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Evaluation of radiographers' and CT technologists' knowledge regarding CT exposure parameters

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Abstract

Introduction: Since the CT operators play an important role in the diagnosis and treatment of diseases and exposing the patients to radiation exposure, they must be aware of all CT parameters which affect the image quality and patient dose and update their knowledge in parallel with the progresses in CT technology. Therefore, the knowledge of radiographers and CT technologists regarding the CT parameters was assessed in this study to identify and resolve any potential deficiencies.

Material and methods: This study was conducted in 2018 among 113 radiographers and 103 CT technologists in Khuzestan province using a three-part questionnaire containing demographic characteristics, general opinion on CT scan dose and questions assessing technologists' knowledge of CT exposure parameters. Data were analyzed using SPSS software.

Results: Total knowledge scores of radiographers and CT technologists about CT exposure parameters were 36 and 42, respectively. The highest knowledge score among technologist was the knowledge of changing parameters based on patient characteristics and the lowest was in the field of awareness of noise index and diagnostic reference levels.

Conclusion: Total knowledge scores of radiographers and CT technologists about different scan parameters affecting dose and image quality was very low. Reviewing and updating the content of academic education and holding retraining courses are suggested.

Key words: computed tomography; image quality; knowledge; questionnaires; radiation dosage.

Introduction

Computed tomography (CT) has created a dramatic change in modern medicine and facilitated rapid diagnosis and monitoring of disease processes. Notable advances in CT technology and instrument in recent years including multidetector CT, iterative reconstruction algorithms, dual-energy CT and automatic tube current modulation (ATCM) led to the improvement in speed and image quality [1,2]. This progress increased the clinical use of the CT more than twice over the past three decades and made it one of the most important technical innovations in medicine [3-6]. As a result of the increased use, radiation dose from CT has grown. Nowadays, CT is the greatest source of the population exposure from medical procedures that alone contributes almost one half of the total radiation exposure from medical use [7,8]. It is estimated that 2% of current cancers in the United States are due to CT scans performed in the past [9].

In all CT examinations, doses delivered to patients must be kept as low as possible to ensure that the patients benefit from an accurate diagnostic scan, always outweighs the potential risks involved (ALARA principle) [10].

There are various parameters such as peak kilovoltage (kVp), tube current–time product (mAs), pitch, slice thickness, ATCM, detector configuration and reconstruction algorithms that control radiation output and image quality in CT. Several combinations of these parameters are available for users to choose. Some of which may be manufacturer specific. Nevertheless, default settings and manufacturer recommended protocols may be designed for an average sized patient and optimize image quality rather than patient dose [11,12]. It is a vital task of the technologists to select the best combination on a patient-by-patient basis for achieving the acceptable image quality with the lowest possible dose according to the ALARA principle.

To make such an optimization, accurate knowledge of all CT parameter is critical. Furthermore, as CT technology will continue to change at a rapid pace, technologists must always reevaluate and update their knowledge [13,14].

Accordingly, the present study was designed to assess the level of radiology expert' knowledge regarding the parameters affecting image quality and patient dose and factors affecting their knowledge, to identify and resolve any potential deficiencies.

Material and Methods

This cross-sectional descriptive-analytical study was conducted in 2018 in Khuzestan province (southwest of Iran). Participants were 103 CT technologists in addition to 113 radiographers (with no work experience at CT departments) who were recruited in the study by simple random sampling method.

A modified questionnaire from S. J. Foley [15], containing 58 questions in three sections was used to assess the technologists' knowledge of CT exposure parameters. Modification was made in the first part of the Foley questionnaire. This section includes 5 questions collected demographic information (level of education, shift work, work experience, background and tendency to join training courses), in addition, 6 questions about scans performed by CT technologist (number of scans done per shift, years of CT experience, confidence in altering protocols, design and changing protocols) and opinions on CT dose. The second part contained 47 questions on specific CT scan protocols, parameters, and diagnostic reference levels. The third part includes open-ended questions.

The questionnaire was assessed for suitability of topics, phrasing and overall content by a radiologist and two CT scan expert university professors.

Before collecting data, participants were informed about the objectives of the study and the benefits of sharing as well as how to complete the questionnaire. In addition, they were reminded to complete the questionnaires based on their knowledge and not using books or other sources. Confidentiality and privacy were guaranteed all over the study, then verbal consent was taken.

