Establishment of regional diagnostic reference level for CT planning of breast cancer and comparing them with international values

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ABSTRACT

Background: All over the world, Computed Tomography (CT) scan is used as an essential method in radiation therapy treatment planning. Ionizing radiation for the medical exposures should follow principle "As Low as Reasonably Achievable" (ALARA) to reduce the dose. The objective of this study is to establish a Diagnostic Reference Level (DRL) for breast Computed Tomography planning (CTp) and compare it with other DRLs because there are no dose guidelines for breast cancer CTp in Iran. The established DRL can be used for dose optimization in CT planning. ***Materials and Methods:*** We surveyed six RT centers in Tehran and collected data from patients with breast cancer, who were of average size, regarding the volume Computed Tomography Dose Index ($CTDI_{vol}$), the dose length product (DLP), the dose parameters, the scan length, the thickness of the slices, and the use of automated exposure control (AEC). DRLs were calculated for each dose descriptor using the rounded 75th percentile of the distribution of means. ***Results:*** Data were collected on a total of 90 breast cancer CT localization scans from six CT centers. Significant variation was observed in mean DLP and mean $CTDI_{vol}$ among centers (p value < 0.0001). Moreover, mean mAs and scan length significantly differed across centers (p < 0.0001). Calculated DRLs for breast localization are 296.29 mGy cm and 6.64 mGy for DLP and CTDIvol, respectively which were lower compared with other studies conducted in this field. ***Conclusion:*** There were differences in doses used for breast CT planning among centers. DRLs were proposed for dose optimization and patient radiation protection in CT planning.

INTRODUCTION

In external radiation therapy (RT), the healthy tissues around malignant cells are in the path of radiation, and unfortunately they absorb unwanted radiation. Therefore, before starting radiation therapy, it is necessary to determine the appropriate dose for the tumor. The best solution is to prepare a Computed Tomography (CT) scan with cross-sectional images. In fact, CT scan is the only and best way to calculate three-dimensional (3D) dose distribution in external beam radiation therapy. The scan before radiotherapy for the purpose of treatment planning is called Computed Tomography planning (CTp). In CTp procedure, for the patients with unilateral breast cancer, both breasts are exposed by X-rays directly. Previous research has determined that CT scans have a high radiation dose that can increase the risk of carcinogenesis [(1)]. On the other hand, CT planning involves high-quality images and a variety of scan sizes, so the dose levels are typically higher than those of diagnostic CT scanning. Hence, when CT scan is used, the amount of dose received by the patient should be considered, and should be controlled by ALARA principle.

In scanning volumes that include the breast tissue, there are higher effective doses [(2)]. On the other hand, the breast tissue is a sensitive organ to radiation; so stochastic risks, such as breast cancer will increase. In order to reduce patient risks such as breast cancer, all ionizing radiation imaging processes, including CT planning, need to be adjusted to reduce the effective dose. To minimize the dose in imaging procedures, dose reference level (DRL) was introduced by the International Commission on Radiation Protection (ICRP) in 1996 and its compliance is required by the directive of European Commission 13/59 of the European Atomic Energy Community (EURATOM) [(3)]. Compared to diagnostic CT scans; few studies were conducted on DRLs in radiation therapy computed tomography (RTCT). This deficiency is in terms of the legislative bodies' negligence and ignorance of the CT scans role in RT that impeded the development of DRLs in this field. By complying with DRL for diagnostic imaging, such as CT scan, dose reduction was observed over time [(4)] therefore, we can hope

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that the same result will happen in the case of RTCT.

Since dose levels of CT planning are lower than radiotherapy doses, some critics may believe that there is no need to create DRLs in CT planning, but this analogy is not correct because CT planning should be considered a non-therapeutic diagnostic procedure like radiology and diagnostic CT scan.

O'Connor *et al*. established the first national DRL in breast CT planning. The study found that CT dose varied across centers, hence developing DRL is necessary for optimizing CT (5). Zalokar *et al*. offered that the imaging techniques of CT planning should be examined and improved, because statistically significant discrepancies in $CTDI_{vol}$ values discovered. Therefore; they established DRL for CT planning procedures in Slovenia (6). Weber *et al.* estimated $CTDI_{vol}$ and DLP parameters related to breast tissue in CT planning (7). Bozanic *et al.* obtained DRL for breast cancer CT planning by calculating the third quartile of $CTDI_{vol}$ and DLP. The comparison of these calculated numbers with international values showed that optimizing the CT planning method in Croatia is necessary (8).

