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Artikel Asli/*Original Articles*

Radiation Dose Obtained from Abdominal Computed Radiography: Comparison Between Supine and Prone Positions

(Dos Sinaran yang Diperolehi Daripada Radiografi Berkomputer Abdomen: Perbandingan antara Posisi Supin dan Pron)

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ABSTRACT

The aims of this study were to compare the entrance surface dose (ESD) between anteroposterior (AP) supine with posteroanterior (PA) prone projection of computed radiography (CR) abdominal examination and to determine the relationship between body mass index (BMI) and ESD of a patient. AP supine and PA prone projections on the same patients for CR abdominal examination of intravenous urography (IVU) were acquired on 50 patients at Hospital Raja Permaisuri Bainun, Ipoh. All the radiographic examinations were carried out on a Siemens Multixtop general x-ray unit and the images were processed with CR Carestream Direct view Max. Entrance surface dose (ESD) in miligray (mGy) was measured using optical stimulated luminescence dosimeters (OSLD) calibrated by the Malaysian Nuclear Agency. Data were analyzed using dependent t-test comparing the AP and PA projections on the same subject and Pearson correlation was used to determine the relationship between BMI and percentage of reduction of ESD. Results showed a significant different ($p < 0.01$) between AP supine (mean ESD = 6.42 ± 7.13 mGy) and PA prone (mean ESD = 3.92 ± 3.56 mGy) projection at all BMI. The BMI has a positive correlation with percentage of reduction of ESD ($r = 0. 61$) and was statistically significant ($p < 0.01$). In conclusion, PA abdomen prone projection significantly reduces the radiation dose and there is a positive correlation between BMI and percentage of reduction of ESD. The use of PA prone projection for CR abdominal examination should be considered as the routine projection at all BMIs level. Awareness that as the BMI increases the ESD also increases at a moderate positive linear relationship.

Keywords: Digital radiography; computed radiography; obesity; radiation dose; BMI

ABSTRAK

Objektif kajian ini ialah untuk membandingkan dos masuk permukaan (ESD) antara projeksi anteroposterior (AP) supin dengan posteroanterior (PA) pron pada pemeriksaan radiografi berkomputer (CR) abdomen dan untuk menentukan hubungan indeks jisim tubuh (BMI) dan ESD pada pesakit. Projeksi AP supin dan PA pron telah dilakukan pada pesakit yang sama dalam pemeriksaan CR abdomen urografiintravena (UIV) ke atas 50 pesakit dari Hospital Raja Permaisuri Bainun, Ipoh. Pemeriksaan radiografi dijalankan dengan unit x-ray Siemens Multixtop, imej diproses dengan peralatan CR Carestream Direct view Max. Dos masuk permukaan dalam miligray (ESD) dalam miligray (mGy) diukur dengan menggunakan dosimeter pendarkilau optik (OSLD) ditentukurkan di Agensi Nuklear Malaysia. Data telah dianalisa menggunakan ujian-t bersandar antara projeksi terhadap BMI dan untuk hubungan antara BMI dan peratus penurunan ESD ujian korelasi Pearson telah digunakan. Keputusan menunjukkan perbezaan yang signifikan secara statistik ($p < 0.01$) antara projeksi AP supin (ESD min = 6.42 ± 7.13 mGy) dan PA pron (ESD min = 3.92 ± 3.56 mGy) terhadap BMI. Terdapat juga korelasi yang positif antara BMI dan peratus penurunan ESD ($r = 0.61$) signifikan secara statistik ($p < 0.01$). Projeksi PA pron abdomen mengurangkan dos sinaran secara signifikan serta terdapat korelasi yang positif antara BMI dan peratus penurunan ESD. Penggunaan projeksi PA pron bagi pemeriksaan CR abdomen perlu dipertimbangkan sebagai pemeriksaan rutin CR abdomen pada kesemua tahap BMI pesakit. Kesedaran bahawa jika BMI meningkat, ESD juga meningkat dengan linear sederhana secara positif.

Kata Kunci: Radiografi digital; radiografi berkomputer; obesiti; dos sinaran; BMI

INTRODUCTION

Radiography plays an important supporting role in an emergency department in the first diagnosis. Most of the radiology departments are using computed radiography (CR) or digital radiography (DR) or a combination of both modalities. DR comprises of all the acquisition produced in the digital method for general radiography, inclusive of CR but not photographic film (Siebert 2009).