Questions were in true/false, yes/no and multiple choices format. For each correct answer +1 score, and for wrong or blank answer -0- was considered. To obtain the mean of each person's knowledge score in percentage terms, the total score obtained by each person divided by the sum of the expected scores and multiplied by 100. Then the mean scores of all participants were calculated to obtain the total knowledge score.

If a person answers the whole question of a particular field (for example, ATCM), this is considered as complete knowledge, and if he/she does not answer any questions of that particular field correctly, considered as without knowledge.

Statistical analysis of data performed by SPSS program (version 16.0) using descriptive statistics, independent samples t-test, ANOVA/LSD post hoc test and Pearson correlation test. A P-value <0.05 was considered significant. Open-ended questions have also been examined using content analysis.

Results

Demographic characteristics of radiographers and CT technologists including the level of education, shift work, confidence in altering protocols, scan protocol decision, participation at retraining course, work experience and the number of scans done per shift are shown in **Table 1**.

Table 1. Demographic characteristics of radiographers and CT technologists.

variable		education			work shift					confidence in altering protocols correctly				scan protocol decision				retraining course		personnel changing protocols based on patient characteristics	work experience (year)	number of scans done per shift
		associated degree	bachelor degree	master degree	fixed day shift	fixed evening shift work	fixed night shift work	regular rotating shift work	irregular rotating shift work	excellent	good	medium	poor	radiologist	physicist	technologist	software specialist	participated in retraining courses	desire to participate in retraining courses			
n / mean ∓ σ	radiography	8	99	6	9	1	1	11	91	-	-	-	-	-	-	-	-	16	109	-	5.1 ± 5.4	-
	CT scan	4	89	10	4	-	-	10	89	9	44	47	3	35	2	46	17	33	101	58	4.4 ± 4.7	65 ± 12

Table 2. Mean, median, standard deviation (SD), mean difference (MD), minimum and maximum of total knowledge score radiographers of and CT technologist about different CT parameter.

	occupation	mean	med	SD	max	min	MD	P-Value
total Knowledge of CT parameters	CT technologists	42.76	41.46	12.28	75.61	12.20	6.76	0.00027
	Radiographers	36.00	34.15	14.58	75.61	7.32		
parameter changes based on patient's characteristics	CT technologists	61.89	50.00	29.67	100.00	25.00	15.65	0.00017
	Radiographers	46.23	25.00	30.48	100.00	25.00		
ATCM	CT technologists	27.96	20.00	28.88	100.00	0.00	5.83	0.12
	Radiographers	22.12	0.00	26.77	80.00	0.00		
mAs.eff (Noise Index)	CT technologists	18.93	0.00	23.34	100.00	0.00	2.78	0.34
	Radiographers	16.15	0.00	19.74	75.00	0.00		
kVp	CT technologists	36.50	40.00	20.08	80.00	0.00	8.54	0.003
	Radiographers	27.96	20.00	21.14	80.00	0.00		
mAs	CT technologists	40.77	50.00	37.54	100.00	0.00	-3.03	0.55
	Radiographers	43.80	50.00	36.68	100.00	0.00		
pitch	CT technologists	58.98	50.00	30.89	100.00	0.00	14.51	0.001
	Radiographers	44.46	50.00	34.68	100.00	0.00		
tube rotation speed	CT technologists	45.14	50.00	38.04	100.00	0.00	0.45	0.93
	Radiographers	44.69	50.00	39.17	100.00	0.00		
slice thickness	CT technologists	38.34	50.00	28.18	75.00	0.00	4.06	0.29
	Radiographers	34.29	25.00	27.99	100.00	0.00		
image reconstruction	CT technologists	33.00	50.00	35.39	100.00	0.00	9.11	0.05
	Radiographers	23.89	0.00	33.47	100.00	0.00		
image noise	CT technologists	53.39	55.55	22.12	100.00	22.22	4.92	0.09
	Radiographers	48.47	44.44	21.05	100.00	11.11		

Total knowledge scores of radiographers and CT technologists about different scan parameters are shown in **Table 2**. According to this table, the total knowledge of radiographers and CT technologists about CT exposure parameters was 36±14 and 42.76±12, respectively. This difference was significant statistically.

The highest knowledge score among technologist is the knowledge of parameters change based on patient's characteristics and the lowest is the knowledge of noise index (mAs.eff).

