DOSIMETRIC EVALUATION OF ADULT CT SCANS IN TOGO

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Abstract. The purpose of this study is to evaluate the doses delivered to adult patients during CT examinations in order to establish CT diagnostic reference levels (DRL) in Togo. It was a cross-sectional study conducted from March 6 to July 30, 2016 in all health facilities with a CT unit in Togo. The study included cerebral, thoracic, abdominopelvic, thoracic abdominopelvic (TAP), cervical and lumbar spine CTs of patients aged 15 years and over. The 1,155 adult CT scans were dominated by cerebral and abdominopelvic CTs with 34.2 % and 15.15 %, respectively. The sex ratio (men/women) was 1.42. The brand of the CT scan equipment was in 80 % of cases General Electric. All CT scan machines were either 6 or 16 bars and 60 % of them were installed in 2010. The CT dose index (CTDIvol) of cerebral CT was the highest compared to the CTDIvol of the other types of examination. The dispersion of DLPs per acquisition and for a complete examination was significant within and between health facilities. The DRLs (75^{th} percentile of DLP) per acquisition were 1,199.14 mGy·cm (non-traumatic cerebral), 1,596.45 mGy·cm (traumatic cerebral), 635.63 mGy·cm (cervical), 401.98 mGy·cm (thoracic), 594.42 mGy·cm (abdominopelvic), 675.73 mGy·cm (thoracic abdominopelvic) and 681.35 mGy·cm (lumbar). The mean effective doses associated with the different types of examinations ranged from 2–3 mSv for head and neck exposure, to 24 mSv for abdominopelvic CT. The wide dispersion of dose delivered during CT in Togo requires a process of homogenization of procedures and optimization based on DRLs thus determined.

Key words: CT dose index, dose length product, diagnostic reference levels, CT scan.

INTRODUCTION

The usefulness of ionizing radiation in medicine has been established and the justification for its application, in general, is a fact. Nevertheless, the deleterious biological effects of ionizing radiation are real and medical applications are by far the main source of exposure to ionizing radiation of artificial origin [4, 9]. Computed tomography (CT) is a cross-sectional imaging technique that can deliver the highest radiation dose to patients [6]. It is responsible for 47 % of medical irradiation in some European countries such as United Kingdom [10].

Received: July 2021;
in final form July 2021.

ROMANIAN J. BIOPHYS., Vol. 31, No. 4, P. 199–213, BUCHAREST, 2021

The evaluation of radiation doses to which patients are exposed during diagnostic procedures is a very important issue in radiation protection. Unfortunately, a wide range of practices results in a variation in the doses delivered to patients for the same examination. To remedy this situation, the concept of diagnostic reference level (DRL) was introduced, which is a dosimetric indicator reflecting national practice for an examination. This concept, defined in 1996, is used as a tool for evaluating imaging techniques and as a mean of optimizing doses, particularly in the case of standardized examinations performed on typical patients [3].

The establishment of DRL requires the quantification of doses (dosimetry) received by patients during examinations using ionizing radiation.

In Africa, dosimetric evaluations of patients are rare in radiodiagnostics and many countries, such as Togo, do not have their own dosimetric database of CT patients [7].

In Togo, more than fifteen years after the introduction of CT in radiodiagnostics practice, CT examinations are used more and more frequently for patient management, but no national dosimetric evaluation study has yet been carried out to establish CT DRL for the country. It was therefore of capital importance to quantify the doses delivered to patients during CT examinations performed in all health facilities with CT equipment in order to optimize practices.

It is with this in mind that we undertook this work, which general objective was to evaluate the doses delivered to adult patients during the main CT examinations performed in Togo.

MATERIALS AND METHODS

The present work is a cross-sectional study conducted from March 6 to July 30, 2016 in all both public and private imaging facilities with a functional CT unit in Togo. It concerned seven CT examinations most frequently performed in adult patients in the country. These CT examinations consisted in: cerebral CT, cervical CT, thoracic CT, abdominopelvic CT, lumbar CT, thoracic abdominopelvic CT (TAP). Cerebral (brain) CT scans were subdivided into traumatic and non-traumatic (NT). The above-mentioned CT scans performed in patients under 15 years of age were not included.

In order to ensure the confidentiality of the collected data, the health centers included in this study (2 private and 3 public) are named C1 to C5. The survey form, developed in accordance with the literature, was based on the following parameters: patient profile, type of examination, brand and characteristics of the CT equipment, parameters, number and height of acquisitions, dose ratio (CTDIvol, DLP per acquisition and complete examination). Twenty to 40 examinations were selected consecutively for each examination type.

The collected data were processed and analyzed in Microsoft Word, EPI DATA V.31 and SPSS V.24. The analyses were carried out for each facility on the one hand, and on the other hand globally for all 5 facilities.