Based on the articles (9-11), breast cancer is the second most common cancer in the world. In the course of women's lifetime, one in eight women is susceptible to developing breast cancer. Women are more likely than men to develop breast cancer, with women experiencing 100 times more cases than men. This kind of cancer affects more than 1.5 million women worldwide each year. In fact, there are methods to treat breast cancer, but prevention for this type of cancer is still a challenge worldwide (9,11) and one of the most important solutions is reduction of unreasonable dose in diagnostic radiation modalities like CT planning. A patient who is a candidate for radiation therapy, should take a CT planning examination before RT. In Iran, like the global statistics, the number of women with breast cancer is high (12,13). Although there are many articles on radiology and CT scan doses, there has been no study on CT scan planning dose. CT planning is essential before RT but no attention was paid to CT planning doses until now.

Breast CT planning doses were discussed among selected RT centers in Tehran and then DRLs were calculated by the recorded dose parameters. The calculated DRLs can be the basis for limiting and optimizing the radiation dose in CT planning for breast cancer patients in Tehran, and finally, they can lead to the protection of all organs, especially radiation_sensitive organs that are directly exposed to radiation.

We believe the importance of radiation protection can be further shown by conducting studies on the received dose and introducing DRLs for the patients with breast cancer. Therefore, we established the first regional diagnostic reference levels (DRLs) for breast CT planning, in Iran. Since DRLs were introduced for optimization by the International Commission on Radiological Protection (ICRP) (14), the dose and DRLs values reduced in CT scan procedures over the years (4). DRL serves as a threshold to facilitate the identification of high doses that are unjustified. As a consequence, this study's results can be used as a basis for DRLs in breast cancer CT planning, which will facilitate optimization in future studies.

MATERIALS AND METHODS

Study population

Ethical approval (IR.IUMS.REC.1398.1310) granted by the Research Ethics Committee, Iran University of Medical Sciences, Tehran, Iran. This audit concentrated on CT localization scans of females with breast cancer who were getting tangential breast radiation therapy (RT). Six RT centers accepted the invitation to participate in a dose survey. It was decided to exclude the post-mastectomy population, patients with oversize bodies and patients with bilateral breast cancer for the purpose of collecting data. European guidelines recommend a minimum sample size of 10 patients for dose evaluation; this number is used in various diagnostic research projects (15). We selected 15 patients from each center and all of the data collected for this research were completely anonymous.

Ninety patients with breast cancer were selected to complete the data of this research within six months. They were required to have a CT scan before treatment. Parameters related to each patient's scan, including age and gender, milliampere second (mAs), kilovoltage (kV), pitch factor, scan length, slice thickness, the volume Computed Tomography Dose Index ($CTDI_{vol}$), dose length product (DLP) were recorded. A predetermined checklist was used to record device information, including the manufacturer, year of installation, number of detector rows, the presence or absence of automatic exposure control (AEC) and the model of the device. All devices have already passed quality control (QC) tests in the past year (table 1).

Data registration

For each patient, immediately after finishing the scan, dosimetry information including $CTDI_{vol}$, KVp, mAs, scan margin, DLP and pitch factor were recorded using the Picture Archiving and Communication System (PACS) and the scanner console.

Dose estimation

Dose calculation software called "NCICT" (version 2.01) designed to calculate organ dose. NCICT; National Cancer Institute dosimetry system for Computed Tomography, is a dose calculator (16). We measured the effective dose and the received dose to

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breast and sensitive organs over the course of this study. This software provides information about scan length in centimeters and doses using gender, size of patient, scan margin, $CTDI_{vol}$, KVp, mAs, DLP and pitch factor.

