The Effect Of Different Gonad Shields On Entrance Surface Dose To The Ovary For Pa Chest Radiography

Muhamad Ilhami Bin Mohd Ali Hanafiah, B.Sc
Department of Diagnostic Imaging and Radiotherapy, Kulliyyah of Allied Health Sciences, International Islamic University Malaysia, Jln Sultan Ahmad Shah Bandar Indera Mahkota 25200 Kuantan, Pahang, Malaysia
ilhami.hanafiah@gmail.com

Norfariha Bt Che Mohamed, M.Sc
Department of Diagnostic Imaging and Radiotherapy, Kulliyyah of Allied Health Sciences, International Islamic University Malaysia, Jln Sultan Ahmad Shah Bandar Indera Mahkota 25200 Kuantan, Pahang, Malaysia
fareehafarry@gmail.com

***Moey Soo Foon, P.hd**
Department of Diagnostic Imaging and Radiotherapy, Kulliyyah of Allied Health Sciences, International Islamic University Malaysia, Jln Sultan Ahmad Shah Bandar Indera Mahkota 25200 Kuantan, Pahang, Malaysia
moeysf@iium.edu.my

**Corresponding author:* Moey Soo Foon, moeysf@iium.edu.my

Article History:
Received on October 26, 2020
Accepted on April 6, 2021
Published on June 10, 2021

Abstract:

Background: The use of higher tube potential (kVp) and lower tube current-time (mAs) can deliver a lower patient exposure dose in chest radiography. However, the production of scattered radiation especially with high kVp technique can cause an increase in radiation dose to the area outside the collimated region if it is not optimized. The study aimed to compare the effect of different tube potentials on the entrance surface dose (ESD) of the ovary without gonad shield, with shadow shield and with contact shield using Optically Stimulated Luminescence Dosimeter (OSLD) during PA chest radiography. This study also sought to determine the differences in ESD when using shadow and contact gonad shield when exposed with different kVp.

Materials and Methods: The experimental study was performed in the Radiography Laboratory, International Islamic University Malaysia, Kuantan. The ESD of the ovary was measured using OSLD placed at the back of the PBU-50 phantom at the level of the ovary. Tube potentials ranging from 109 kVp to 150 kVp were utilized.

Result: The ESD to the ovary decreased with increased tube potential. Although there was no significant difference in ESD to the ovary without gonadal shielding and with shielding, the ESD was the highest at the lowest kVp used without shielding. The contact gonad shield resulted in a lower ESD compared to the shadow gonad shield even though statistically it was not significant.

Conclusion: Use of high kVp and contact gonad shield for PA chest can maximize the radiation protection for the patient.

Keywords: Chest radiography; Entrance surface dose; Radiation protection; Radiation dosage

Introduction:

Chest radiography which accounts for 43% of the total number of plain radiography examinations remains the most frequent radiological examination (Ministry of Health Malaysia, 2009). Although the radiation dose exposed per examination is relatively low, it is crucial for the radiologic technologist to perform good practices in producing quality diagnostic images while maintaining the lowest possible dose to the patient. By optimization of tube potential (kVp) using the high kVp technique in the radiological examination, the patient dose can be minimized (Carlton & Adler, 2006). A study performed by Fung and Gilboy (2001) suggested that the recommended kilovoltage used for the high kVp technique for chest radiography in adults should be in the range of 100-150 kVp. The high kVp technique uses a low tube current-time (mAs) thereby resulting in a low absorbed dose in the tissues (Rill, 2001). However, sensitive organ doses such as in the ovary may increase due to the more forward scattered photons resulting from higher energies due to the usage of high tube potentials (Carlton & Adler, 2006).