The dispersion of the data set by type of examination was estimated by calculating, not only the 75th percentile of the CTDIvol but also the 75th percentile of the distribution of DLPs. This value is used to establish the DRL by acquisition and for a complete examination.

The study was approved by the national Radiation Protection Committee of the Ministry of Health of Togo. The patients included in this study gave written informed consent to participate in this research and written informed consent to publish this research. The data used and/or analyzed during the current study are available from the corresponding author on reasonable request.

RESULTS

GENERAL CHARACTERISTICS OF PATIENTS AND DEVICES

A total of 1,157 CT scans with a predominance of cerebral CT (34.2 %) followed by abdominal and pelvic CT (Table 1) were included in this study. These examinations were performed in 680 male patients (58.78 %) and 477 female patients (41.22 %). The sex ratio was 1.42. The age of the patients ranged from 15 to 99 years with a mean age of 47.4 years.

Four of the five machines (80 %) used in the facilities, were General Electric (GE) and the fifth was SIEMENS. They were all equipped with an iterative reconstruction system. The majority (3 out of 5) were installed in 2010 and the other 2 in 2014. Four devices (80 %) were equipped with 16 bars and the 5th was equipped with 6 bars.

Table 1

Distribution of examination types by center

	C1		**C2**		**C3**		**C4**		**C5**		**Total**	
	N	%	N	%	N	%	N	%	N	%	N	%
Cerebral-NT	40	14.5	40	15.2	40	15.9	40	37.4	40	15.4	200	17.3
Cerebral-T	40	14.5	37	14.1	40	15.9	40	37.4	38	14.6	195	16.9
Abdominopelvic	40	14.5	37	14.1	34	13.5	27	25.2	37	14.2	175	15.1
Thoracic	40	14.5	38	14.4	34	13.5	0	0.0	38	14.6	150	13.0
Lumbar	40	14.5	40	15.2	40	15.9	0	0.0	40	15.4	160	13.8
Cervical	37	13.5	36	13.7	32	12.7	0	0.0	35	13.5	140	12.1
TAP	38	14.0	35	13.3	32	12.7	0	0.0	32	12.3	137	11.8
Total	**275**	**100.0**	**263**	**100.0**	**252**	**100.0**	**107**	**100.0**	**260**	**100.0**	**1157**	**100.0**

N: Number, Cerebral-NT: Non-traumatic cerebral, Cerebral-T: Traumatic cerebral, TAP: Thoracic abdominopelvic.

TECHNICAL PARAMETERS OF THE DIFFERENT CT EXAMINATIONS PERFORMED IN THE HEALTH CENTERS

The technical parameters (load, tension, cutting thickness, rotation time and pitch) were almost identical for each type of examination in C1–C4 (Table 2).

Table 2

Distribution of the technical parameters of acquisition of the 4 main CT examinations in the centers of our study

	Voltage (kV)	**Load (mA)**	**Cutting thickness (mm)**	**Rotation time (s)**	**Pitch**
Cerebral					
C1	120	Modulated	2.5–5.0	0.8–2.0	0.938
C2	120	Modulated	1.25	0.8	1.375
C3	120	Modulated	1.25	0.8	0.562
C4	120	Modulated	1.25	0.8	0.938
C5	130	165	1.25	1	0.65
Thoracic					
C1	120	Modulated	2.5	0.8	1.75
C2	120	Modulated	1.25–2.50	0.8	1.75
C3	120	Modulated	1.2–2.5	0.8	1.75
C4	–	–	–	–	–
C5	130	Modulated	1.25–5.00	0.8	1.35
Abdominopelvic					
C1	120	Modulated	2.5	0.8	1.75
C2	120	Modulated	2.5	0.8	1.75
C3	120	Modulated	2.5	0.8	1.75
C4	120	Modulated	2.5	0.8	1.75
C5	130	Modulated	1.25–2.50	0.8	1.35
Lumbar					
C1	120	Modulated	1.25–2.50	0.8	1.75
C2	120	Modulated	1.25	0.8–1	1.75
C3	120	Modulated	1.2–2.5	0.8	1.75
C4	–	–	–	–	–
C5	130		1–2.5	0.8–1	1.75

The number of acquisitions of the different types of examination varied from 1 to 4 depending on the type of examination at C1 and from 1 to 5 in the other centers. More than half of the examinations were performed with a single acquisition (Table 3).