Phantom study

To confirm the accuracy of data obtained from patient scan, standard CT dosimetry based on the protocol recommended by the European Commission was performed [15]. Head and Body Nested phantoms (04-203 - Pro-CT Dose, (Pro-Project) Okszow, Poland) was used. These phantoms are made of Poly Methyl Methacrylate (PMMA). The diameter of the body phantom is 32 cm, and it has four holes at 90° intervals on the periphery. The diameter of the head phantom is 16 cm, and it has one hole in the center. Head phantom placed inside the body phantom. To measure the dose, a CT Dose Profiler probe (ionization chamber of the pencil type) and Ocean 2014 Professional software (RTI Group, Sweden) were used. The CT Dose Profiler probe is a point dose detector that has a solid-state sensor placed 3 cm from the end of the probe that it puts in the phantom holes (figure 1).

Table 1. The specifications of CT scanners in centers (CMC, P, SHT, EH, SH7T and F are abbreviations for centers in this study).

center	CT scanner	CT model	Number of detector rows	Year of installation	CT company	country of origin
CMC	General Electric (GE)	Light speed	16	2012	General Electric company	United States
P	Siemens	sensation	16	2018	Siemens	German
SHT	Siemens	emotion	16	2004	Siemens	German
EH	Siemens	emotion	1	2005	Siemens	German
SH7T	Toshiba	Aquilion	16	2016	Toshiba	Japan
F	Siemens	Somatom scope power	16	2018	Siemens	German

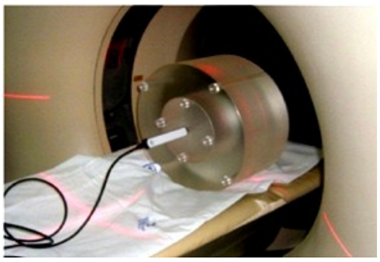

Figure 1. PMMA body phantom with 32 cm diameter.

Every CT scan center placed the CT Dose Profiler probe in one hole of the phantom and recorded the scan parameters (kV, pitch (-), tube rotation time (s), collimation (mm) and phantom type (body) using Ocean 2014 Professional. Then the phantom was scanned with the same parameters as the routing protocol. This way of doing a dosimetry test was repeated for all five holes in the phantom. Immediately after each exposure for one hole, $CTDI_{100}$ (mGy) was shown by Ocean software. Since the $CTDI_{100}$ is a linear measurement of the dose distribution on a pencil ionization chamber, it is not considered. Therefore the $CTDI_w$ (Weighted Computed Tomography Dose Index) (mGy) and the $CTDI_{vol}$ (mGy) were obtained by the following equations (1 and 2) [17]:

$$CTDIw = \frac{1}{3} * CTDI100\,(center) + \frac{2}{3} * CTDI100\,(peripheral) \quad (1)$$

$$CTDIvol = CTDIw\,/pitch \quad (2)$$

($CTDI_w$ is the first proposed quantity as a reference dose for a single axial rotation) [18].

($CTDI_{vol}$ is a standardized value of the scanner of a computed tomography system) [19].

Statistical analysis

$CTDI_{vol}$ and DLP are the main dose descriptors in CT dose research [20], which were finally used for the evaluation of DRLs as the dose reference level in this survey, and then they were compared with other research in this field. Generally speaking, DRLs should be given at the 75th percentile of the median dose distribution [21], while some researchers propose optimizing at the 25th percentile [22]; however, this would also affect the quality of the picture. In this survey, DRLs were calculated based on the 75th percentile of median dose distribution and did not rate the quality of the images. The obtained information was recorded in Excel software version 2016 and SPSS software version 22 for analysis and processing. After checking the distribution of $CTDI_{vol}$ values and using the Kolmogorov-Smirnov test, it was determined that the distribution of this variable follows the normal distribution; therefore, one-way ANOVA and Tokay's post-test were used to examine the difference in the mean of $CTDI_{vol}$.

RESULTS

Six RT and CT scan centers in Tehran accepted the invitation to participate in this survey. The scanner details, including the maker, model, installation year, and number of detector rows were recorded in a list for each CT center. The number of rows in all scanners were 16 rows, except in one scanner, and the year of installation for three scanners was after 2016.