Additionally, the omission or inadequate shielding can also lead to unnecessary radiation dose to the gonads (Teferi, Tequabo, & Bedane, 2017). The present practice of gonad shielding varies in the imaging department and the radiographers sometimes neglect the practice of gonad shielding which ultimately contributes to unnecessary radiation doses to patients (MacKay et al., 2012; Hayre et al., 2018) . In posteroanterior (PA) chest radiography, the ovaries are located outside the collimation area however the scattered radiation could give rise to unnecessary radiation to the nearest organ outside the region of interest (Matyagin & Collins, 2016). Furthermore, the ovaries are surrounded by abdominal tissues and the presence of bony structures such as the lumbar spine may influence the significant increase in scattered radiation towards the ovaries as compared to the testes (Obed, Ogbole, & Majolagbe, 2015). A study by Hashimoto et al. (2004) suggests that there is a reduction of absorbed dose to the ovaries when the gonad shield is used.

The use of gonad shielding can reduce the x-ray stochastic effect while protecting the radiosensitive organs from unnecessary radiation especially for a child or woman of child-bearing age. Thus, an appropriate and effective gonadal shielding must be utilized especially if the gonads are located within the useful beam or 5cm (2.5 inches) of the collimation edge of the primary beam although it is well collimated (Zainuddin, 2014). Since it is essential for radiation dosimetry to be monitored to enhance the radiation protection practice in radiography, the entrance surface dose (ESD) is used to monitor patient’s radiation doses whether directly measured using the optically stimulated luminescent dosimeter (OSLD), thermoluminescent dosimeter (TLD), ionization chamber or using a mathematical model calculation (Yusof et al., 2017).

Numerous studies have been conducted on the effects of radiation doses on varying positions of the gonad shield and or manipulation of tube potential (Njeh, Wade, & Goldstone, 1997; Fung & Gilboy, 2001; Clancy et al., 2010). However, a medium kVp range was utilized in the experiments. Moreover, previous studies conducted have used Rando phantom and TLD which can thus affect the outcomes of the research. Although many studies have been done, information on radiation doses with the use of a specific gonad shield is still lacking. As such this study aims to compare the effects of different tube potential (kVp) on the ESD of the ovary without gonad shield, shadow shield and contact shield during PA chest radiography using OSLD.

Materials and Methods:

Instrumentation and procedure

The x-ray machine used in this study is a ceiling-mounted x-ray tube, Siemens AXIOM ARISTOS (Siemens, Germany). A torso of an anthropomorphic phantom; PBU-50 (Kyoto Kagaku, Japan) was placed in a standing position with the anterior side of the phantom facing the erect bucky for the PA chest examination. The central ray was directed perpendicularly at the level of T7 with a beam collimation size of 35 x 35 cm to include the region of interest. The PA chest examinations were taken using high tube potential with the use of a grid. The tube potentials utilized for the projection were at 109, 121, 133, 141 and 150 kVp while the tube current exposure time (mAs) were governed by the automatic exposure control (AEC) unit to make sure that the x-ray film density is consistent. Table 1 shows the imaging parameters used in this study. The setup of the experimental study using shadow and contact gonad shield are shown in Figure 1 and Figure 2 respectively.

Table 1: Imaging parameters used for PA chest radiographic examination

Parameters	Details

Kilovoltage (kVp)	109, 121, 133, 141, 150
Imaging plate size (cm)	35 x 43, lengthwise
Central ray	Perpendicular to the center of IR, the midsagittal plane at the level of T7
Source-to-image distance (cm)	180
Focal spot	Large focal spot (1.0 mm)
Grid (grid ratio)	Moving grid (12:1)
AEC	On
Chamber	Both side chamber
Location of gonad shield	Shadow gonad shield: 2 inches inferior to the iliac crest Contact gonad shield: 1 inch inferior to the iliac crest

Figure 1: Equipment setup for the experimental study (PA chest radiography with shadow gonad shield)

Figure 2: Equipment setup for the experimental study (PA chest radiography with contact gonad shield)

A pilot study was carried out to observe the quality of images produced using different tube potentials and to measure the ESD for the examination without the use of a gonad shield. The preliminary image was taken and the S-value was observed to ensure the exposure was adequate to produce a good image quality for PA chest examination. The dose reading was taken three times for each kVp and an average dose reading was obtained.

