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Knowledge and Practices of Computed Tomography Exposure Parameters among Radiographers

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Abstract
Knowledge and practices of Computed Tomography (CT) exposure parameters have a direct impact on radiation exposure to patients in CT examinations. This study is aimed to determine the level of knowledge and practice of CT exposure parameters among radiographers in a teaching hospital in Malaysia. A cross-sectional survey using a validated questionnaire was conducted on 60 radiographers who are practicing CT in a teaching hospital in Klang Valley, Malaysia. The results demonstrated that the radiographers had good scores (76.5%) and excellent scores (88.3%) in knowledge and practice, respectively. Further training on CT optimization practice should be executed for radiographers in the future.

Keywords: Computed tomography; knowledge, practice; radiographers

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1.0 Introduction

Computed Tomography (CT) has shown tremendous improvement concerning both its practical applications and technology since its development in 1970 (Rawashdeh *et al.*, 2018). CT has been established as one of the most significant methodological advancements in modern medicine. Even though CT has indisputable value in producing high-resolution cross-sectional images for medical diagnostic purposes, the high radiation dose of CT remains a great concern. Fundamentally, radiation exposure to patients undergoing CT examination is determined by two factors including equipment-related factors and application-related factors (Nagel, 2007). Regarding application-related factors, it is important to understand how the radiographers use the CT scanner which has an impact on radiation exposure to patients. These factors include scan parameters, examination parameters, reconstruction and viewing parameters (Nagel, 2007). The radiographers need to understand various exposure parameters that control the radiation output in CT and their impact on CT image quality, such as the peak kilovoltage (kVp), tube current–time product (mAs), pitch, slice thickness and others. Image quality in CT is directly proportional to the amount of radiation used, therefore it is crucial to use enough to ensure diagnostic yield while avoiding excessive amounts which result to increase patient risk. To achieve CT optimisation, users must tailor CT parameters to match the presenting indication, the region being scanned and patient size, as not all examinations require the highest level of detail (Foley, Evanoff, & Rainford, 2013). Large variations in radiation dose between sites and across countries have been reported even for similar-

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sized patients, which may be attributed to differences in CT equipment and local scan protocols (Foley et al., 2013). Moreover, using CT scan parameters incorrectly might change the radiation dosage by up to 41% (Matsubara et al., 2009). Such dose discrepancies may also point to a lack of understanding or manipulation of parameters, especially on an individual basis.

A lack of knowledge of CT exposure parameters among radiographers has been reported in the literature, which leads to their inability to modify CT parameters for dose optimisation. Radiographers have been reported to have insufficient knowledge of the impact of exposure parameters on the radiation dose and how to optimize the CT image quality by adjusting the CT parameters (Rawashdeh et al., 2018). Studies on knowledge and practice of CT exposure parameters among radiographers from various populations have been addressed in literature including American (Foley et al., 2013), Jordanian (Rawashdeh et al., 2018), Nigerian (Muhammad et al., 2019) (Abdulkadir et al., 2021), Emiratis (Abuzaid, Elshami, Noorajan, Khayal, & Sulieman, 2020) and Iranian (Mahmoudi, Naserpour, Farzanegan, & Davudian Talab, 2019)(Kazemi, Hajimiri, Saghatchi, Molazadeh, & Rezaeejam, 2023). However, limited report on the local Malaysian radiographers has been discussed about their knowledge and practice of CT exposure parameters. Therefore, this study is aimed to determine the level of knowledge and practice of CT exposure parameters among radiographers in a teaching hospital in Malaysia.

2.0 Literature Review

All diagnostic CT examinations must adhere to the "as low as reasonably achievable" (ALARA) principle, which states that doses contributed to patients must be maintained as low as feasible to guarantee that the benefit to patients always outweighs the potential risks. Depth understanding of the parameters that influence radiation output and image quality in CT is essential to achieve CT optimization. Hypothetically there is a strong relationship between CT image quality and radiation dose. The too-low dose can compromise the quality of the CT images (Foley et al., 2013) (Goldman, 2016). mAs, kVp, slice thickness and pitch are among the exposure parameters which could be manipulated by the radiographers during the CT scan procedure, which directly affect the image quality and radiation dose. Among those parameters, mAs and kVp have a direct relationship with patient dose (Goldman, 2016), while pitch and slice thickness have an inverse relationship to the dose. As a result, an increase in mAs and kVp and a decrease in slice thickness and pitch will lead to an increase in the quantity of x-rays and image quality, thus leading to an increase in patient radiation dose (Martin & Sookpeng, 2016).

