

ARTICLE

Establishment of local diagnostic reference levels for breast cancer CT protocols in radiotherapy in a single Moroccan center

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Abstract – The objective of this study was to establish local diagnostic reference levels (LDRLs) for breast cancer computed tomography imaging in radiotherapy (CT-RT) at a single hospital in Morocco. Data were collected from 106 adult breast cancer patients aged between 33 and 78 yr during five months. Data were obtained using a Hitachi Supria 16-slice CT simulator at a regional oncology center in Morocco. CT-RT images are intended for 3D conformal radiotherapy treatment planning. Dose length product (DLP) and volumetric computed tomography dose index (CTDIvol) were evaluated by determining the 75th percentile as diagnostic reference levels for CT-RT breast cancer. LDRLs for CT-RT breast cancer have been determined in terms of DLP and CTDIvol, and they were 330.4 mGy.cm and 6.8 mGy, respectively. The DRLs were compared with other European studies. DRLs for this study were lower than those for the United Kingdom (UK), Croatia and Slovenia. The results of this study can be a reference for the establishment of local and national DRLs in Morocco and the optimization of CT-RT breast cancer procedures.

Keywords: DRL / Computed tomography / ALARA principle / breast cancer CT protocols

1 Introduction

The current global cancer data estimates that 19.3 million new cases were diagnosed in 2020. Most notably, breast cancer, with over 2.3 million cases reported in this year, was the most prevalent form of cancer (Sung *et al.*, 2021). Morocco is also affected by this global scourge. The estimated number of new cancer cases per year is close to 50,000, of which breast cancer is the most frequently diagnosed among Moroccan women, accounting for 20% of all cancer cases, according to data from the country's cancer registry (Ministry of Health, Morocco, 2020). Radiotherapy is an inherent integral part of oncology care. Thus, more than 60% of cancer patients receive radiotherapy as their principal treatment (Doury, 2019).

The most crucial and commonly used imaging modality in radiotherapy is CT (Computed Tomography) (Nhila *et al.*, 2023). All patients receiving radiotherapy undergo dosimetric

CT scans for treatment planning. Thus, the increase in cancer incidents implies a rise in the number of performed CT scans, which in turn leads to an increase in the number of individuals exposed to ionizing radiation from CT scans. Even if CT doses are considered well below therapeutic doses, they must be monitored and kept as low as possible (ALARA principle) (Clerkin, Brennan and Mullaney, 2018). According to the linear no-threshold model, all ionizing radiation imaging processes, including CT simulations for radiotherapy, must be optimized to reduce risks, especially for cancer patients with long life expectancies (Zalokar *et al.*, 2020). Diagnostic reference levels (DRLs) are the most commonly used tool for optimizing and identifying unusually high doses to patients from radiological examinations (Paulo *et al.*, 2020; Elnour *et al.*, 2021). In fact, the principles of DRLs as a tool for the optimization of patient doses were first established in 1996 through ICRP publication 73 and were updated in publication 135 from the same institution in 2017 (Talbi *et al.*, 2022). DRLs should not be considered a boundary between acceptable and unacceptable medical practices or as dose

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Table 1. Minimum, Maximum and Mean values of different exposure parameters as well as CTDIvol and DLP.

Breast cancer CT Protocol	Min-max	Mean
kV	120	120
mAs	54.8-190.5	86.23
Rotation time (s)	0,75	0,75
FOV	358-500	459
Scan length (mm)	335-810	437
Slice thickness(mm)	5	5
Pitch	1.06	1.06
AEC	On	On
Reconstruction Filter	F31	F31
CTDIvol (mGy)	4.6-21.2	6.76
DLP (mGy.cm)	209-1267	319.8

limits (Vaño *et al.*, 2017). Instead, their purpose is to prevent individuals from receiving excessive doses of radiation that provide no additional clinical benefit (Damilakis *et al.*, 2023). In order to remain consistent with evolving practices and standards, DRLs must be periodically updated in all countries (Siiskonen *et al.*, 2018; El Mansouri *et al.*, 2022). DRLs are based on CTDIvol and DLP values at the 75th percentile (Uushona *et al.*, 2022). For an optimal trade-off between the benefits and drawbacks of CT scanners, hospitals are recommended to make the most of the updated (Aberle *et al.*, 2020). Although recent studies have determined DRLs for dosimetric scanners for different radiotherapy localizations (Toroi *et al.*, 2015; O'connor *et al.*, 2016; O'connor, Ardlie *et al.*, 2016; Clerkin *et al.*, 2018; Zalokar *et al.*, 2020; Božanić *et al.*, 2022), they are very few compared with DRLs for diagnostic CT scanners. No studies of this type have been published in Africa, and particularly in Morocco.