In radiography, the ethical guidelines ALARA (As Low As Reasonable Achievable) suggest maintaining a balance between getting a good image with minimum dose (AELB 1984). Reducing the lowest possible dose that can be achieved due to the additional thickness in patients with high body mass index (BMI) is also a challenge in terms of work ethics (Vano 2005). The most domineering issue in the radiography is the image quality coupled with radiation dose. Most of the studies in these fields are on the image quality and diagnostic efficacy or with the combination of radiation dose compared to other relevant aspects (Uffmann et al. 2005; Yanch et al. 2009 & Reynolds et al. 2011).

Mekiš et al. (2010) study using phantom on plain radiography of the sacroiliac joint (SIJ) found that the ESD received by the testes significantly lowered by using PA prone projection compared to AP projection by 93.1% lower when not using protection ($p \leq 0.020$) and 94.9% lower with protection ($p \leq 0.019$). The dose to scrotum was measured with thermoluminescence dosimeter (TLD). The TLD was preferred because it was suitable for diagnostic x-ray energy exposures and the total standard error of the TLDs was considered to be approximately 10%. Image quality and the projection of abdomen AP supine and PA prone have not been associated although the PA prone projection of the abdomen was recommended as a viable method for patient dose reduction (Nic An Ghearr & Brennan 1998). Beside that Brennan & Madigan (2000) in a study to find the advantages of PA prone projection of lumbar spine measured tissue displacement from supine to prone position and its' influence in relating to the dose reduction. Significant dose reductions of 38.6%, while the image quality remains alike in that particular lumbar spine study. This is further supported by Davey & England (2014) study using an anthropomorphic phantom where the PA projection of lumbar spine lowered the mean effective dose (ED) by 19.8% and also the mean absorbed dose to the stomach (70.4%), colon (61.1%), remainder tissues (33.2%), ovaries (7.3%) and testes (15.9%).

However, all of these studies were either using phantom or on the different patients comparing between AP supine and PA prone projection. In Brennan & Madigan (2000) study, sample body weight of 70 ± 5 kg was used and the sample in AP and PA projection were not the same. Physicists more likely to use body thickness rather than BMI in studying its effect on the image quality in radiology. In the phantom study, subcutaneous adipose tissue added to the phantom trunk by a suitable material to represent the increase BMI (Yanch et al. 2009; Fisher & Hintenlang 2014). The term BMI, tissue thickness and body size are interchangeably used in radiographic studies to evaluate the optimum exposure factors (Le et al. 2015). Phantom studies were limited to using only a single body habitus of normal BMI as the reference. As the position of a patient in radiographic technique changes, tissue displacement change as well as the thickness of the body depending on the BMI. The radiographer should be aware of this as it is their professional role in reducing radiation dose when performing an x-ray examination. Most of the automatic exposure system terminating the exposure based on the optimal parameters for an 'average' person (Ching et al. 2014). There is still a need to further study on BMI, body index and tissue displacement in CR with relation to the adaptation of optimum exposure factors and to correlate it with radiation dose. In previous studies, the relationship between BMI and ESD has not been established.

The aim of this study primarily was to compare the entrance surface dose (ESD) between AP supine with PA prone projection of computed radiography (CR) abdomen radiographic examination. Beside that this study was also to investigate the correlation of BMI on the ESD to the patient. In this study it was hypothesized that there is a difference in ESD between AP supine and PA prone of CR abdomen examination with different BMI and the BMI has a linear relationship with the ESD. The relationship between BMI and ESD could be used in the clinical setting as the basic guide for minimizing the exposure factors and radiation dose for the CR abdominal examination. The findings would also be beneficial for technologists performing radiographic examination on the different categories of BMI patient and awareness of the extra radiation risk on the higher BMI and obese patients. Furthermore the technologist could also use the best radiographic projection when performing abdominal x-ray examination on the patient in order to reduce the radiation dose if the condition of patient permits based on the suggestion given from this study.

EXPERIMENTAL METHODS

This was a prospective cross-sectional study on the target population of patients who undergoes plain x-rays at Hospital Raja Permaisuri Bainun (HRPB), Ipoh Perak with inclusion of all adult patients (n = 50) with mean age 48.52 ± 11.84 years old. Exclusion criteria in this study were patient too ill to lie on prone position or contraindicated to lie on prone position, trauma patient and patient found not suitable for contrast medium during the administration by the radiologist.