Table 3

Distribution of the number of acquisitions of the set

	Number of acquisitions											
	1		**2**		**3**		**4**		**5**		**Total**	
	N	%	N	%	N	%	N	%	N	%	N	%
Cerebral-NT	152	76.0	47	23.5	1	0.5	0	0.0	0	0.0	200	100
Cerebral-T	192	98.5	3	1.5	0	0.0	0	0.0	0	0.0	195	100
Abdominopelvic	5	2.9	20	11.4	28	16.0	107	61.1	15	8.6	175	100
Thoracic	47	31.3	70	46.7	23	15.3	10	6.7	0	0.0	150	100
Lumbar	153	95.6	7	4.4	0	0.0	0	0.0	0	0.0	160	100
Cervical	123	87.9	14	10.0	3	2.1	0	0.0	0	0.0	140	100
TAP	0	0.0	29	21.2	29	21.2	76	55.5	3	2.2	137	100
Total	**672**	**58.1**	**190**	**16.4**	**84**	**07.3**	**193**	**16.7**	**18**	**01.6**	**1157**	**100**

Cerebral-NT: Non-traumatic cerebral, Cerebral-T: Traumatic cerebral, TAP: Thoracic abdominopelvic.

Brain CT non-traumatic had the shortest acquisition length while TAP the longest in all centers (Table 4).

Table 4

Distribution of acquisition length (cm) by type of examination for all centers

	Minimum	**Maximum**	**Average**	**Standard deviation**
Cerebral-NT	13.50	26.62	18.79	2.06
Cerebral-T	19.00	37.00	24.92	2.61
Abdominopelvic	29.50	62.20	47.43	5.09
Thoracic	24.08	58.75	34.19	4.83
Lumbar	19.25	55.25	28.70	3.74
Cervical	15.40	54.00	24.62	8.89
TAP	24.90	71.75	58.64	7.63

Cerebral-NT: Non-traumatic cerebral, Cerebral-T: Traumatic cerebral, TAP: Thoracic abdominopelvic.

DOSIMETRIC QUANTIFICATION

The CTDIvol by type of examination at C5 was relatively low compared to the other centers (Table 5). At the national level, the CTDIvol of cerebral CT was the highest compared to the CTDIvol of the other types of examination (Table 6).

Table 5

Distribution of mean and 75th percentile CTDIvol (mGy) by center for different types of examination

	C1		C2		C3		C4		C5	
	Mean	75th percentile	Mean	75th percentile	Mean	75th percentile	Mean	75th percentile	Mean	75th percentile
Cerebral-NT	51.64	59.47	44.56	50.32	60.20	65.68	57.54	61.90	45.53	45.53
Cerebral-T	55.99	62.60	41.26	41.37	63.13	68.69	58.53	60.85	45.53	45.53
Abdominopelvic	9.78	10.69	9.95	12.62	10.85	12.48	9.48	11.01	6.57	6.69
Thoracic*	10.11	10.58	11.75	14.63	11.95	14.56	–	–	4.81	5.47
Lumbar*	16.31	19.48	27.20	32.61	20.17	21.53	–	–	17.91	20.92
Cervical*	24.59	27.21	12.73	13.88	32.12	33.85	–	–	18.30	22.34
TAP*	9.10	10.24	10.91	13.70	8.08	8.77	–	–	6.56	8.72

*These types of examinations were not retained at C4.
Cerebral-NT: Non-traumatic cerebral, Cerebral-T: Traumatic cerebral, TAP: Thoracic abdominopelvic.

Table 6

Distribution of mean and 75th percentile CTDIvol (mGy) for each type of examination in all surveys

	Mean	**75th percentile**
Cerebral-NT	51.89	60.41
Cerebral-T	53.14	60.81
Abdominopelvic	9.30	10.69
Thoracic	9.59	12.31
Lumbar	20.40	21.53
Cervical	21.69	27.45
TAP	8.73	10.63

Cerebral-NT: Non-traumatic cerebral, Cerebral-T: Traumatic cerebral, TAP: Thoracic abdominopelvic.

Variations in DLPs per acquisition and for a complete examination were significant within the same center and between centers for the same examination type (Figs 1–7). The 75th percentile DLP at C5 for the different types of examinations was lower than that of the other centers.