Scan parameters for breast cancer CT planning in each center are shown in table 2. As reported at all sites, the mean amount of current (mAs) varied significantly between the centers (p-value < 0.001);

however, the tube potential (Kv) remained the same with the exception of one. The minimum scan time was 9 seconds, and the maximum was 14 seconds, corresponding to the P center and the CMC center, respectively. The mean scan time for all scans performed in this study was 11.45 seconds.

Table 2. scan parameters for breast CT planning based on data from 15 patients in each center (CMC, P, SHT, EH, SH7T and F are abbreviations for centers in this study).

center		Kv	mAs	scan time (s)	Scan length (cm)	Pitch factor	Slice thickness (mm)
CMC	max	120	120	14	48.87	1.37	5
	mean	120	120	13	43.10		
	min	120	120	12	28.87		
P	max	110	90	11	62.05	1.2	5
	mean	110	90	10	41.90		
	min	110	90	9	37.90		
SHT	max	110	111	13.61	58.56	1.5	3
	mean	110	80	11.72	47.10		
	min	110	46	9/83	32.33		
EH	max	110	124	14	49.78	2	5
	mean	110	92.13	12	41.25		
	min	110	75	10	34.00		
SH7T	max	110	50	11	65.24	1.43	5
	mean	110	50	10	49.02		
	min	110	50	9	39.91		
F	max	110	125	14	44.48	1.35	5
	mean	110	98.8	12	39.98		
	min	110	74	10	35.34		

Tube potential (kV). Tube current (mAs). Exposure time (scan time (s)). Pitch (-).

Scan length

By comparing recorded data, the change in the scan length among the centers was observed. The minimum scan length was 28.87 centimeters (cm) corresponding to the CMC center and the maximum was 65.24 centimeters at SH7T center. The mean scan length in this study was 43.72 cm (table 2).

phantom dosimetry

Before collecting the patient's data, a phantom dosimetry examination was performed in centers. In each center, the phantom $CTDI_{vol}$ was calculated. There was no significant difference among the determined values (phantom $CTDI_{vol}$) and the doses reported by the control console, and the mean percentage differences (for $CTDI_{vol}$ calculated from the phantom dosimetry examination and the $CTDI_{vol}$ displayed by the CT scan console) were in acceptable range; they were less than 20 percent (table 3).

Table 3. Mean percentage difference of phantom dosimetry and CT scanner in each center (CMC, P, SHT, EH, SH7T and F are abbreviations for centers in this study).

center	CMC	P	SHT	EH	SH7T	F
Mean percentage difference	4%	13%	4%	17%	1%	7%

It is evident that, after calculating $CTDI_{vol}$, we can obtain DLP and then estimate the effective dose [23]. We obtained the effective dose using dosimetric parameters and NCICT software in each center separately. Table 4 shows the distribution of dose–length product (DLP), CT dose index volume ($CTDI_{vol}$), and effective dose (ED) for breast cancer CT planning, with 15 patients per center. It was found that the highest mean values of $CTDI_{vol}$, DLP, and effective dose were respectively 8.15, 351.29 and 7.75, which were related to center CMC.

Table 4. minimum and mean and maximum dose parameters (volume Computed Tomography Dose Index (CTDIvol) and Dose Length Product (DLP) and Effective Dose (ED)) in each center (CMC, P, SHT, EH, SH7T and F are abbreviations for centers in this study)

Dose parameter	Min/ mean/ max	CMC	P	SHT	EH	SH7T	F
$CTDI_{vol}$ (mGy)	min	8.15	6.15	3.31	2.94	4.20	5.06
	mean	8.15	6.15	5.61	4.00	4.20	6.97
	max	8.15	6.15	7.63	6.15	4.20	9.22
DLP (mGy*cm)	min	316.77	233.10	154.31	111	167.60	183.95
	mean	351.29	257.67	270.30	170	201.82	279.56
	max	398.31	381.59	440.29	280	219.60	376.33
ED(mSv)	min	6.91	5.03	3.37	2.73	3.87	4.28
	mean	7.75	5.71	5.72	3.71	4.46	6.38
	max	8.43	7.90	8.94	5.10	4.89	8.51