Technologists who had previously participated in CT retraining courses have higher scores compared to others. This difference was significant statistically. There was no significant relationship between the level of education, work shift, work experience and the number of scans done per shift with knowledge of technologists.

A significant difference was seen between radiographers and CT technologists' scores in fields of kVp, reconstruction parameters and pitch factor effects on image quality and patient dose as well as knowledge about CT parameter changes based on patient size and age, anatomical region and clinical indication.

Self-reported knowledge score of diagnostic reference levels (DRLs) amongst radiographers and CT technologists was 8.55 ± 23.79 and 5.50 ± 19.85 respectively. However, when asked them to express the correct value, it was reduced to 1.78 ± 10.67 and 1.62 ± 9.17. In this regard, 97.1% of CT technologists and 96.5% of radiographers could not express any of the DRL values, and no one was able to express all six DRL correctly.

Knowledge score of DRL for personnel with regular rotating shifts was significantly higher than those who are working with the constant shift. However, no significant difference was seen between knowledge score of personnel concerned about patient dose and unresponsive personnel. In addition, there was no significant relationship between participation in retraining courses, level of education, work experience and the number of scans done per shift with knowledge of DRL values.

Based on ANOVA test, knowledge score of ATCM in associated technologists was significantly less than bachelors (Mean difference = -19.08, P-value = 0.02) and the masters (Mean difference = -22.08, P-value = 0.04). But no significant difference was observed between bachelor and master technologists. Also, the knowledge score of ATCM (P-value = 0.020, Mean difference = 10.55) and Pitch factor (P-Value = 0.049, Mean difference = 10.741) among the group that previously had participated in CT scan-related training courses was significantly more than the group that did not have an experience of attending these courses.

The relationship between awareness of noise index and reconstruction algorithm with education level, work experience and participation in retraining was not significant statistically.

According to **Figure 1**, the relationship between dose and mAs were predicted correctly by 57.3% of CT personnel and 61.1% of radiographers and only 24.3% of CT personnel and 26.5% of radiographers were able to predict the relationship between tube current and image noise.