Entrance Surface Dose (ESD)

Before the irradiation process was performed, the initial reading of OSLD was taken and recorded. The reading from the OSLD was collected and recorded inside the logbook. The result of the post-irradiated dosimeter was then subtracted with the reading of the pre-irradiated dosimeter to obtain the ESD.

The OSLD was placed on the posterior side of the PBU-50 phantom body at a pre-determined location of the ovary as suggested by Bardo et al. (2009) where the ovary is located on the lateral aspect of the pelvis, next to the ASIS, superior to the symphysis pubis and just inferior to the iliac crests and umbilicus. Using the exposure settings in Table 1, the OSLD reading was taken three times for every exposure to obtain the average reading. The experimental study was repeated using a shadow gonad shield and contact gonad shield. The shadow shields can be adjusted and placed near the patient while the contact shield is directly applied to the patient's gonads.

After each exposure, the dosimeter was read using the OSLD reader and the dose recorded in the logbook. The same OSLD was irradiated again three times for each kVp. The ESD was obtained by subtracting the new (post) collected dose from the previous (pre) collected dose. The calculation used is as follows:

Actual absorbed dose = (post-irradiation) – (pre-irradiation)

Statistical analysis

Data from this study was collected and analyzed using the IBM Statistical Package for Social Sciences (SPSS), version 23. Two-way ANOVA statistical analysis was selected to compare the mean differences between shadow gonad shield and contact gonad shield with different tube potential and its effect on the ESD. Two-way ANOVA is commonly used to simultaneously test the effect of each independent variable on the dependent variable enabling the simultaneous testing of the effect of shadow gonad shield and contact gonad shield with different tube potential on the ESD (Pallant, 2016).

Results:

Image quality of PA chest radiographs using CR

The S-value and L-value for each of the exposure were recorded to make sure that the radiographic image produced is within the acceptable diagnostic quality image. The S-value represents the average exposure level whereas the L-value serves as an indicator for the exposure's latitude.

Table 2: The S and L-values for variation of tube potential

Exposure factors		S-value	L-value
kVp	mAs		
109	1.98	620	2.41
121	1.71	588	2.39
133	1.50	562	2.37
141	1.43	538	2.36
150	1.35	500	2.32

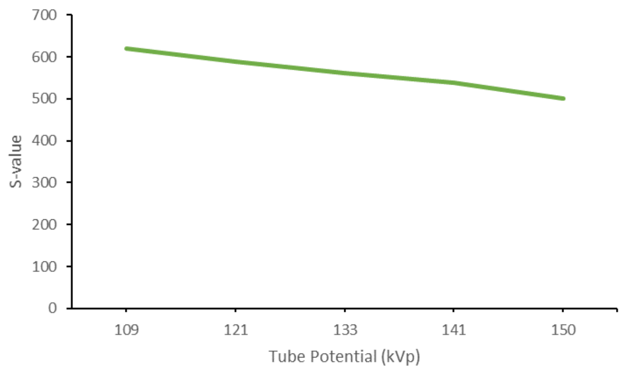

Figure 3: The S-value for variation of exposure factors

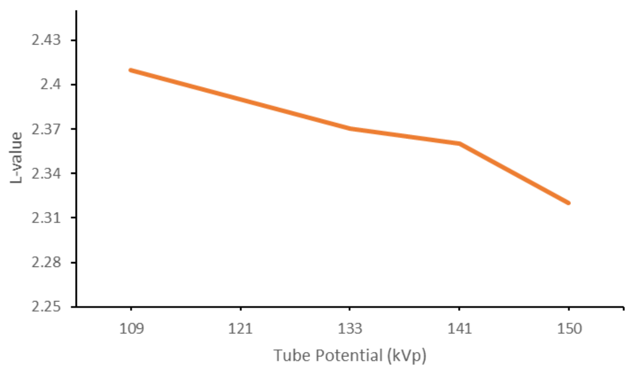

Figure 4: The L-value for variation of exposure factors

Table 2 shows that the image quality of the chest radiographs obtained from the study is within the acceptable image quality as recommended by Fujifilm Medical Systems CR Users Guide (2004). Figure 3 and Figure 4 show the decrease in S and L-values respectively as the kVp is increased. However, the image quality is preserved as the values fall within the range of 200 to 600 for the S-value and 1.3 to 2.7 for the L-value. Figure 5 shows the radiographic images obtained using the stated technical parameters. These values are acceptable for the radiographic image of the chest.