CTDIvol (mGy) = CTDIw/Pitch; DLP(mGy*cm) = scan length/CTDIvol; ED(mSv) = K (organ conversion factor) * DLP

Based on the results of statistical tests, the mean of $CTDI_{vol}$ was significantly different ($p < 0.0001$) among selected hospitals. The same results were obtained for the mean of DLP and the mean of the effective dose (ED). In all scanners, after finishing the scan, dose parameters are shown. For each center separately, $CTDI_{vol}$ and DLP were recorded from the scanner console for 15 patients. Then the mean of dose parameters was calculated for 90 patients and obtained data for $CTDI_{vol}$ and DLP were 218.18 mGy and 5.21 mGycm, respectively (table 5). DRLs were calculated based on the 75th percentile of dose indicators (DLP and $CTDI_{vol}$). According to SPSS software, DLP and $CTDI_{vol}$ were calculated in the third quartile and found to be 296.99 and 6.64, respectively. Table 5 show DRLs values in this survey and other studies.

Table 5. Measured values of CTDIvol , DLP, DRL (CTDIvol) and DRL (DLP).

studies	$CTDI_{vol}$ (mGy)	DLP (mGy.cm)	DRL ($CTDI_{vol}$)	DRL (DLP)
The present study	5.21	218.18	6.64	296.29
Connor *et al.* [5]	19.38	548.65	16	732
Weber *et al.* [7]	9	355	*	*
Zalokar *et al.* [6]	11.20	514.30	13.30	606.6
Wood *et al.* [24]	7.50	283	10	390
Diklic *et al.* [25]	7	287	*	*
Božanić *et al.* (8)	*	*	16	731

DISCUSSION

Ionizing radiation as a linear no-threshold model can induce cancer, so for all imaging examinations that use ionizing radiation, this risk should be

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reduced by optimizing protocols, and one of the proposed methods of dose optimization is determining the Dose Reference Level (DRL)[26].

ICRP introduced the concept of DRL in 1996 [14] and after that, many countries and legal institutions introduced this parameter for all procedures performed by ionizing radiation like CTp. In patients with unilateral breast cancer, the DRL and optimization must be determined because additional CT scans are often needed for planning and because the breast is more sensitive to radiation. Although the purposes of DRL descriptions are to create a threshold for identifying excessive doses, optimizing diagnostic methods, and consequently, reducing the dose, it should be noted that dose level determination alone cannot be sufficient to optimize the dose and cannot introduce as an absolute standard for optimization because the CT scan tool is different in each center, as well as the medical dossier, patient anatomy, post-processing effects, diagnostic information, and image quality must consider [27].

As determined in the present study, the DRLs estimated using the third quartile of the DLP and $CTDI_{vol}$ parameters, which were 296.29 and 6.64, respectively. The data obtained from this study were compared with other studies that were performed for breast CT planning (table 5). O'Connor *et al.,* who proposed national DRLs (NDRL) for the breast CT planning in Ireland [5], Zalokar *et al*., who reported NDRLs in Slovenia [6], Bozanic *et al.,* who obtained the third quartile of DLP and $CTDI_{vol}$ as NDRL in Croatia [8] and two other studies conducted for regional DRL [24,25]. It was found that the results obtained in this study are lower than the aforementioned studies. Based on previous articles presented about breast CT planning, we analyzed the cases that can affect dosage values and increase or decrease the DRLs. Before the patient lies on the CT scan bed, the majority parts of dose optimization are finished. Tube potential (measured in kilovolts), tube current (measured in milliamperes), pitch factor, scan time, automatic exposure control (AEC) and scan length have the greatest impact on the dose variation, which will affect DRL in the end.

One of the methods to estimate the dose difference in each center is to set up a phantom study. Since the values of kV and mAs were different in each center, so the results from the mean percentage differences were different. Although, table 3 showed that in all centers, the mean percentage of differences was less than 20% (within the recommended range of the Atomic Energy Organization of Iran) but it verified the dose variation among CT centers. Therefore; determining and defining DRL can help to optimization dose in centers. Afzalipour *et al*., reported this conclusion from the phantom study on CT dose optimization in 2019 [28].