The Institute for Radiation Protection and Nuclear Safety (IRSN) suggests conducting regular assessments of patient doses in medical facilities for common radiological procedures (IRSN Report, 2020). These doses should be compared to national and international reference levels (Héliou *et al.*, 2012; Talbi *et al.*, 2022). If the results consistently exceed these levels, the facility must review its procedures and inspect its facilities. Thus, if the excess is not justified, corrective action should be applied (Hendrick, 2010).

This survey aims to establish local (institutional) DRLs for breast cancer CT-RT at a single hospital in Morocco and to compare them with national DRLs in European countries.

2 Materials and methods

Data were collected for 5 months (from 19 January 2023 to 20 June 2023) from a single simulator scanner (Hitachi, Supria, 16-slice) installed in a regional oncology center in Morocco. Data collection was prospectively performed, because the operators do not record all patient information, such as weight.

106 data were collected from adult patients between 33 and 78 yr of age who underwent CT-RT imaging with breast cancer protocols. These protocols are intended for 3D conformal

treatment planning. In addition, data were acquired for patients undergoing CT-RT for curative breast radiotherapy and post-mastectomy and patients receiving supraclavicular lymph nodes radiotherapy. Also, data collection did not lead to additional radiation exposure to patients or affect the facility's workflow. The data collected included: tube voltage (kV), tube current (mAs), slice thickness, rotation time, pitch, scan length, field of view (FOV), as well as CTDIvol and DLP.

Image quality control is not verified at this center, but all CT-RT images for breast localization were verified and approved by Radiation oncologists after confirming their suitability for volume delineation. Also, the delineation of the clinical target volume (CTV), which includes the conservative breast or chest wall and supraclavicular nodal regions as well as organs at risk (OAR), was defined according to the Radiation Therapy Oncology Group (RTOG) protocol.

2.1 Data analysis

The data collected were evaluated using software (IBM SPSS Statistics version 22) as quantitative variables, which are represented by arithmetic mean, a first quartile (25th percentile), a median (50th percentile), and a third quartile (75th percentile) (Vaño *et al.*, 2017). Moreover, the DRLs established in this study were compared with those of other European countries such as the (United Kingdom) UK (Wood *et al.*, 2018), Slovenia (Božanić *et al.*, 2022), and Croatia (Zalokar *et al.*, 2020).

3 Results

Table 1 shows the acquisition parameters adopted in the breast cancer CT-RT protocol, such as kV, pitch, rotation time, slice thickness, and reconstruction filter, which are constant for all patients. Thus, the same table shows the minimum and maximum values and means of parameters that vary according to the patient, such as mAs, FOV, scan length, as well as CTDIvol and DLP. The minimum CTDIvol value collected was 4.6 mGy and the maximum value was 21.2 mGy. As for DLP, 209 mGy.cm was the minimum value and 1267 mGy.cm was the maximum value.

Table 2 shows the 25th percentile, median, and 75th percentile values of the dosimetric indicators in terms of CTDIvol and DLP of CT-RT breast cancer. Also, the LDRLs are also shown graphically in Figures 1 and 2, and represent the 75th percentiles of the CTDIvol and DLP distributions.