Radiographers should make well-informed decisions on each examination protocol requested by medical professionals as they are on the front lines of radiation delivery. To adhere ALARA principle and CT optimization, radiographers should have a sufficient understanding of the association between each exposure parameter and CT image quality. As CT image quality is directly related to the quantity of radiation utilised, it is critical to employ sufficient quantities to achieve diagnostic yield while avoiding excessive amounts that merely increase the patient's risk (Foley et al., 2013). Therefore, a proper trade-off between patient dose and image should be well justified by the radiographers.

Due to the rapid improvements in CT technology in recent years, it may be difficult for CT users to familiarize themselves with all the functions of their specific system, especially if they are operating many scanner versions from various manufacturers. Despite varying patient circumstances, 42% of the radiographers claimed that CT protocols were not altered accordingly. Lack of knowledge about CT scan parameters supports the strong correlation between the level of knowledge and protocol optimisation (Foley et al., 2013). Furthermore, insufficient education and familiarisation during training have contributed to poor radiation protection practices among radiographers (Abdulkadir et al., 2021). Knowledgeable and well-trained radiographers are essential for healthy radiation safety culture.

3.0 Methodology

3.1 Ethical consideration

Research ethics approval from the Research Ethics Committee of the Faculty of Health Sciences, Universiti Teknologi MARA was granted for the study (FERC/FSK/MR/2021/0038). Participation in the study was voluntary and consent was acquired from the respondents.

3.2 Research design and sample size

A cross-sectional survey was performed in this study. A self-administered questionnaire was distributed using an online Google form to radiographers who were working in the Department of Radiology of a teaching hospital in Klang Valley, Malaysia. The radiographers were recruited using a convenience sampling method. Participation of the radiographers in the study was voluntary basis and they consented to participate in the study. The required sample size of 60 was calculated using the Raosoft sample size calculator, based on a 95% confidence interval, a 5% margin error and a 50% response distribution. Radiographers with a minimum of one year of working experience in CT modality were included and trainee radiographers were excluded from the study.

3.3 Research tool

The questionnaire was adopted and adapted from the previous studies by (Foley et al., 2013) and (Rawashdeh et al., 2018). The questionnaire was constructed into three sections. The first section collected demographic information of the radiographers (four questions). The second section acquired knowledge of the radiographers concerning CT exposure parameters (six questions) and the third section acquired the current practice of the radiographers concerning CT exposure parameters in their clinical CT practice (five

questions). Questions were mostly in true/false and yes/no format. The scores were categorized as low (≤ 60%), moderate (61% – 70%), good (71% - 80%) and excellent (≥ 81%) (Abuzaid, Elshami, Noorajan, Khayal, & Sulieman, 2020). The questionnaire was first piloted with ten radiographers from another teaching hospital in Klang Valley to test the reliability of the questionnaire. Answers to the questions accessing the knowledge of CT exposure parameters were compared and referred to the published CT textbooks (Hsieh, 2003; Seeram, 2009).

3.4 Statistical analysis

Statistical analysis was performed using software SPSS version 26.0 for Windows (SPSS Inc., USA) with a p-value <0.05 was deemed statistically significant. The demographic data, knowledge and practice of CT parameters were expressed as frequencies and percentages. Cronbach's alpha was used to analyse the reliability of the questionnaires.

4.0 Findings

4.1 Demographic characteristics

A total of 60 respondents answered the survey with 100% response. All the respondents completed every question in the survey. Among them, 30 respondents (50%) were male and 30 (50%) were female, with the age ranging from 21 to over 40 years old. Most of the respondents (35%) had 1 – 5 years of working experience with CT, 31.7% had 6 -10 years of experience, 23.3% had 11 – 15 years of experience and 10% had 16 – 20 years of experience. Among them possessed a diploma (n=36, 60%), bachelor's degree (n=20, 33.3%) and master's degree (n=4, 6.7%). The demographic characteristics of the participants are shown in Table 1.

Table 1. Demographic characteristics of the participants

Demographic	N (%)
Gender	
Male	30 (50%)
Female	30 (50%)
Age	
21 – 25 years	7 (11.7%)
26 – 30 years	15 (25%)
31 – 35 years	21 (35%)
36 – 40 years	11 (18.3%)
> 40 years	6 (10%)
Years of working experience in CT	
1 – 5 years	21 (35%)
6 – 10 years	19 (31.7%)
11 – 15 years	14 (23.3%)
16 – 20 years	6 (10%)
Qualification	
Diploma	36 (60%)
Bachelor's degree	20 (33.33%)
Master's degree	4 (6.7%)

4.2 Knowledge of CT exposure parameters

A total of 23 questions were answered by the respondents on knowledge of CT exposure parameters including parameters manipulation, automated tube current modulation (ATCM), tube current (mA), pitch, rotation time and image noise. Overall, a good score of knowledge on CT exposure parameters with an average of 76.5 % was achieved by the respondents.