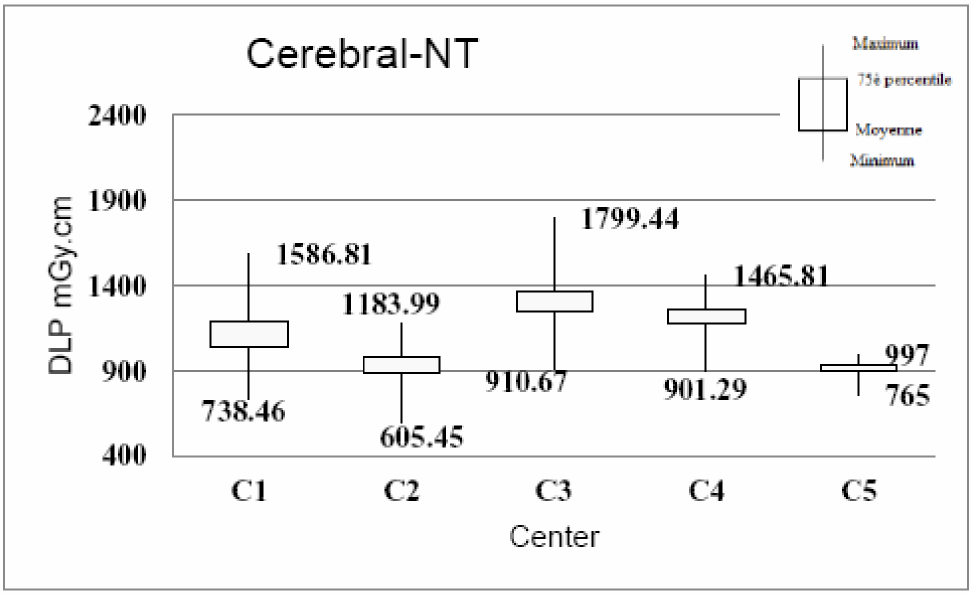

Fig. 1. Intra- and inter-center variation in DLP of non-traumatic cerebral CT scans (1 acquisition).

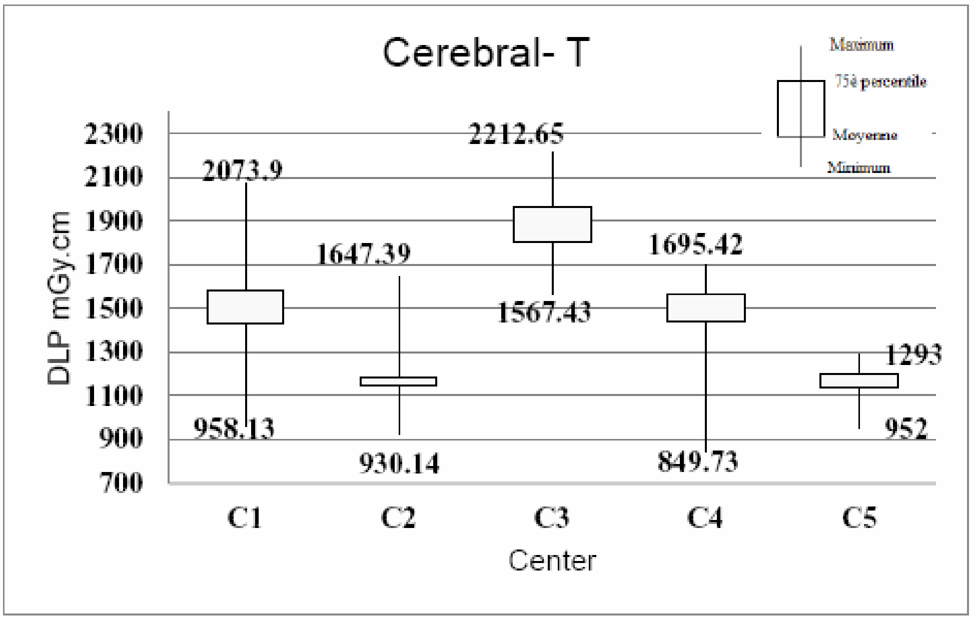

Fig. 2. Intra- and inter-center variation in PDL of traumatic cerebral CT scans (1 acquisition).