Two factors that reduced the patient's dose were the appropriate determination of mAs and kV for every patient. A direct correlation exists between the tube current and the dose, which is why reducing it is the most effective way of limiting the dose absorbed by the organs. Many articles were published to prove this subject, such as Singh *et al*.'s study. They said when the tube current was reduced 15 to 50 mAs, despite the dose reduction, they were still able to detect lung and mediastinal abnormalities [29]. In addition to tube current, the tube potential (measured in kilovolts) is one of the main scanning parameters that affect the organs dose delivered. Based on a study by Rao *et al*., reducing the tube potential from 140 to 120 kV, results in a 35% reduction in dose [30]. The automatic exposure control (AEC) option was another reason for reducing the dose in this review. When AEC is used in CT scan methods, it can reduce the value of $CTDI_{vol}$, DLP, and ED. Based on Moon *et al*.'s study, when they used the AEC mode for chest exams the values of $CTDI_{vol}$, DLP parameter and effective dose were reduced by 25%, compared to the mode when the exposure conditions were selected manually [31].

The position of the patient's arm can be effective in increasing the dosage. During the data collection, we noticed that only in the SHT center, for CT planning, the arm on the side affected is placed in the upper position by radiotherapy technician. Bayer *et al.* [32] stated that the ED difference between arm-up and arm-down was approximately 28%. To prove this, the ED of the SHT center was compared with the ED of the F center, which had almost similar DLP values. Although the slices thickness in the SHT center was thinner than that in the F center, the ED value decreased from 6.38 to 5.72.

In a comparison of chest CT planning images and diagnostic chest CT scans, Sandrod *et al.* found the noise index was lower in CT planning images. They stated that this difference was in terms of the image quality requirements in CT planning, therefore, higher mAs should be applied. The received dose for patients requiring CT planning was reported to be approximately four times higher than for diagnostic chest CT scan [33]. But, if the technician changes the radiation conditions based on the size of the patient, the received dose and the effective dose will decrease. On the other hand, in chest CT scan with unnecessary reduction in tube current, the image noise will increase [29]; so, more attention should be paid to mAs reduction. Additionally, previous research comparing diagnostic chest CT scans to breast cancer CT planning has revealed that the lungs exhibit greater intrinsic image contrast than the breasts, so it is necessary to administer higher doses to the breast tissues in order to achieve the desired image contrast [5]. Therefore, according to these reasons, it is necessary to be careful about the effective factors that reduce the dose because, it is a fact that to achieve optimum results, a balance must be struck between a patient's absorbed dose and the image quality. The evaluation of image quality was not within the scope of this survey, and the images were approved by the opinion of oncologists, and they did not state the requirement to increase the dose parameters.

The advancements in CT technologies, such as using high-efficiency detectors and innovative reconstruction algorithms, are mostly to blame for the measured DRLs falling below the other studies. About scanners technology in this study, except for one center, all scanners were multi-slice computed tomography (MSCT) (16 rows) and the installation year of three scanners was after 2016 (table 1). There are several advantages to multi-slice CT scanners, including high speed and spatial resolution, the ability to produce isotropic voxels, and the ability to analyze the details of normal and abnormal body anatomy as well as a number of pathologies. These features result in providing high quality images in a short scan time. The short scan time can be the reason for the low absorbed dose in patients. When the absorbed dose decreases, the amount of DRL will decrease. Tahmasebzadeh *et al*., stated that by reducing the amount of several scan parameters, such as $CTDI_{vol}$, tube current, automatic exposure control (AEC), kVp, mAs, scan length, and proper position; the absorbed organ dose can be reduced [34]. Furthermore, they expressed that dose reduction depends on the skill and knowledge of the radiology technician and the scanner model. Moreover, the CT scan technician should be careful in using the pitch factor in single-slice or multi-slice scanners, because in a study by Mahesh *et al.*, in multi-slice scanners, for pitch factors 2, 4 and 8, the dose rates were 9.92, 9.94 and 10.12 mGy, while, in single-slice scanner for pitch factors of 0.5, 1 and 2, the dose rates were 12.72, 6.68 and 3.62 mGy, respectively, respectively [35]. Single slice scanners have a higher pitch factor, which reduces dose, but multi-slice scanners have increased noise, so if you increase the pitch factor, the scanner automatically increases mAs to improve image quality and if constant mAs were applied, the dose can be decreased by increasing the pitch [36]. Compared to the study of Mahesh *et al.* [35], it seems that the pitch factors in this study were well chosen for MDCTs (the mean was 1.37), so the dosage was low. Pitch factor in the EH hospital with single-slice scanner was higher than other centers, so the values of dose parameters were low. (table 2) It should be noted that although the CT scanner was installed in this center in 2005, the tube was recently replaced.

