entirely successful or convenient. Using the available post processing tools the white collimation borders can be turned in to black background and veil glare can be effectively eliminated [5]. Therefore, this tool should carefully be used to eliminate disturbances to the viewer's eye. Further, by removal of background or the white unexposed borders results in an overall reduction of pixels and reduces the amount of information needed to be stored in a digital image. However, this technique is not a replacement for proper collimation. It is an image manipulation art only and does not change the amount or angles of scatter. There is no substitute for appropriate pre-patient collimation since it surely reduces the patient dose ensuring the principle of "as low as reasonably achievable (ALARA)" [6].

Methodology:

This study was carried out in a private healthcare facility equipped with a Digital Radiography system. In that system depending on the selected protocol, Automatic Exposure Control (AEC) chambers are automatically activated (for erect and table buckey) and collimation is adjusted accordingly. This can be further adjusted using manual collimation knobs available on the collimator assembly. However, collimation of the X-ray field beyond the area of the detector is restricted. Following a successful exposure, resultant combination of kVp and tube current (mAs) are displayed on the console monitor together with the estimated Dose Area Product (DAP) in μGy.m^2. Immediately after the exposure, through wired and wireless technology the automatically cropped image will appears on the screen according the pre-set area defined to suit different regions in the body. The image footer display the corresponding length and breadth of the initially collimated area as number of pixels in columns and rows. This pixel count changes simultaneously with the area of the electronic collimation when adjusted using the cropping tool. A sample of 194 X-ray projections were extracted for the evaluation including 18 Cervical spine-Antero posterior (AP), 17 Cervical spine-Lateral (LAT), 68 Chest -Postero anterior (PA) 15 Abdomen AP, 11 Shoulder AP and 6 Shoulder LAT and 24 Sinus PA. According to the figure 1 the actual radiation field areas and electronically collimated areas were noted for each projection. Due to the limitation of direct numerical measurement with the available software, the pixel count was considered reliable for calculating the area. The number of pixels in rows and columns of the post processed image was noted. Then using masking removal tool the image was converted back to original stage where the outline of actual radiation field was visible as a silver lining around the exposed area.

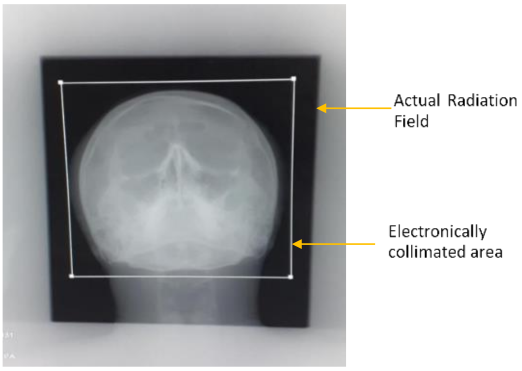

Figure 1: Illustration of electronic collimated area and radiation field in a sinus PA view. Note how the masking tool was used to eliminate the unnecessary exposed neck area in the given sinus x-ray projection

With the same cropping tool, the radiation field outline was carefully mapped and respective pixel counts in rows and columns were noted. Using the average pixel counts in rows (field width) and columns (field height) the mean areas of electronic collimated field and the radiation field were calculated separately for 9 anatomical projections. The difference of the mean area of electronic collimation and radiation field was calculated as a fraction of mean area of the radiation field and multiplied by 100 to obtain the percentage of over exposed area using the below equation.

$$\text{Percentage of over exposed area} = \frac{\text{Mean area of radiation field} - \text{Mean area of electronic collimation}}{\text{Mean area of radiation field}} X\ 100\%$$

Moreover, the percentage of over exposed areas belongs to different projections were evaluated in order to determine the practices which needs the immediate attention related to collimation.

Results, and Discussion:

The data and the results of the present study were summarized in the table 1 given below. Accordingly in 4 out of 9 anatomical projection types, the over exposed area due to improper collimation was more than 50% and cervical spine lateral showed the highest overexposed percentage of 55.1%. Also, among all projections abdomen AP showed remarkably the least percentage of over exposure of 5.9%. Moreover, the four edges of the initial pre-patient collimation were evident in the cases of alarming over exposures. However in other cases, where the four edges of pre-patient collimation was not visible, the area of the detector was considered as the area of the pre-patient collimation or the radiation field due to the inbuilt restriction of the equipment which avoids the radiation field to extended beyond the physical detector.