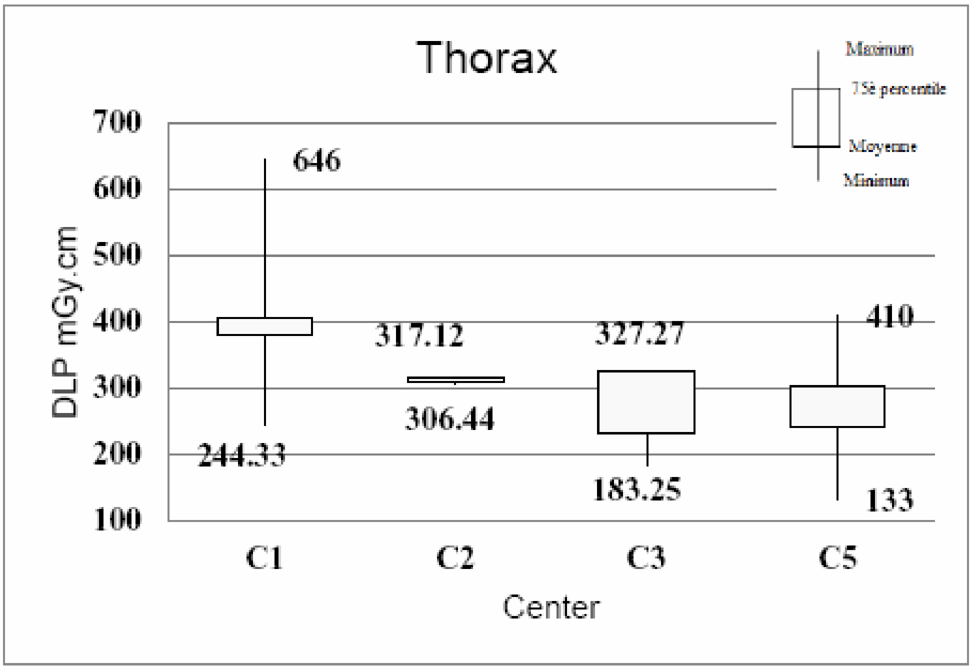

Fig. 3. Intra- and inter-center variation in DLPs of CT scans of the thorax (1 acquisition).

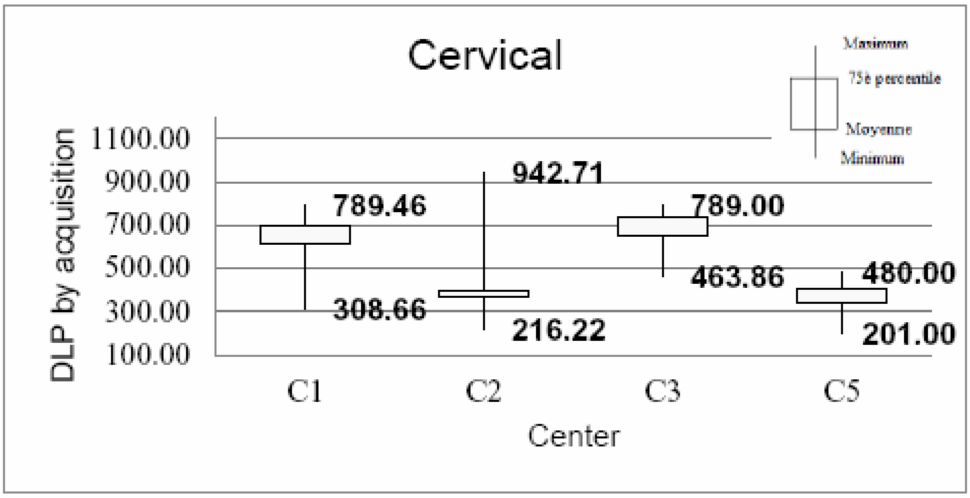

Fig. 4. Intra- and inter-centre variation in cervical CT DLP (1 acquisition).

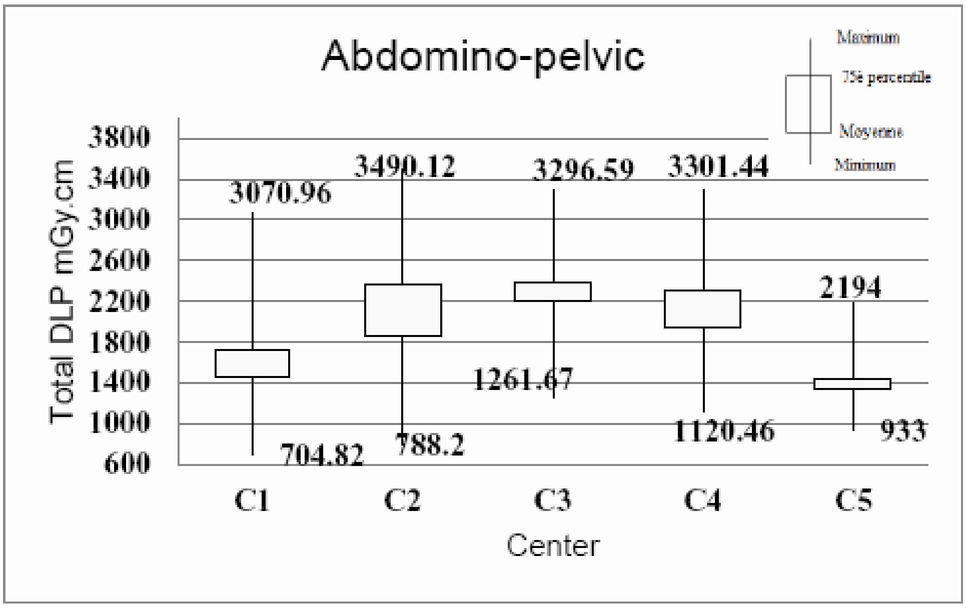

Fig. 5. Intra- and inter-center variation in DLPs of abdominopelvic CT scans (2–5) acquisitions.