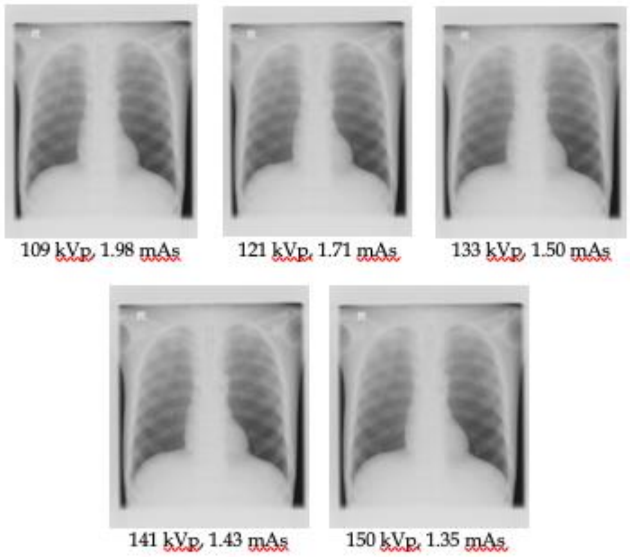

Figure 5: Radiographs obtained using the stated technical parameters

Estimated ESD between no shielding, contact gonad shielding and shadow gonad shielding

The ESD obtained using OSLD was read using the inLight MicroStar Reader Software version 5.0. The ESD value is higher when no gonad shielding is utilized. The ESD obtained using the contact gonad shield is the lowest compared to without using the gonad shield or with the shadow gonad shield. Further, the ESD decreases as kVp increases without the use of gonad shielding or the other two types of gonad shields. The findings are as shown in Figure 6. The ESD obtained for the study is summarized in Table 3.

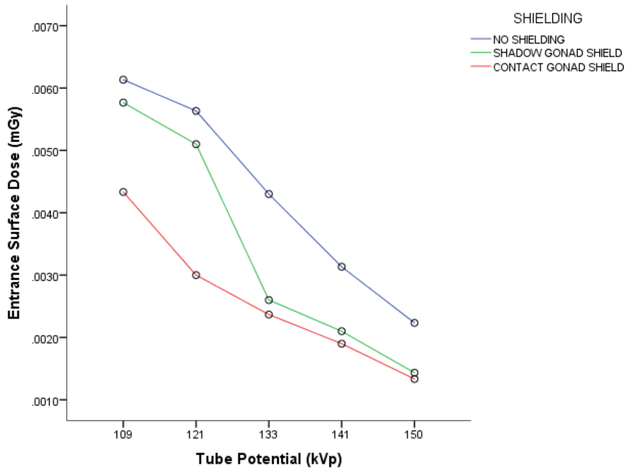

Figure 6: The estimated overall ESD with different tube potential using no shielding, shadow gonad shield and contact gonad shield

Table 3: The ESD with no shield, using shadow gonad and contact gonad shields

Exposure factors		No gonad shield (mGy)	Shadow gonad shield (mGy)	Contact gonad shield (mGy)
kVp	mAs			
109	1.98	0.0061	0.0058	0.0043
121	1.71	0.0056	0.0041	0.0030
133	1.50	0.0043	0.0026	0.0024
141	1.43	0.0031	0.0021	0.0019
150	1.35	0.0022	0.0014	0.0013

ESD using contact gonad shield

For tube potential of 109 kVp, the ESD to the ovary using the contact gonad shield was 0.0043 mGy. The ESD was the highest compared to when other kVps (121 kVp, 133 kVp, 141 kVp, 150 kVp) were used. However, the percentage difference when using 109 kVp for the contact gonad shield was the lowest (29.5 %) when compared to when no shielding was used. At 150 kVp, the ESD to the ovary when the contact gonad shield was used showed only 0.0013 mGy. The percentage difference was 40.9% when compared to when no shielding was utilized. Table 4 summarizes the ESD to the ovary when using contact gonad shield and without using the gonad shield.