With regards to routine CT parameters that should be amended based on several factors, the results showed that the radiographers had excellent scores (≥ 81%) on modification of CT parameters based on patient size, study indication and patient age, but low scores on anatomical region factor (56.7%). An excellent score (82%) was indicated for the overall knowledge of modification of CT parameters. With regards to the knowledge of patient dose, metallic implant and patient positioning factors affecting ATCM, overall results showed a moderate score of 65.8%. Among them, most of the radiographers (83.3%) correctly answered that ATCM has an impact on dose reduction. However, the remaining factors showed moderate and low scores of knowledge, ranging from 53.3% to 66.7%. With regards to the knowledge of tube current, 85% of the respondents correctly answered that tube current has a linear relationship with radiation dose but only 63.3% of them correctly responded that ATCM is affected by centring of the patient within the gantry. The overall results showed a low score of 60.8%.

Interestingly, the radiographers showed excellent scores of knowledge on the impact of pitch on image quality and radiation dose with overall results of 85%. 86.7% of them correctly answered that pitch is the factor affecting the image quality and radiation dose and 83.3% of them correctly answered that the dose will be lowered as a result of the higher pitch in single-slice helical CT. With regards to gantry rotation time, the respondents had good (75%) and moderate knowledge (63.3%) that this parameter would linearly decrease the dose and increase the image noise, respectively. With regards to knowledge of the parameters affecting image noise, most of the radiographers had excellent scores on most of these parameters including kVp (95%), mA (93.3%), collimation (81.7%), slice thickness

(88.3%), helical pitch (81.7%) and exposure time (86.7%). On the other hand, the radiographers had a good score of knowledge on window width (75%) and reconstruction algorithm (78.3%), but a moderate score on window level parameters (65%). Correct responses by the radiographers about knowledge of CT exposure parameters are summarized in Table 2.

Table 2. Correct responses by the radiographers about knowledge of CT exposure parameters

Knowledge attributes	Percentage (%)
Factors affecting the manipulation of routine CT parameters.	
Patient size	96.7%
Anatomical marker	56.7%
Study indication	83.3%
Patient age	91.7%
Automatic tube current modulation (ATCM)	
ATCM has been shown to decrease the patient dose on average.	83.3%
ATCM can increase the patient dose in the pelvic region.	66.7%
ATCM should not be used in the presence of the metallic implant.	46.7%
ATCM is affected by centering of the patient within the gantry	66.7%
Tube current (mA)	
Tube current has a linear relationship with radiation dose.	85%
Reducing the tube current by 50% increases the noise two-folds	63.3%
Pitch (table movement per rotation/total nominal beam width)	
Pitch may impact image quality and patient dose.	86.7%
For single-slice helical CT, the use of a higher pitch will reduce the dose	83.3%
Impact of decreasing the gantry rotation time	
Linearly decreases the patient dose	75%
Increases the image noise	63.3%
Factors influencing image noise.	
kVp	95%
mA	93.3%
Window width	75%
Collimation	81.7%
Slice thickness	88.3%
Helical pitch	81.7%
Exposure time	86.7%
Window level	65%
Reconstruction algorithm	78.3%

4.3 Practice CT exposure parameters

Furthermore, this study showed that most of the radiographers (88.3%) were concerned about CT scan doses in their CT practice. Our survey also observed that the decision of routine CT scan protocols was made by the radiologist (n= 41, 68.3%), followed by the radiographer (n = 14, 23.3%), physicist (n = 2, 3.3%) and others (n =3, 5%). Concerning paediatric CT protocol, most of the radiographers (n = 54, 90%) agreed that different scan protocols should be employed for adults and children. Similarly, a question from the case study was presented in the survey about paediatric CT protocol and the result revealed that most of the radiographers (n=52, 86.7%) agreed to modify the CT protocol accordingly. Interestingly, our findings observed 88.3% (n=53) of the radiographers believed that further training in CT parameter optimization would be beneficial for their practice. Overall, the results indicated that the radiographers had an excellent score level of practice (88.3%) on CT exposure parameters. Correct responses by the radiographers about the practice of CT exposure parameters are summarized in Table 3.