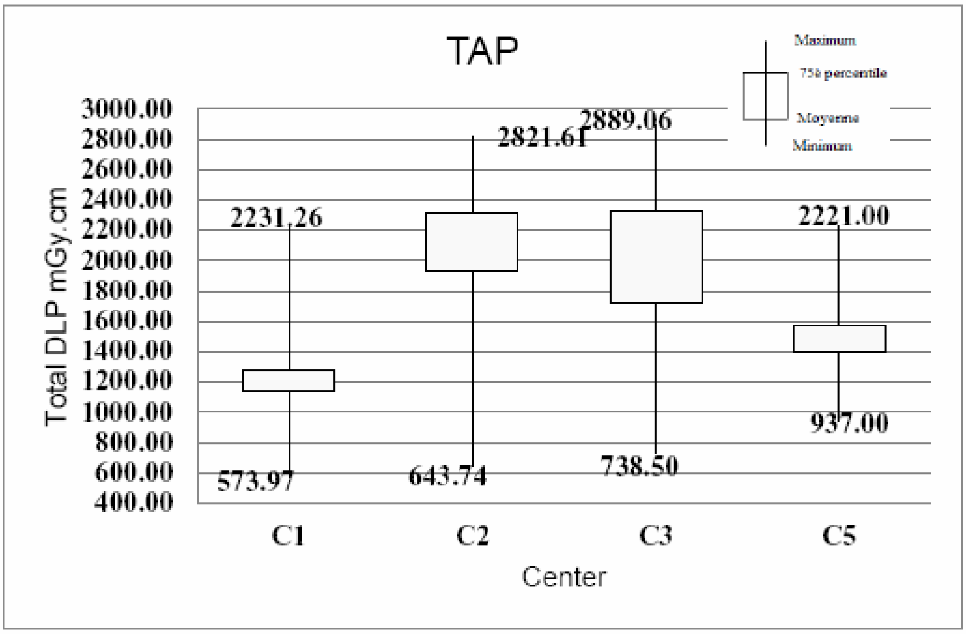

Fig. 6. Intra- and inter-center variation in DLP of thoracic abdominopelvic CT scans (2–5) acquisitions.

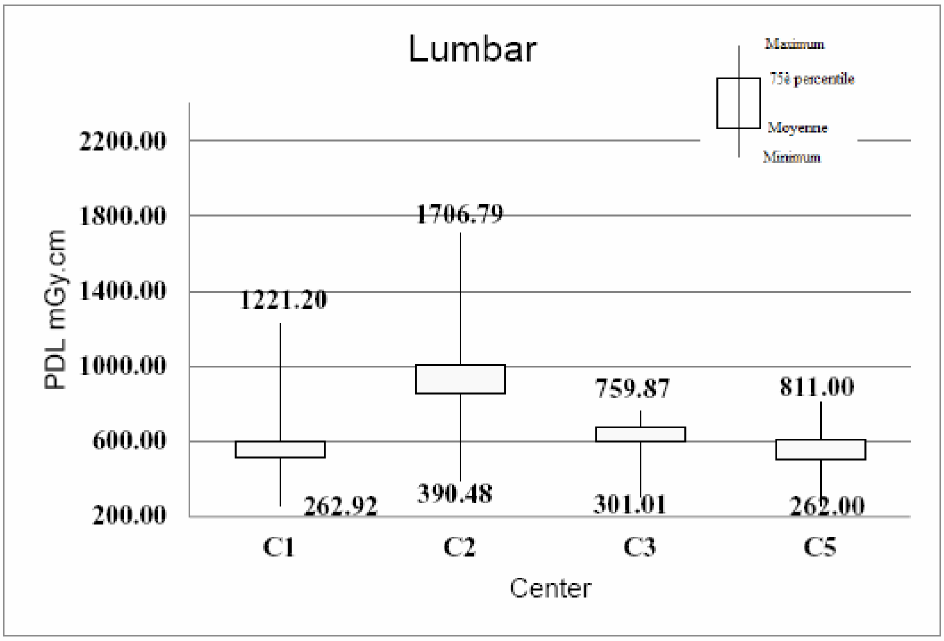

Fig. 7. Intra- and inter-center variation in DLPs from lumbar CT scans (1 acquisition).

Table 7 records the national average DLP, the DRL (75th percentile of DLP) and the average effective dose of the different CT scans performed in Togo.

Table 7

Distribution of national average DLPs, DRLs (75th percentile of DLPs) and average effective doses of the different CT scans performed in Togo

	Average DLP (mGy·cm)	**DRL (mGy·cm)**	**Mean effective dose (mSv) according to ICRP 103**
Cerebral-NT	1,045.89	1,199.14	1.98
Cerebral-NT	2,103.72	2,362.61	3.9
Cerebral-T	1,398.25	1,596.45	2.6
Cervical	481.43	635.63	2.5
Cervical	1,358.33	1,622.09	7.0
Thoracic	481.43	401.98	7.2
Thoracic	942.82	1,302.20	14.1
Lumbar	615.20	681.35	8.6
Abdominopelvic	494.19	594.42	6.9
Abdominopelvic	1,740.01	2,127.55	24.3
TAP	537.30	675.73	7.5
TAP	1,543.28	2,037.06	21.6

Cerebral-NT: Non-traumatic cerebral, Cerebral-T: Traumatic cerebral, TAP: Thoracic abdominopelvic.