ESD using shadow gonad shield

At the lowest tube potential (109 kVp), the ESD to the ovary with the use of shadow gonad shield was 0.0058 mGy. However, when compared to ESD to the ovary without the use of the gonad shield, the percentage difference using 109 kVp for contact gonad shield was the lowest (4.9 %). At the highest tube potential (150 kVp) when using shadow gonad shield, the ESD was the lowest (0.0014 mGy). However, when comparing the ESD to the ovary using 150 kVp, there was only a 36.4% difference when using the shadow gonad and without the use of the gonad shield. Table 5 summarizes the ESD to the ovary when using a shadow gonad shield and without using the gonad shield.

Table 4: Comparison of ESD without gonad shield and with contact gonad shield

kVp	mAs	ESD without gonad shield (mGy)	ESD with contact gonad shield (mGy)	Percentage difference (%)
109	1.98	0.0061	0.0043	29.5
121	1.71	0.0056	0.0030	46.4
133	1.50	0.0043	0.0024	33.9
141	1.43	0.0031	0.0019	38.7
150	1.35	0.0022	0.0013	40.9

Comparing the ESD to the ovary using contact gonad shield and shadow gonad shield

When tube potential of 109 kVp was utilized, the ESD to the ovary when using the shadow gonad shield was the higher (0.0058 mGy) as compared to when using the contact gonad shield (0.0043 mGy). Further, the percentage difference between using these two types of gonad shield was also the highest (24.6%). However, when the 150 kVp tube potential was used, the ESD to the ovary for both the contact gonad shield and shadow gonad shield were at the lowest at 0.0013 mGy and 0.0014 mGy respectively. The percentage difference of ESD to the ovary at this tube potential between using these two types of gonad shield was also at the lowest (4.5%). Table 6 summarizes the ESD to the ovary at the tube potential used when using the contact gonad shield and shadow gonad shield.

Table 5: Comparison of ESD without gonad shield and with shadow gonad shield

kVp	mAs	ESD without gonad shield (mGy)	ESD with shadow gonad shield (mGy)	Percentage difference (%)
109	1.98	0.0061	0.0058	4.9
121	1.71	0.0056	0.0041	26.8
133	1.50	0.0043	0.0026	39.5
141	1.43	0.0031	0.0021	32.3
150	1.35	0.0022	0.0014	36.4

Table 6: Comparison of ESD with contact gonad shield and shadow gonad shield

kVp	mAs	ESD with contact gonad shield (mGy)	ESD with shadow gonad shield (mGy)	Percentage difference (%)
109	1.98	0.0043	0.0058	24.6
121	1.71	0.0030	0.0041	19.6
133	1.50	0.0024	0.0026	4.7
141	1.43	0.0019	0.0021	6.5
150	1.35	0.0013	0.0014	4.5

Significant difference in ESD to the ovary using different tube potential and types of gonad shield

The results from the statistical test showed no significant difference in mean ESD to the ovary when using shadow gonad shield and contact gonad shield with different tube potentials, p=0.095. Further, the use of different tube potential on ESD was not significantly affected by the type of gonad shielding (p=0.984).

Discussion:

The tube potential (kVp) controls the energy of photon striking the object for any given mAs. The increase in kVp will increase the penetrating power of the x-ray beam for a given quantity of x-ray photons. The increase in kVp, followed by a decrease in tube-current time (mAs) will result in higher x-ray beam penetrability, hence resulting in a reduction of ESD to the ovary (Dance et al., 2014). This indicated that using the highest acceptable kVp will result in a low ESD to the ovary while maintaining the diagnostic image quality. Tube potentials ranging from 109 kVp to 150 kVp were utilized in this study by referring to the recommendation of the Commission of European Communities (1996). However, statistically, no significant difference was found in ESD when the above tube potentials were used. The results were expected because an automatic exposure control (AEC) was used in this experimental study where the mAs was determined by the AEC. As such, usage of high kVp will result in low mAs and vice versa.