Table 3. Correct responses by the radiographers about the practice of CT exposure parameters

Practice attributes	Percentage (%)
Concerning CT scan dose in the department	
Yes	88.3%
No	11.7%
Decision on the routine CT scan protocol in the department	
Radiologist	68.3%
Radiographer	23.3%
Physicist	3.3%
Other	5%
Application of different scan protocols for adults and children	
Yes	90%
No	10%
Consideration to change the current CT protocol for a CT pulmonary angiography (CTPA) case of an 8- months-old patient who has respiratory distress syndrome.	

Yes	86.7%
No	3.3%
Never	10%
Belief in the benefits of further CT training in CT parameter optimization	
Yes	88.3%
No	11.7%

5.0 Discussion

The present study showed that the radiographers have an overall good score (76.5%) on knowledge of CT exposure parameters. This finding is better than those presented in the previous studies. Moderate knowledge of CT parameters has been reported among Jordanian radiographers at 68.3% (Rawashdeh et al., 2018). Similarly, this study is comparable with the initial study on Irish CT specialists which reported that they had good knowledge of CT parameters with a good score of 70.3%, but low knowledge of the manipulation of the parameters related to radiation dose reduction (Foley et al., 2013).

Despite the mixed academic qualification and CT working experience of the radiographers, they demonstrated excellent knowledge of the factors affecting the manipulation of routine CT parameters and CT pitch. This knowledge is very important for a radiographer to trade off the CT image quality and patient radiation dose, thus achieving CT optimization. Nonetheless, this study revealed that the radiographers had moderate and low knowledge of ATCM and tube current, respectively. Regardless of the patient's attenuation characteristics, ATCM functions to maintain image quality at an acceptable level, which results in decreased patient radiation dose and improper parameter selection by the radiographers (Kalra et al., 2004). Hence, further improvement of knowledge about these parameters is necessary for radiographers to achieve CT optimisation.

Generally, this study showed the excellent practice of CT exposure parameters among radiographers. Most of the respondents (88.3%) were concerned about radiation dose in the department. Since most of the radiographers (65%) have working experience in CT for more than five years, their familiarity with the various scanning parameters may contribute to their excellent practice. The survey demonstrated that the routine CT protocol was mostly decided by the radiologist, radiographer, and medical physicist which comply with the ACR recommendation suggesting that radiologist, CT technologist, and medical physicists should be involved in the design of all new or modified protocol settings (Rawashdeh et al., 2018).

Interestingly to be addressed that most radiographers were concerned about radiation dose in CT practice for children. Modification of CT protocol appropriately is one of the effective strategies to reduce radiation dose for paediatric patients. This practice complies with the guidelines of several authorities including the International Commission on Radiological Protection, the International Atomic Energy Agency, and the European Commission which addresses CT dose reduction in children (Almohiy, 2014). Fundamentally, children have a faster rate of cell division than adults, increasing sensitivity to radiation (Bushong, 2013). Furthermore, a positive attitude was demonstrated by the radiographers as most of them believed in the benefits of further CT training in CT parameter optimization. This positive attitude may support the finding of the excellent practice of CT exposure parameters among radiographers. This positive finding could be explained by the numerous CT training and knowledge acquisition programs conducted in the teaching hospital.

This study showed the importance of reviewing the current application-related factors which affect radiation exposure to patients. Knowledge and practice of these factors e.g., scan parameters among the users, particularly radiographers should be routinely reviewed to ensure CT optimization is successfully implemented in the CT clinical practice. CT dose differences between various institutions and nations were almost entirely related to how the institutions used the machines, rather than differences in patient or institutional characteristics, machine manufacturer, or model (Smith-Bindman et al., 2019). Therefore, it is crucial for the radiographers who are responsible for CT scanning protocol decisions to have sufficient knowledge and good practice on CT exposure technicalities, which would further reduce dose variance in CT practices.

This study encountered several limitations. Firstly, the study population is limited to a single health institution, which may affect the study's generalizability. Secondly, the respondents may not truly answer the questionnaires based on their routine clinical practice instead of seeking answers and sources from internet access, which may introduce the study bias.

6.0 Conclusion & Recommendations

Good knowledge and excellent practice on CT exposure parameters which have an impact on CT radiation dose and image quality were found among radiographers. However, some areas of knowledge need improvement. More continuous education programs, courses and training on CT dose optimization are essential for radiographers in the future.

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Paper Contribution to Related Field of Study

The results of this study would be valuable to understanding the current level of knowledge and practice of CT exposure factors among the radiographers which have a direct impact on patient radiation dose in CT procedures. The outcomes of the present study would be useful for the radiological authorities to review the current CT practice among the radiographers and provide necessary training to improve their knowledge and practice, hence leading to achieving CT optimization.

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