In a common CT scan the scan length should extend at least 5 cm above and below the target area, based on American Association of Physicists in Medicine (AAPM) [37], so the length of the scan for chest examination is considered approximately from the top of lung to the upper border of the liver. Since CT planning includes the possibility of metastases, the scan length is longer than diagnostic chest CT scans, thus increasing the $CTDI_{vol}$ and DLP values, which ultimately affect the level of dose reference. Alleviating the scan length as much as possible can optimize the dose and reduce the absorbed dose. Botwe *et al*. stated that the scan length without extra coverage can decrease DLP value without degrading the CT image quality while ensuring a 0.8%–79.1% reduction in the absorbed organ dose [38]. Thus, Tack *et al.* reported that reducing the Z-axis coverage can be a secondary goal for optimization [39]. For some patients, it is impossible to reduce the scan length, but the output parameters of CT scanners can be changed to lower the dose, although the quality of the images may decrease. To improve the reduced quality of images, it can be compensated by reconstruction to optimize the desired protocol. In the selected centers, all images of cancer patients were reconstructed.

Slice thickness is another case that can increase the dose value. CT planning uses slice thickness based on dose and image quality to ensure accurate visualization of the structure during contouring and image matching. Using the large section thickness may be a factor in dose optimization, but it hurts spatial resolution [5]. We observed that with thin slice thickness, the mean DLP values can increase. This procedure supports the idea that there is an inverse relationship between the thickness of the slices, and the dose given to the patient. The slice thickness in this study was thinner than the study by Connor *et al*., so the DLP value was lower (tables 2 and 5).

The total radiation dose in a CT scan is calculated by multiplying the $CTDI_{vol}$ by the scan length and is represented as DLP. Consequently, by performing a scan in the defined area, it directly reduces the patient dose following a linear relationship (between scan time and DLP) [40]. Tables 2 and 4 show this relationship. The highest amounts of scan time and DLP were in the CMC center. The previously published data on the dose parameters of breast CT planning were provided by Connor in Ireland [5], Weber [7], Zalokar in Slovenia [6], Wood [24] and Diklic *et al.* [25]. They have presented $CTDI_{vol}$ 19.38, 9, 11.2, 10 and 7 mGy, respectively. Table 5, showed that the amount of $CTDI_{vol}$ obtained in this study (5.21 mGy) was lower than the amount of previous studies.

By comparing the DLP of previous researches, it was found that the DLP in this study (218.18 mGy·cm) was lower than other studies that reported in this field (table 5). Some studies provided comments on the obtained DLP, such as Weber *et al.* [7]. They estimated the $CTDI_{vol}$ and DLP parameters as 9 ± 2mGy and 355 ± 61 mGy.cm, respectively. According to them, the $CTDI_{vol}$ was almost in line with international values, but DLP was higher than international values due to the need for a longer CT scan [7]. However, Diklic *et al.* had another suggestion; they reported DLP and scan length for breast CT planning as 287mGy.cm and 40.9 cm, respectively,

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and stated that the dose parameters were similar to the other published values, but the scan length was more prolonged. They suggested that the output of the scanner could be slightly increased to improve the quality of the images [25]. In this study, the DLP value was lower than the data of previous studies, but the scan length (43.72 cm) was longer.