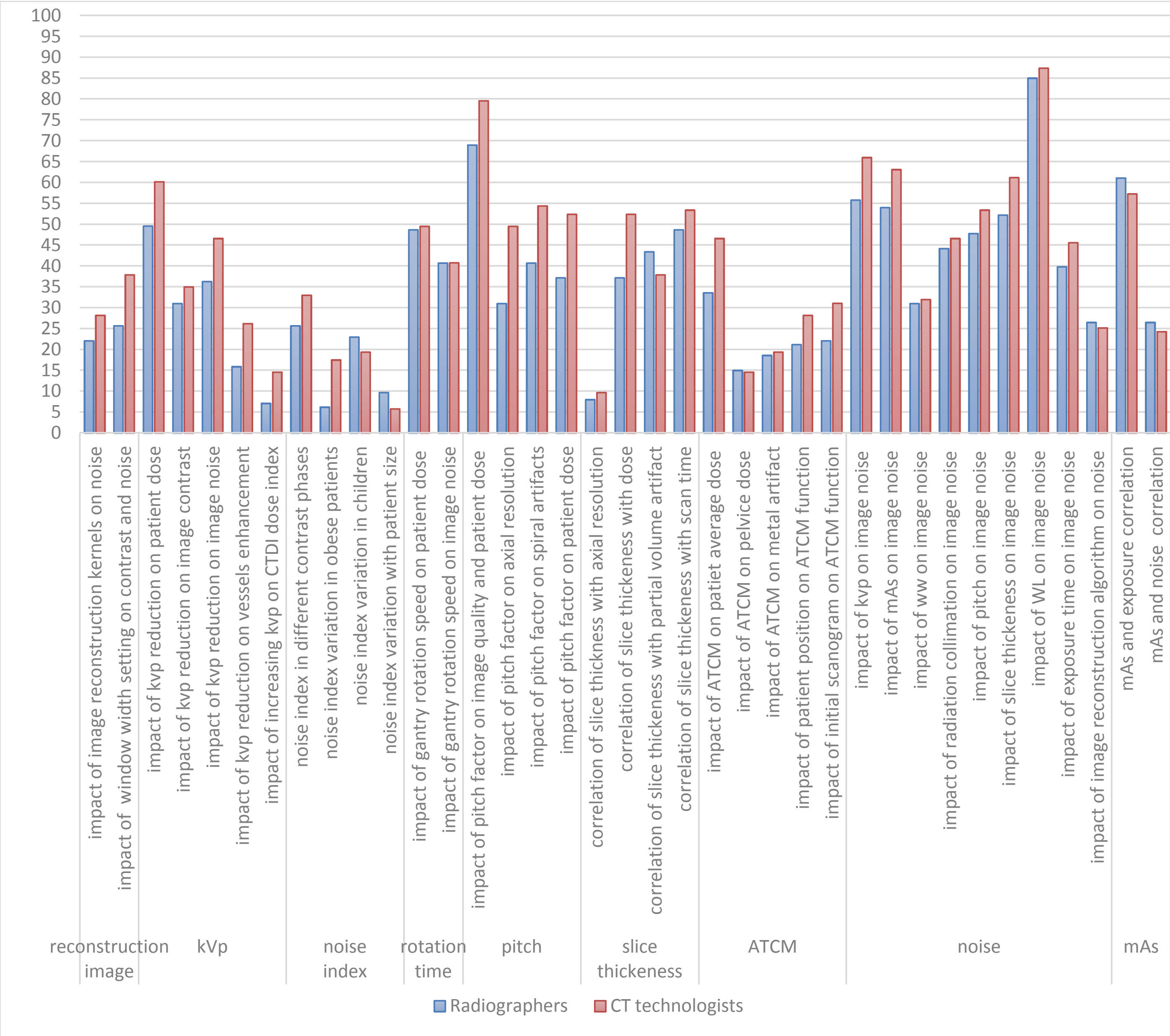

Figure 1. Percentage of technologists that answer to questions of different field correctly.

In term of image noise, highest and lowest awareness scores in both groups were about the window level and reconstruction algorithm effect on image noise, respectively. In this regard, as shown in **Figure 2**, only 3.9% of CT personnel and 0.9% of radiographers were able to predict all factors affecting image noise.

According to **Figure 2**, 30.1% of CT technologists and 19.5% of radiographers stated that routine CT parameters should be altered according to patient size and age, desired anatomical region and clinical indication.

24.3% of CT personnel and 25.7% of radiographers were able to predict the effect of gantry rotation speed on image noise and patient dose.

Regarding awareness of DRLs, 97.1% of CT technologists and 96.5 % of radiographers were without knowledge and no one has complete knowledge in both groups.

Discussion

The significant impact of CT on rapid diagnosis and monitoring of disease processes has led to the expansion of its application. Subsequently, concern is increasingly being raised regarding the potential hazard of this imaging modality [9,16]. To achieve the best image quality along with the lowest radiation dose, the accurate knowledge about CT scan parameters is critical.

Results show total knowledge of technologists about parameters effects on image quality and patient dose was lower compared to Karim and Foley studies [14,15]. This can be attributed to the less work experience of technologists in this study. Furthermore, the population studied by Karim *et al.* was selected from radiologists, medical officers, physicists and radiographers, which is slightly different from the present study.