The x-ray equipment used was a general x-ray Siemens Multixtop (80 kW) generator 3-phase high frequency Polydoros with aluminum filtration of 2.5 mm. This unit was fixed with an automatic exposure control (AEC) having 3 types of iontomat chamber configuration and also has a 'microprocessor catapult.' CR equipment used was a Max Direct view CR system (Carestream Health Inc, USA). Carestream CR cassette plates of size 35 × 43cm having a spatial resolution of 10 pixels/mm was used. It was ascertained that in the period during the study the same CR cassette was used. For dosimetry the ESD was measured using the optical stimulated luminescence dosimeters (OSLD) Nanodot (Figure 1) and the reader used was Microstar (Landauer Inc., USA). This OSLD has a slightly higher sensitivity compared to TLDs and suitable for x-ray energies (McKeever et al. 2004). OSLD was borrowed

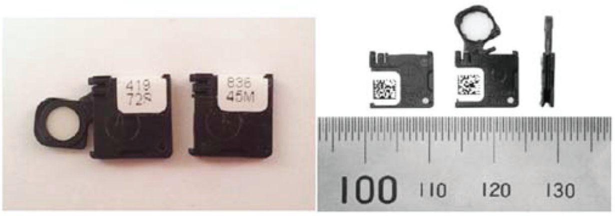

FIGURE 1. OSLD used

from the Malaysian Nuclear Agency (MNA) calibrated and assigned to measure the ESD. Readings were also recorded at the MNA. It was ensured that during the study OSLD did not interchange between the AP supine and PA prone positions or between the patients.

Ethics approval was obtained from Universiti Kebangsaan Malaysia (NN-030-2015) and Malaysian Medical Research Ethics Committee of Ministry of Health (MOH) (NMRR-15-1427-25397) in order to use the HRPB public hospital facility. Before the series of abdomen x-ray of IVU examination performed weight and height was measured. This was followed by the control series of abdomen x-ray in AP supine position with OSLD for measuring the radiation dose. The OSLD was placed on the surface of the abdomen at the middle of the centre beam as suggested for measuring ESD (CEC 1996) (Figure 2). After the radiologist injected contrast media other series of AP supine projection were performed at the standard radiographic practice in the study hospital. Finally, in post micturition series PA prone was used instead of AP supine. The OSLD was placed again on the top surface of the patient's dorsum at the centre of the beam (Figure 2). Both projections AP supine and PA prone were compared with the analysis of data in terms of radiation dose.

AP supine projection PA prone projection

FIGURE 2. CR abdomen examination and position of OSLD

Technical parameters for abdomen x-ray examination as certified by the Commission of the European Communities (CEC 1996) were used in this study shown as in Table 1.

Data was analysed by using the Statistical Package for the Social Sciences (SPSS) 22 (IBM, New York, USA). The Shapiro-Wilk test was used to check the normality of the data (n = 50). The *p*-value was 0.37 thus the data was in normal distribution for parametric distributions. The dependent *t-test* was calculated in comparing the PA prone with AP supine projection on the ESD with level of significance set at $p < 0.01$. The correlation between BMI and ESD were also computed by using Pearson correlation at the same significant level.

TABLE 1. Technical parameters used

	Actual parameters
Radiograpic device	Grid table
Nominal focal spot value	1
Total filtration	2.5 mm Al equivalent
Anti-scatter grid	r =12; 40/cm
Screen film system	CR (Carestream EI mean = 1450)
Automatic Exposure Control for tube current miliampere seconds (mAs)	Chamber selected-central
Exposure time (s)	< 400 ms
Image field size used	35 × 43 cm
Focus film distance	100 cm
kVp (Radiographic voltage)	85 kVp

RESULTS

A total of 50 subjects irrespective of gender with a mean age of 49.0 ± 12.71 with the BMI ranging from 26.26 ± 6.51 (lowest BMI was 16. 1 and the highest was 44.91) were used as sample. The age selected was between 27 to 65 years as the inclusion criteria requirement. A total of 54% (n = 27) subjects were male. The height varies from 1.65 ± 0.07 meters and the female average was 1.59 meters compared to male 1.69 meters.

The technical factors used in this present study was also tabulated (Table 2). Comparing the overall percentage ESD dose reduction between AP supine and PA prone a statistically significant ($p < 0.01$) reduction of mean 30.70 ± 14.50% was obtained (Table 2).