The influence of the number of bars on the average DLP of the different types of examination is presented in Table 8.

Table 8

Distribution of average DLP (mGy·cm) as a function of the number of scanner bars

	Average DLP (mGy·cm)	
Scanner bars	6	16
Cerebral-NT	903.65	1,099.68
Cerebral-T	1,141.58	1,462.60
Abdominopelvic	320.51	540.75
Thoracic	214.88	422.94
Lumbar	505.30	657.68
Cervical	336.86	540.09
TAP	417.63	573.77

Cerebral-NT: Non-traumatic cerebral, Cerebral-T: Traumatic cerebral, TAP: Thoracic abdominopelvic.

DISCUSSION

The data analyzed in this study were collected in 5 health facilities with 20–40 consecutively selected examinations of each type. Our procedure is comparable to that of Moifo *et al*. [7] in Cameroon. In their work, 15 to 30 examinations were selected for each type in 9 health facilities. Leclet *et al*., recommended a minimum of 30 examinations of each type, regardless of size or age [5]. The participation rate of the facilities in activity in this study was 100 % while it was 81.81 % in Cameroon [7] and 85 % in France [11].

The age of the patients ranged from 15 to 99 years with a mean age of 47.4 years. A male predominance was found with a sex ratio of 1.42. This unexplained male predominance (sex ratio: 1.17) was also found in the work of Moifo *et al*. in Cameroon (sex ratio: 1.26) [7].

Computed tomography is the first line of investigation for brain pathologies. These pathologies constitute the first reason for requesting CT examinations, consequently, cerebral CT examinations represented 34.2 % of the total, followed by abdominopelvic CT (15.1 %). The predominance of cerebral and abdominopelvic CT scans was observed in Cameroon [7] and France [11] with respectively 41.2 % and 24.1 % for cerebral CT scans, 26.9 % and 21.6 % for abdominopelvic CT scans.

The factors influencing the dose delivered to the patient in CT are diverse. There are intrinsic factors that cannot be modified by the user and that are specific to each device (focus and beam geometry, collimation, detector properties) and extrinsic factors that can be modified by the user such as voltage, load and pitch.

In our series, the technical parameters of the exposure such as voltage and load, used for the acquisition of the examinations, were almost identical in the centers.

The doses delivered to patients during CT examinations also depend on certain parameters related to patient morphology, such as the acquisition length (height) of the anatomical area explored and the number of acquisitions.

The average acquisition length for thoracic and thoracic abdominopelvic CTs was respectively 34.19 cm and 58.64 cm while it was 38.3 cm and 68.2 cm according to the French Institute for Radioprotection and Nuclear Safety (IRSN) data in its 2020 mission report [11]. As the number of acquisitions is closely related to the search for diagnostic information, the average number of acquisitions in our series was 1.2 for non-traumatic brain and 3.6 for abdominopelvic respectively.

To quantify the dose delivered in CT, two specific quantities are used: the CT dose index (CTDIvol) and the DLP [2]. Our study reveals a dispersion of the average values and the 75th percentile of the CTDIvol of the same type of examination in the different facilities. This disparity can be explained by the heterogeneity of the technical parameters of acquisition of the same type of examinations carried out in the various facilities.

Comparing the 75th percentile CTDIvol of the present study with those of other countries (Table 9), the 75th percentile CTDIvol of the brain scan in our study was higher than those of France [11] and Switzerland [12] but lower than that of Canada (Quebec) [8]. On the other hand, the CTDIvol of the thoracic, abdominopelvic and combined thoracic-abdominopelvic (TAP) examinations were almost identical to the CTDIvol of other countries. This could be due to the iterative reconstruction software incorporated in the processing software of the devices included in our study. This reconstruction method allows the optimization of protocols to reduce the dose delivered to the patient while maintaining image quality.

The DLP is calculated as a function of the CTDIvol and the acquisition length. For the same anatomical area explored, the DLP value depended on the length of the acquisition or the number of acquisitions.

The latest technical developments in modern scanners, allow examinations of more extensive anatomical regions to be carried out and these explorations to be repeated for different phases (without contrast, with contrast: arterial time, venous time). Taking into account these features, in order to determine the quantities that are related to the risk incurred, the European Commission has introduced the dosimetric indicator Dose Product Length for a complete examination [1].