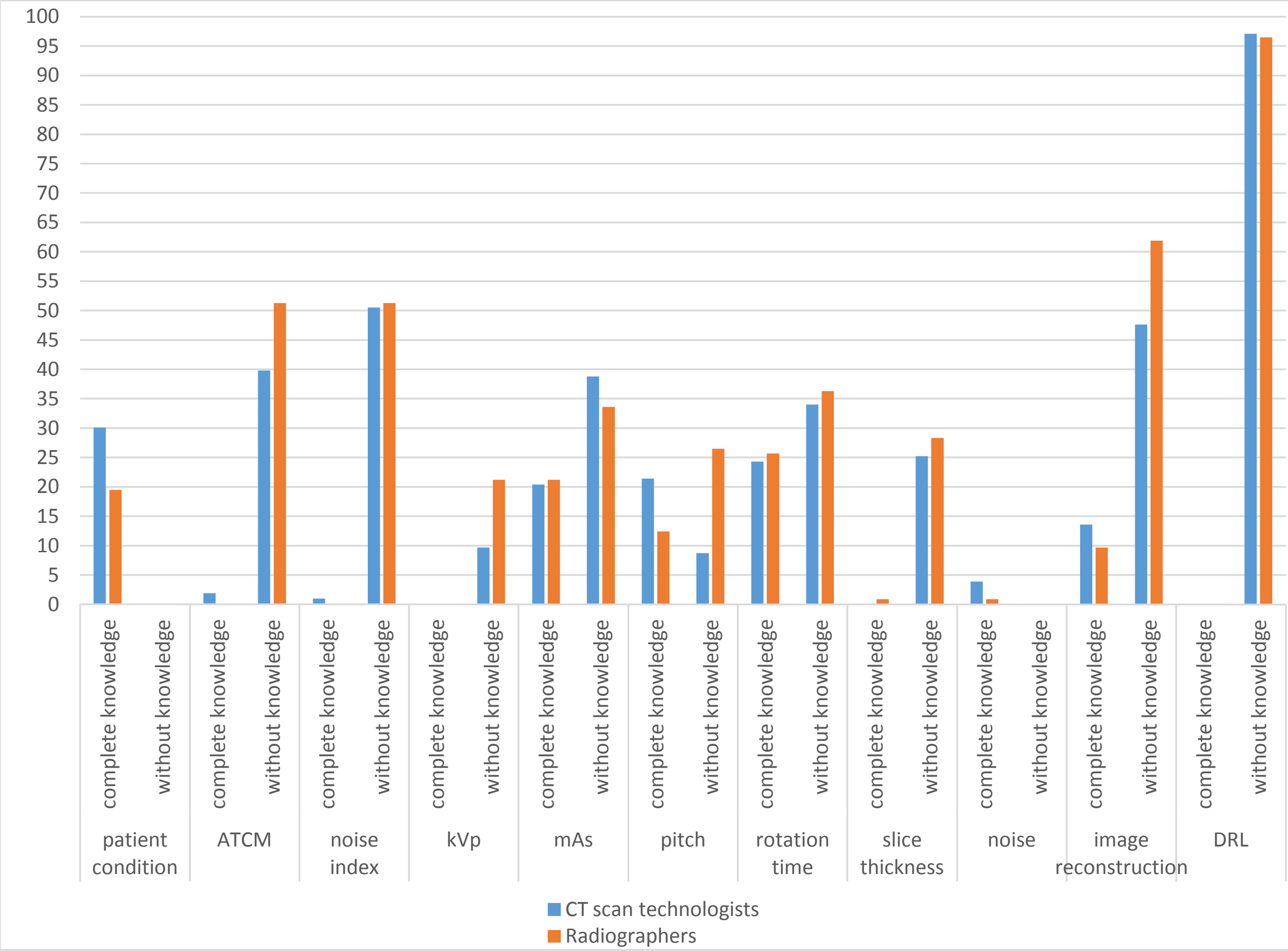

Figure 2. Percentage of technologists with complete and without knowledge in different fields.

Despite the same academic educational courses, total knowledge of CT technologists about CT exposure parameters, parameters change based on patient condition and the impact of kVp, image reconstruction, and pitch factor on the image quality and patient dose were higher than radiographers. This can be due to the work experience of CT technologists in the CT department and their familiarity with the various parameters of the scanner. With this hypothesis, it seems that college internship courses have not had a desirable efficiency in this regard. Considering the higher score of the personnel participating in retraining courses, another possible reason could be a greater number of CT personnel participating in these courses compared to radiographers. The impact of retraining courses on personnel knowledge is also mentioned in other studies [15,17].

42 percent of CT personnel stated no changes to protocols based on different patient conditions. Since there was a significant relationship between knowledge level and optimization of protocols, one of the reasons for this, maybe the lack of knowledge about CT scan parameters. Karim *et al.* also stated that a large percentage of personnel did not have enough knowledge for changing protocols [14]. Another possible reason could be the lack of self-confidence to changing protocols despite the sufficient knowledge. In this regard, as shown in **Table 1**, only nine technologists have excellent confidence level to alter protocols [14,18-20].

This study shows that the technologists performing more scans per shift were less worried about patient dose (P-value = 0.004, Mean difference = 10.45). In these cases, the greatest challenge for the technologist is to perform the scan as soon as possible regardless of the scan quality and patient dose. So, the protocol optimization is not considered.

DRLs

Unlike traditional radiographic imaging, a CT image never looks “overexposed” in the sense of being too dark or too light; the normalized nature of CT data (i.e., CT numbers represent a fixed amount of attenuation relative to water) ensures that the image always appears properly exposed; hence, the technologist should be aware of the DRLs and optimize the protocols based on them to prevent patient overexposure [21-26].