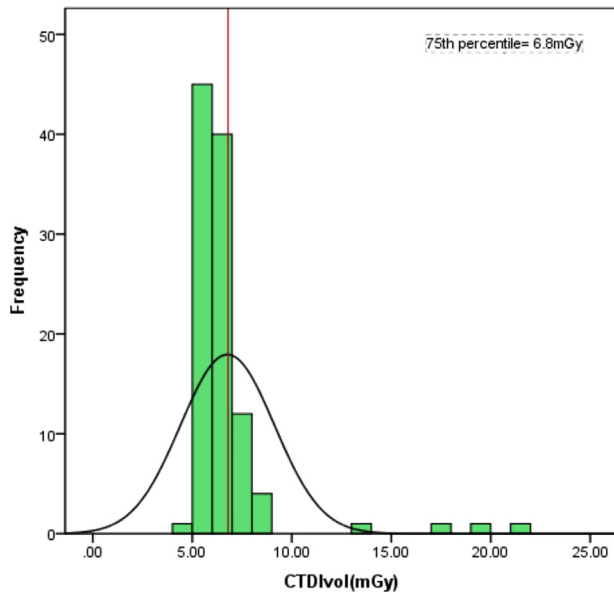
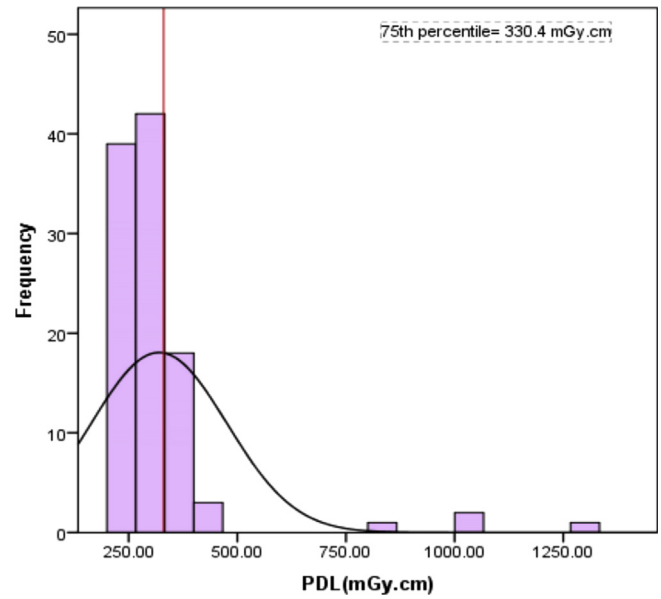
The established DRLs from this study were compared with other DRLs conducted in Uk (Wood *et al.*, 2018), Croatia (Božanić *et al.*, 2022), and Slovenia (Zalokar *et al.*, 2020) as shown in Table 3.

4 Discussion

Morocco has recently enacted a comprehensive reform of its health system, which includes the adoption of new laws and regulations designed to increase access to health services, ensure better patient care, and adhere to safety standards set by international organizations. This reform has also included

Table 2. 25^e percentile, Median and 75^e percentile for CTDI_{vol} and DLP at breast cancer CT-RT protocols.

Dosimetric quantities	CTDI _{vol} (mGy)			DLP(mGy.cm)		
	25 ^e percentile	Median	75 ^e percentile	25 ^e percentile	Median	75 ^e percentile
Breast	5.9	6.1	6.8	253.7	276.3	330.4

**Fig. 1.** Distribution of CTDI_{vol} values for CT-RT breast cancer.**Fig. 2.** Distribution of PDL values for CT-RT breast cancer.

changes to the radiation protection system. For this, Moroccan Agency for Nuclear and Radiological Safety and Security (AMSSNuR) is developing a regulatory project that consists of establishing and utilizing DRLs. This project has resulted in several published surveys of DRLs in different medical imaging modalities.

No previous study has been published on DRLs for CT protocols in radiotherapy in a Moroccan hospital. Therefore, the present study has been performed to establish local DRLs for breast cancer CT-RT protocols.

The results obtained show that the 75th percentile of CTDI_{vol} and DLP for breast cancer CT-RT protocols are considerably lower than those of the European countries listed in Table 2. The UK comes closest to the DRLs in our study, with CTDI_{vol} and PDL values of 10 mGy and 390 mGy.cm, respectively.

There are several possible reasons for these wide variations. The main reason seems the difference between CT protocols and scanner brands, and generations (Kumsa *et al.*, 2023). In addition, disparities in operator training and experience, which vary from one country to another, may contribute to variations in exposure levels (Tahiri *et al.*, 2022).

Moreover, even within the same country, significant dose differences may exist between centers, usually due to the lack of a standardized protocol. In some cases, the cause of these differences is difficult to explain. For instance, a study conducted to establish DRLs for the breast cancer CT-RT protocol by O'Connor *et al.* (O'Connor, Ardle and Mullaney,

2016) concluded that significant dose differences between CT radiotherapy centers were unjustifiable.