The use of gonadal shielding serves to absorb and block the scattered photons from reaching the ovary of the patient. A study by Ahmed and Shaddad (2003) showed that there was a significant reduction in ESD for organs exposed outside the border of the collimated beam when gonad shield was used compared to those without gonad shield in PA chest radiography. The ESD reading from the OSLD at the ovary is due to scattering radiation as it is outside the area of irradiation (Njeh et al., 1997). In this study, the ESD without gonadal shielding is higher compared to that of the contact gonad shield and shadow gonad shield, which is 0.0061 mGy at 109 kVp. These findings were aligned with the experimental study performed by Njeh et al. (1997), Fung and Gilboy (2001) and Hashimoto et al. (2004) in which the highest ESD was recorded when no gonad shield was utilized as compared to with gonad shield. However, the ESD from their study was higher compared to this experimental study. This possibly is the result of using different phantom and different dosimeters in the study.

No significant differences was determined when comparing the ESD using shadow and contact gonad shields. However, there were only slight differences in ESD ranging from 4.5% to 24.6% when contact gonad shield was utilized compared to the shadow gonad shield. This was possibly due to the gap between the shadow shielding and the patient's body, thereby allowing the scatter radiation from reaching the location of the OSLD. The finding of this study is similar to the finding by Frantzen et al. (2012) in which the use of gonad shielding can block appropriately 46.4% of forward scatter towards the ovary, hence reducing the absorbed dose at the gonad area.

The ESD to the ovary showed a decreasing trend with increasing kVp with or without gonad shielding. The ESD without gonad shielding is the highest followed by the shadow gonad shield and contact gonad shield for a given tube potential. Nevertheless, the value is still below the dose reference level (DRL) for PA chest radiography (Schaefer et al., 2008). It has been established in this study that the ovary receives a considerable dose saving in PA chest radiography with the use of contact gonad shield and shadow gonad shield as compared to without gonad shield. The results indicated that the ESD to the ovary was lower when using the contact gonad shield compared to the shadow gonad shield even though the statistical test did not indicate any significant difference. Hence it is recommended that the contact gonadal shielding be used for all patients undergoing PA chest radiography using the highest acceptable kVp.

Conclusion:

Dose to the ovary is important to study as a lack of or inadequate shielding of the gonadal region may increase radiation dose exposure to these organs which in turn can lead to genetic and hereditary effects, especially in children. Although there was no significant difference in ESD to the ovary without gonadal shielding and with shielding, the ESD was the highest at the lowest kVp used without shielding. Taking the cues from this study, the use of high kVp and contact gonad shield for PA chest radiography can maximize the radiation protection for the patient. As such, the highest acceptable tube potential should be used to ensure that the patient undergoing an x-ray examination is unharmed in line with the 'As Low as Reasonably Achievable' (ALARA) concept.

Acknowledgement:

The authors wish to acknowledge the support provided by all the clinical instructors in the Department of Diagnostic Imaging and Radiotherapy, Kulliyyah of Allied Health during the data collection process.

References:

Ahmed, A. A., & Shaddad, A. (2003). Measurement of dose received by patients from scattered radiation in diagnostic radiology in Khartoum. *Proceedings of the Sixth Arab Conference on the Peaceful Uses of Atomic Energy*. Egypt: Arab Atomic Energy Agency. Atomic Energy Authority. 3, 557-567.

Bardo, D. M. E., Black, M., Schenk, K., & Zaritzky, M. F. (2009). Location of the ovaries in girls from newborn to 18 years of age: Reconsidering ovarian shielding. *Pediatric Radiology*, *39*(3), 253–259.

Carlton, R. R., & Adler, A. M. (2006). *Principles of radiographic imaging: An art and a science* (4th ed.). New York: Delmar/Cengage Learning.

Clancy, C. L., O'Reilly, G., Brennan, P. C., & McEntee, M. F. (2010). The effect of patient shield position on gonad dose during lumbar spine radiography. *Radiography*, *16*(2), 131–135.