Knowledge about DRLs of the six scans in this study is much less than the other studies [15], and a large number of both groups were unable to state DRL values for any of these scans. This may lead to unaware and unwanted patient overexposure.

Since the local and national DRLs have not been established for Iran, in this study DRLs from European Commission 2014 [27] have been used. Lack of local and national DRLs may be one of the possible reasons for the low knowledge level about CT DRLs.

It was expected that technologists concerned about patient dose would be more aware of DRL values than unresponsive technologists; nevertheless, no significant difference observed between the two groups, which show there is a lack of awareness and proper training about importance of DRLs despite well technologists' attitude.

Furthermore, no significant relationship was observed between participation in retraining courses, level of education, work experience and the number of scans done per shift with the awareness of DRLs, which indicates no attention to the DRL. In this regard, training courses, monitoring of patient dose and comparisons to national values are recommended [28-32].

CT protocols

According to the ACR (American College of Radiology) statement, the radiologist, CT technologist and physicist should converge on the design of all new or modified protocols to achieve the acceptable image quality with the lowest possible dose [33]. However, compliance amongst these groups is low in consistent with Foley *et al.* [15], therefore, encouragement of physicians, application specialist and physicists in cooperation with technologists to design protocols is recommended.

As discussed earlier, due to normalized nature of CT data, users are not technically compelled to alter parameters for different patients, which may result in excess radiation dose [26]. It is, however, a fundamental task of the CT operator to take patient size and age, anatomical region and clinical indication into account during protocol designing. Worryingly, similar to other studies [14,15], a significant number of technologists have expressed no need for altering parameters based on patient conditions. Indicating that patients may potentially be exposed to higher doses than necessary.

As with radiographic and fluoroscopic imaging, providing appropriate guidelines for selecting parameters as a function of patient condition (often referred to as technique chart) can be useful [26].

ATCM

The purpose of using ATCM is to maintain image quality at an acceptable level, regardless of the patient attenuation characteristics, which leads to a reduction in patient dose and the improper parameter selection by the technologist [34,35]. Total knowledge of radiographers and CT technologists about ATCM was 22.12 and 27.96, respectively that seems to be low. This can lead to patient overexposure and degraded image quality.

None of the radiographers and only one of CT technologist had complete knowledge of ATCM. According to the higher knowledge score about ATCM achieved by associated technologists and personnel that participated in retraining courses, updating the content of academic education to introduce new concepts in CT scan to students is suggested.

Peak kilovoltage (kVp)

kVp controls the overall energy and number of output X-rays. Therefore, any change in it will affect the image noise, contrast, and patient dose [36]. In CT systems, it can vary between 80-140 [37-39]. kVp reduction from 120 to 100, while keeping all other parameters constant, can decrease the patient dose and enhance vascular contrast in the angiography while increasing noise. More than half of the personnel were not able to predict these changes correctly, and none of them had complete knowledge about kVp effects on patient dose and image quality. While patient dose reduction, increasing noise and no impact on vascular enhancement have stated by a large number of technologists in similar studies [15].

Tube current (mAs)

Tube current (mAs) represents the number of output x-ray photons and therefore determines image noise and patient dose [32]. About 60 percent of personnel had predicted the relationship between exposure change and tube current, while their knowledge about the relationship between tube current and image noise was low.

mAs.eff (mAs/slice), rotation time and pitch

Effective mAs or mAs/slice is defined as the true mAs*rotation time/pitch. This distinction between mAs and average mAs along the z-axis is very important. In multidetector CT, when the effective mAs is used, as pitch is increased or rotation time is decreased, scanner software may automatically increase the mA (this is not true in SDCT). Thus, Noise and patient dose remains constant as pitch and rotation time are varied for a constant value of effective mAs/slice. The user may be unaware that the actual mA was increased in systems that use the average mAs along the z-axis concept [26]. Therefore, technologists must always be careful about changing other parameters when altering a parameter. Mean knowledge score of radiographers and CT technologists about effective mAs and pitch in this study are very low compared to Foley *et al.* [15], and knowledge score of pitch effects on image resolution, patient dose and spiral artifacts in CT technologists was significantly higher than radiographers.

Conclusion

Total knowledge scores of CT technologists about different scan parameters affecting dose and image quality was higher than radiographers, however, it is very low compared to other studies. Reviewing and updating the content of academic education and holding retraining courses, according to a large number of personnel willing to attend these courses, are suggested.

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