When comparing the dosimetric indicators for CT-RT breast cancer in the UK with our own, we observed that despite the longer scan length values in this study (median value of 420 mm *versus* 280 mm), the DLP values are lower than those in the UK. Thus, when comparing the acquisition parameters published in the two surveys, it seems that the principal causes of the differences between CTDI_{vol} and DLP relate to acquisition parameters affecting dose, such as FOV, mas, slice thickness and pitch as demonstrated in previous studies (Davis *et al.*, 2018).

Worldwide data on DRLs for CT-RT breast cancer are scarce. Thus, even though the doses of our study are lower than those of previous studies, they seem insufficient to confirm the optimality of our results. In this context, we were required to compare the results of DRLs for CT-RT breast cancer against those of thoracic diagnostic CT protocols, similar to the study conducted by Connor *et al.*

In this context, for a complete analysis, it was necessary to compare the results of this study with those of our previous study, establishing LDRLs in Morocco for adult CT scans of different localizations, including the chest (El Mansouri *et al.*, 2022). The results obtained show that the 75th percentile of CTDI_{vol} and DLP of the chest CT were approximately twice as high (12.3 mGy and 632 mGy.cm) as those proposed in the present study. This difference can be explained by the effect of

Table 3. LDRLs for breast cancer CT-RT protocols in Morocco, compared to other DRLs.

Dosimetric quantities	CTDI _{vol} (mGy)				DLP(mGy.cm)			
	This study	UK (Wood <i>et al.</i> , 2018)	Croatia (Zalokar <i>et al.</i> , 2020)	Slovenia (Božanić <i>et al.</i> , 2022)	This study	UK (Wood <i>et al.</i> , 2018)	Croatia (Zalokar <i>et al.</i> , 2020)	Slovenia (Božanić <i>et al.</i> , 2022)
Breast	6.8	10	16	13.3	330.4	390	731	606.6

acquisition parameters, notably kV and mAs settings, which have a significant effect on CTDI_{vol}, as proven in previous studies (Elojeimy, Tipnis and Huda, 2010; El Mansouri *et al.*, 2021; Talbi *et al.*, 2021).

When comparing dose indicators between diagnostic CT scanners, kV setting and AEC mode can be major factors influencing results (Papadakis and Damilakis, 2018; Bebbington *et al.*, 2021). However, in CT-RT protocols, practically all centers use 120 kV setting and avoid AEC technologies adjusting tube voltage to provide unchangeable conversion of attenuation coefficients to electron density, making this parameter insignificant.

4.1 Limitation and perspective

Firstly, the sample size for this study was limited, and patient weight data were not available, thereby making assessment of body size's effect on the NRD value impossible. Secondly, DRL values were established in a single Moroccan center and included data from a single CT examination. Future studies could include other body examinations and variation of scanner brands in several hospitals. Finally, we have established DRLs for CT-RT breast cancer in order to optimize the risk of radiation-induced cancer, especially given the high radiosensitivity of the contralateral breast. Several studies have established DRLs for pediatric CT procedures (Bawazeer *et al.*, 2022; Geryes *et al.*, 2022; Akhlaghi *et al.*, 2014), but as far as we know, no study has addressed DRLs for pediatric CT-RT protocols, and for this reason we would like to eventually explore this issue.

5 Conclusion

In recent years, researchers have approached the establishment of DRLs for CT-RT to provide a platform for dose comparison and optimization of CT procedures. To our knowledge, only a few European countries have been able to establish DRLs for the most common localizations such as pelvis, ORL, and Breast in their countries. This is the first Moroccan study to establish CT-RT breast cancer DRLs in a single institution. The local NRDs established showed good radiation protection practices in this hospital. Therefore, the results of this study could be a benchmark for the establishment of local and national DRLs in

Morocco and the optimization of CT-RT breast cancer procedures.

Conflict of interest

The authors declare that they have no conflicts of interest in relation to this article.

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Ethical approval

This study did not carry out activities that would require approval by a research ethics committee.

Informed consent

This article does not contain any studies involving human subjects.

Authors contributions

All authors contributed to the design and implementation of the research, to the analysis of the results and to the writing of the manuscript. All authors read and approved the final version of the paper.

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