TABLE 2. Technical factors and % reduction of ESD

Technical factors	Mean ± S.D.	p
KVp	85 ± 0	
AP (mAs)	34.66 ± 24.17	
PA (mAs)	24.84 ± 16.56	
AP ESD (mGy)	6.42 ± 7.13	
PA ESD (mGy)	3.92 ± 3.56	
% reduction ESD in PA projection[a]	30.70	< 0.01

[a]using dependant t-test with level of significance at $p < 0.01$

DISCUSSION

The results, as in (Figure 3) manifested, that as the patient BMI increases the ESD also increases (*r = 0.76*) for AP projection and (*r* = 0.73) for PA projection. Obese patient with BMI more than 30 recorded the highest ESD in AP supine and PA prone projection, increase of tissue thickness could be responsible for the high ESD. Increased soft tissue thickness results in a longer distance of necessary travel for the x-ray and causes additional x-ray beam attenuation (Carucci et al. 2013). These subsequently produce scatter, low image contrast, long exposure time, motion artifact and difficult patient positioning. Literature recommendations for improved practice in handling the obese patient are increasing the exposure factors of kVp and mAs (Le et al. 2015). Although the increase of mAs could not be avoided, the present study showed that the use of PA prone projection could lower the ESD in any categories of BMI.

Significant % ESD dose reduction between AP supine and PA prone is in accordance with the previous study of the abdomen using a conventional cassette and film by Nic An Ghearr & Brennan (1998) and lumbar spine study by Brennan and Madigan (2000). As radiation exits through the patient, attenuation or absorption of the x-ray photons take place depending on the thickness, the makeup of the patient's tissues and pathological changes of the tissues (Carlton & Adler 2013).

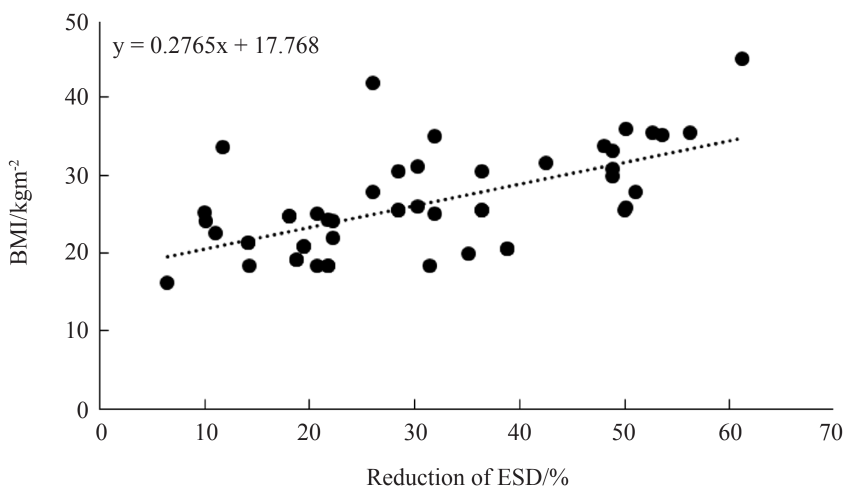

FIGURE 3. Scatterrplots show correlation between BMI and percentage of reduction of ESD. The percentage of reduction of ESD were dependent on BMI

Although Davey & England (2014) study on ED by converting ESD, recorded a lower ED, however, the limitation of this study was not taking into account of different BMI. A single phantom standard size was used and the tissue displacement during the PA prone projection was neglected. Brennan & Madigan (2000) study suggests a reduction of 1.8 cm in the AP diameter of the abdomen when the patient was moved from a supine to a prone position. This reduction in body part thickness allows the implementation of lower exposure factors since a thinner abdomen requires less radiation exposure in order to produce an optimal image (Johnston & Fauber 2012).

Relationship of BMI on the ESD was established by comparing the correlation between the two variables using Pearson correlation. This present study found that there is statistically significant ($p < 0.01$) moderate positive correlation ($r = 0.61$) between % reduction of ESD in relation to BMI (Table 3). The scatterplots in Figure 3 further illustrated the correlation between BMI and % reduction of ESD as linear. The scatterplots in Figure 4 show even the

TABLE 3. Pearson correlation between BMI and % reduction of ESD

	BMI	
	r	*p*
Reduction of ESD in PA projection/%	0.61	< 0.01

ESD AP and ESD PA are linearly correlated with BMI and with ESD PA is much lower than ESD AP. These findings have a lot of weight in terms of radiation dose and awareness. Practically, this will assist the radiographer to be aware when performing the x-ray examination on the higher BMI patients. If the BMI of the patient increases from 20 to 30 the ESD correspondent is 2 mGy would increase to 12 mGy in the AP projection and only to 8 mGy in the PA projection (Figure 4) and the percentage reduction of ESD is about 37% (Figure 3).