Commission of the European Communities (CEC). (1996). European guidelines on quality criteria for diagnostic radiographic images. European Commission. Retrieved from https://www.sprmn.pt/pdf/EuropeanGuidelinesEur16261.pdf.

Dance, D. R., Christofides, S., Maidment, A. D. A., McLean, I. D., & Ng, K. H. (2014). *Diagnostic radiology physics: A handbook for teachers and students*. Vienna, Austria: International Atomic Energy Agency.

Frantzen, M. J., Robben, S., Postma, A. A., Zoetelief, J., Wildberger, J. E., & Kemerink, G. J. (2012). Gonad shielding in paediatric pelvic radiography: Disadvantages prevail over benefit. *Insights Imaging*, *3*(1), 23–32.

FUJIFILM. (2004). Medical Systems CR Users Guide. Retrieved from https://www.spectrumxray.com/sites/default/files/pdfs/FujiFilm-CR-User-Guide.pdf.

Fung, K. K. L., & Gilboy, W. B. (2001). The effect of beam tube potential variation on gonad dose to patients during chest radiography investigated using high sensitivity LiF: Mg, Cu, P thermoluminescent dosemeters. *The British Journal of Radiology*, *74*(880), 358–367.

Hashimoto, M., Kato, H., Fujibuchi, T., Ochi, S., & Morita, F. (2004). Gonad protective effect of radiation protective apron in chest radiography. *Nippon Hoshasen Gijutsu Gakkai zasshi, 60*(12), 1704–1712.

Hayre, C. M., Blackman, S., Carlton, K., & Eyden, A. (2018). Attitudes and perceptions of radiographers applying lead (Pb) protection in general radiography: An ethnographic study. *Radiography*, *24*(1), e13–e18.

MacKay, M., Hancy, C., Crowe, A., D'Rozario, R., & Ng, C. K. C. (2012). Attitudes of medical imaging technologists on use of gonad shielding in general radiography. *Journal of Medical Radiation Sciences*, *59*(2), 35–39.

Matyagin, Y. V., & Collins, P. J. (2016). Effectiveness of abdominal shields in chest radiography: a Monte Carlo evaluation. *The British Journal of Radiology*, *89*(1066), 20160465.

Ministry of Health Malaysia. Report of Medical Radiation Exposure Study in Malaysia. MOH Malaysia 2009.

Njeh, C. F., Wade, J. P., & Goldstone, K. E. (1997). The use of lead aprons in chest radiography. *Radiography*, *3*(2), 143–147.

Obed, R. I., Ogbole, G. I., & Majolagbe, S. B. (2015). Comparison of the ICRP 60 and ICRP 103 Recommendations on the determination of the effective dose from abdominopelvic computed tomography. *International Journal of Medical Physics, Clinical Engineering and Radiation Oncology,* 4(2), 172–176.

Pallant, J. (2016). *SPSS Survival Manual: A step by step guide to data analysis using SPSS Program* (6th ed.). London: McGraw-Hill Education.

Rill, L. N. (2001*). Improvement of the clinical use of computed radiography for mobile chest imaging: Image quality and patient dose*. Unpublished doctoral dissertation, University of Florida, United States.

Schaefer-prokop, C., Neitzel, U., Venema, H. W., Uffmann, M., & Prokop, M. (2008). Digital chest radiography: An update on modern technology, dose containment and control of image quality. *European Radiology*, *18*(9), 1818–1830.

Teferi, S., Tequabo, Y., & Bedane, D. (2017). Preliminary study on the practice of gonad shielding during pelvic radiography. *Radiology and Diagnostic Imaging*, *1*(1), 1–4.

Yusof, M. F. M., Yahya, M. H., Rosnan, M. S., Abdullah, R., & Kadir, A. B. A. (2017). Dose measurement using Al_2O_3 dosimeter in comparison to LiF:Mg,Ti dosimeter and ionization chamber at low and high energy x-ray. *AIP Conference Proceedings*. USA. 1799, 040007.