Table 1: The range and mean height and width of electronic collimated areas and radiation field areas for nine anatomical projections were tabulated with corresponding RF/EC ratios and the percentages of over exposure.*

Region	Projection	Sample (n)	Range (mean) width electronic collimation	Range (mean) height electronic collimation	Range (mean) width radiation field	Range (mean) height radiation field	RF* / EC*	Over exposed percentage %
Cervical spine	AP	18	826-1214 (1069.1)	13421968 (1622)	1186-2006 (1577.1)	1606-2547 (2033.1)	1.84	45.9 %
	Lateral	17	872-1352 (1218.9)	1178-2151 (1759.1)	1786-2840 (2115.4)	1840-2874 (2255.9)	2.25	55.1 %
Chest	PA	68	1464-2694 (2283.2)	12532759 (2154)	1724-2840 (2715.9)	1660-2874 (2562.2)	1.41	29.3 %
Abdomen	AP	15	2222-2598 (2410.7)	2858-3032 (3003.5)	2500-2840 (2557.3)	28743032 (3009)	1.06	5.9 %
Lumbar Spine	AP	18	1058-1344 (1205.2)	2603-3032 (2955.5)	1212-1970 (1516.3)	2643-3032 (3005.3)	1.28	21.8 %
	Lateral	17	1020-1782 (1335.5)	2802-3032 (2966.2)	1420-2516 (2109.2)	3012-3032 (3025.3)	1.6	37.9 %
Shoulder	AP	11	1200-2140 (1693.3)	1070-2008 (1753.7)	16782840 (2518)	11832874 (2396)	2.03	50.8 %
	Lateral	6	706-1646 (1343)	901-2028 (1686)	17102840 (2112)	11672874 (2280)	2.13	53.0 %
Sinus	PA	24	1108-1604 (1315.7)	1303-1761 (1460.5)	1450-2406 (1778.7)	1665-2678 (2163.1)	2.0	50.1 %

*RF- Radiation field *EC- Electronic collimated area.

According to the above results, a considerable degree of over exposure is evident in each projection and therefore it is not always possible to collimate the X-ray field exactly to the area of interest. This is agreeable up to an extent since the pre-patient collimation is based on the surface anatomical landmarks and not on the exact anatomy which is inside the human body. Therefore precise pre-patient collimation is a challenging task and in the case of incorporated patients, such as children. However, it is essential to highlight that the increasing field size would increase the dose to the patient and this increasement is considerable [7][8].

Finally, the findings were presented to the radiographers of the study setting and discussed the importance of proper pre-patient collimation instead of post processing electronic cropping. All of them agreed with the findings and conclusions of the present study. Hence, they noticed the urgent requirement to optimize the current practice of pre patient collimation in order to reduce the radiation dose to the patient. Here after the term "over exposed "in this context is referred to as the unnecessary exposed area due to poor collimation practices.

Conclusion:

The main purpose of this study was to provide evidence to support the existence of potential over exposure in digital systems due to the electronic collimation. Therefore, special attention is required to avoid suboptimal collimation practices and pre-patient collimation should be used in maximum effort in all cases unless otherwise not possible to do so. Furthermore, shuttering should only be used as a post processing tool to mask the ambient light around an image for improving the quality of the displayed image. It should not be used as a substitute for insufficient collimation of the irradiated field. Also, it should not be used to alter the appearance of an obtained projection or to reproduce a different projection. Moreover, the appropriate determination and use of pre-exposure collimation is an important role of the radiologic technologist to comply with ALARA. Accordingly, continuous training related to collimation practice and radiation protection is essential for radiologic technologists to ensure the best collimation practices and to eliminate misconducts. Furthermore, evaluation of the collimation practices should be conducted as a part of the quality audit by the relevant authorities to ensure optimization of the radiation protection within the country. Also, in future a follow-up will be done in order to evaluate the impact of the study findings on the current collimation practices and to study its influence on the reduction of the patient dose.

Acknowledge: This study was supported by the by the project "Accelerating Higher Education Expansion and Development (AHEAD)" which is a World Bank funded Sri Lankan government operation to support the higher education sector (AHEAD 6026-LK/8743-LK).

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