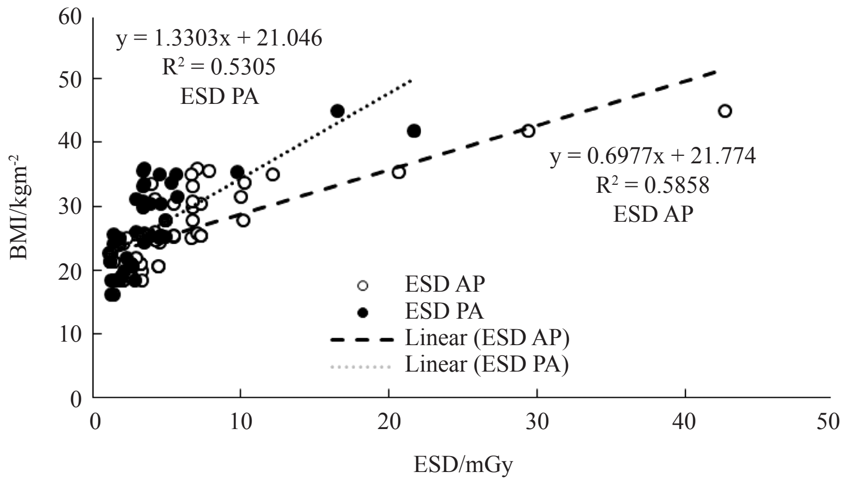

FIGURE 4. Scatterplots show differences of ESD AP and ESD PA linearity which PA has a reduced linearity at same BMI

The fact that the PA prone projection decreases the radiation dose is due to several reasons which includes tissue compression, position of internal organs protected by the pelvic and vertebral bone and reduced distance of organs from the image receptor (Nic An Ghearr & Brennan 1998) except for the kidneys (Carlton & Adler 2013). Dose reduction methods in the plain abdominal x-ray examination are necessary since the abdominal organs irradiated cannot be protected using the lead gown. Switching to the PA prone projection is the best alternative method of reducing ESD and ED for abdominal x-ray. However, further factors that must be considered prior to implementing any changes to standard radiographic positioning. The condition of the patient should be taken into account for PA prone projection during abdomen radiography. Mekis (2010) suggested where the patient's condition allows PA prone projection should be chosen during SIJ radiographic examination. It is practically unsuitable for injured emergency patients, those with acute abdomen cases, arrested respiratory syndrome, or mobility problems (Davey & England 2014; Bontrager & Lampignano 2010).

Patient comfort is also another aspect, AP projection in supine position would probably give a more comfortable patient position during the abdomen radiographic examination (Davey & England 2014). Considering the use of PA prone projection should be practiced deem with minimizing the patient discomfort. Sacrificing the patient discomfort by using PA prone projection could end up with repeating the x-ray examination due to the patient movement. Consequently, patient would get an unnecessary extra radiation dose from this repeated x-ray examination.

When considering the use of PA prone projection, issue of magnification in the abdominal structures was not discussed in the previous studies (Brennan & Madigan 2000; Nic An Ghearr & Brennan 1998; Davey & England 2014). It could be that the organs such as kidney are minimally enlarged in the PA prone projection. Kidneys are retroperitoneal organs and when in PA prone projection its distance from the IR would be increased. Whether this increase could affect the diagnosis of renal pathology in a radiographic image remain questioned. Increased delineation of image structures details and reduction of distortion achieved by placing the area of interest as close as possible to the IR (Carlton & Adler 2013). It is suggested that further study on this could be initiated in order to understand the impact of magnification on the PA prone abdomen image.

CONCLUSSION

The current study demonstrated PA prone projection for abdomen x-ray examination is a viable method of reducing radiation dose. There is a significant difference ($p <$ 0.01) between AP supine (mean ESD = 6.42 ± 7.13 mGy) and PA prone (mean ESD = 3.92 ± 3.56 mGy) projection at all BMI. The BMI has a moderate positive correlation with % reduction of ESD ($r = 0.61$) and it is statistically significant ($p < 0.01$). The higher the BMI the higher the % reduction of ESD in PA prone projection. There is a linear relationship and moderate positive correlation between ESD AP and ESD PA in relation to BMI. PA prone projection for abdomen could be implemented as a standard radiographic practice in radiography after a full consideration of patient condition. The awareness of employing the prone position for abdominal x-ray in an obese patient is apparent in this current study.

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