It is expected that the effective dose (ED) will improve by increasing DLP and $CTDI_{vol}$ values. Based on table 4, since the highest DLP and $CTDI_{vol}$ were related to CMC and F hospitals, the highest effective doses were recorded for them. This relationship was reported by Laham *et al*. as well in 2018 [41]. Using ED, dose of diagnostic CT can be compared with other imaging modalities [42]. The mean of ED was 5.62 mSv (table 4); while this achievement in Tahmasebzadeh [34], Connor [5] and Harison *et al*. studies [43], were reported as 2.56, 7.7 and 7.2 mSv, respectively. Based on a CT simulation of the thorax, Sanklaa *et al*. calculated ED to be 5.01 mSv; they stated that, although the values of ED varied among centers, they were still less than recommended [44]. The received thyroid dose (mean = 11.69 mGy), is high and comparable with received dose in diagnostic head or chest CT scan for this organ [44], because in a study that conducted by Tahmasebzadeh *et al.* the received thyroid dose was 4.75 mGy [34] in a study by Khorramian *et al*. the received dose was 2.66 mGy for females in head CT scan [45]. This conclusion showed that thyroid was utterly exposed by direct radiation and the mean of the breast dose in this study was 8.66mGy, which reported as 15mGy in a study by Laham *et al*. [41]. For two organs that we investigated, the received dose was significantly different among CT centers (p-value < 0.001). In the article published by Angel *et al*., the received breast dose reported with an average of 19mGy (range of the received dose for breast tissue was 14-29mGy) [46] and in a survey by Tahmasebzadeh *et al*. the breast dose was 3.97 mGy in lung CT scan [34]. Based on the comparison of dosimetry results, we found that this study's results were higher than chest CT scan values but lower than other CT planning studies.

In a survey by Connor *et al*.[5], the dose parameters ($CTDI_{vol}$ and DLP) were approximately 2.5 times greater than our parameter values. One of the main differences between two studies was the slice thickness, which Irish CT centers choose to be 2.5 mm, but in this study except for one CT center, thicknesses were 5 mm (table 2). Therefore; if the slice thickness was chosen to be thinner in this survey, the calculated values of dose indicators and DRLs would definitely increase. Despite the long scan length (average scan length of 437 mm), our calculated dose indicators were lower than the results presented by Wood *et al*. (332 mm) [24] and Diklic *et al.* (409 mm) [25]. For example, Wood *et al*. stated that in most scans the selected slice thickness was 3 mm (1.25-5 mm) [24], while in this study, it was 5 mm in most scans. It can be concluded that in terms of the thicker slice thickness, dose values were reduced. The most important factors that caused dose reduction were related to dose indicators (DLP and $CTDI_{vol}$) and slice thickness. The low values of dose indicators, and thicker slice thickness were reasons for reduction of the DRL. Finally, our DRLs were well below the values proposed by other researchers in this field, based on comparisons with international studies. This study was an excellent opportunity to collect information about DRLs in CT planning for breast cancer patients, especially in Iran and may be interesting for researchers and local regulatory bodies to pay more attention to this issue (table 5)

Despite the fact that DRLs are a reasonable criterion for radiation dose optimization, but the American Association of Physicists in Medicine (AAPM) has recently proposed a "size- specific dose estimate" (SSDE), which considers patient size, to optimize $CTDI_{vol}$ based on the physical dimensions of patients [47]. It is therefore recommended that future studies take SSDE into account and compare the results with the findings of this study. Future surveys should consider capturing the patient's dimensions in the imaged region, body mass index and position during the CT scan (e.g., with one arm or both arms up). These factors were not included in the current survey. There are other methods to optimize the breast CT planning protocol and improve the quality of the images; that do not affect the scanner dose, such as the ambient light in the contouring rooms, image quality in PACS system reconstruction, Adaptive Statistical Iterative Reconstruction (ASIR) [48], the performance of the monitors and their image quality, photon-counting detectors [49] and using artificial intelligence (AI) [50], to estimate the DRL, which have brought about many changes in medical imaging. Finally; with improved image quality, the amount of applied parameters for imaging will decrease.

CONCLUSION

We discovered that some centers had significantly different dose parameters for breast CTp. The results of this study are proposed as the first dose parameters, and regional DRLs for breast CTp in Iran. We expect that studies are conducted in other CT centers can optimize the dose by checking the scanning parameters of our study. Paying attention to optimization in the CTp field can lead to the protection of radiation-sensitive organs like healthy breast.

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