In our study, we calculated the mean DLP and the 75th percentile of DLPs for a complete examination with 2–5 acquisitions. The number of acquisitions varied in general from 2–4 and the fifth acquisition was performed in some particular cases. There was a very large difference between the mean and the 75th percentile of the complete (total) DLP for examination types such as thoracic, abdominopelvic, thoracic abdominopelvic, and cervical CT. This discrepancy may be explained by the varying number of acquisitions for the same indication and between facilities.

The distribution of DLPs per acquisition and for a complete examination was analyzed by center for the different types of CT examinations, in order to allow each center to define its practices in relation to all the health centers included in our study. This distribution of DLPs showed, for the same type of examination, a significant variation in DLPs between centers by acquisition. The minimum DLP value for non-traumatic cerebral CT was 605.45 mGy·cm at C2 (the smallest minimum of all centers) while the maximum value for the same type of examination was 1,799.44 mGy·cm at C3 (the largest maximum of all centers). This significant difference in dose (DLP) observed also for examinations involving (2–5) acquisitions, was the likely consequence of the heterogeneity in acquisition protocols (high voltage, load, pitch) of the acquisition length and the average number of acquisitions from one center to another as mentioned above.

In addition, at center 5, where the scanner has 6 bars, the low values of DLP per acquisition compared to the other centers can be explained by the fact that the C5 CT scan has 6 bars compared to 16 bars for the other centers.

The variations in LDPs within or between centers in our study were also observed in the series by Moifo *et al.* in Cameroon [7] and in France [11].

The 75th percentile value of the doses measured for a given procedure on a large number of patients in a large number of centers, representative of the radiological practice of a country is defined as the reference level. The DRL is therefore not an average but, for each practice, a value below which 75 % of the measurements fall. This means that the 25 % of examinations corresponding to the highest doses are not optimized. The DRLs for the different types of examination in our series (defined as the 75th percentile of the DLPs for the same type of examination) are compared with those of other countries (Table 10). It appears that the DRL of the cerebral CT in our series is higher than in Cameroon [7], France [11], and Canada [8]. On the other hand, the DRLs of the thoracic, abdominopelvic and thoracic abdominopelvic CT scans in our series were among the DRL values of these countries.

Effective dose, expressed in mSv, is an indicator of the risk of health detriment from personal exposure to ionizing radiation. The mean effective doses associated with the different types of CT scans ranged from 2–3 mSv for the head and neck exposure (single-acquisition scan) to about 24 mSv for the abdominopelvic scan (2–5 acquisitions) in adults. The low mean effective dose value for cerebral CT was due to the low radiosensitivity of the central nervous system. The presence of radiosensitive organs and the volume explored explain the high value of the mean effective dose in the abdominopelvic region.

Table 9

Comparison of 75th percentile CTDIvol (mGy) by type of examination for different countries

	Our series	France [11]	Switzerland [12]	Canada [8]
Cerebral*	60.41	46.0	51	65.5
Cervical	27.45	–	17	–
Thoracic	12.31	9.5	7	11.5
Abdominopelvic	10.69	13.0	11	16.2
TAP	10.63	11.0	11	–
Lumbar	21.53	28.0	25	–

*Non-traumatic cerebral in our series; TAP: Thoracic abdominopelvic.

The mean effective doses associated with cerebral (1.9 mSv), abdominopelvic (6.9 mSv), thoracic abdominopelvic (7.9 mSv) CT scans in our series were significantly lower than those reported in Canada, which were 3 mSv, 17.2 mSv, and 18.5 mSv, respectively [13].

Table 10

Comparison of DRLs by type of examination in different countries (mGy·cm)

	Our series	Cameroon [7]	France [11]	Switzerland [12]	Canada [8]
Cerebral*	1,199.14	1,155	850	890	1111
Cervical	635.63	–	–	360	
Thoracic	401.98	715	350	250	426
Abdominopelvic	594.42	716	625	540	813
TAP	675.73	–	750	740	
Lumbar	681.35	769	725	–	–

*Non-traumatic cerebral in our series. TAP: Thoracic abdominopelvic.

CONCLUSIONS

This pilot study of dosimetric evaluation of CT scans performed throughout Togo revealed a wide dispersion of dose delivered during CT examinations and also allowed us to establish the first DRLs of the most frequently performed CT examinations in Togo. The DRLs for some types of examinations were relatively high compared to those of other countries. A process of homogenization of procedures and optimization of doses based on the DRLs thus determined is therefore necessary.

Conflicting interests: The authors declare that they have no competing interests.

Authors' contributions: K.A. put the idea and the design of the study. K.K., A.M.Y.A. data collection and have contributed to the conception and design of the manuscript. L.S., K.A. had contributed to the conception and design of the manuscript. All authors have been involved in drafting and revising the manuscript. All authors read and approved the final manuscript.

Funding: This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

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