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ARTICLE ORIGINAL / RESEARCH ARTICLE

Comparative study of clinical indication-based DRLs with anatomical region-based DRLs in adult patients CT-scans in Yaounde - Cameroon.

Etude comparative des NRD basés sur les indications cliniques et des NRD basés sur la région anatomique au scanner des patients adultes à Yaoundé - Cameroun.

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***Mots*-clés :**
NRD ; PDL ; TDM ; indication clinique ; radioprotection ; optimisation.

Keywords :
DRL ; DLP ; CT-scan ; clinical indication ; radiation protection ; optimization.

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RÉSUMÉ

Contexte : Le scanner est la principale source d'irradiation de la population en radiodiagnostic. Les NRD initialement établis par région anatomique, constituent l'un des principaux outils d'optimisation. En pratique, les protocoles d'examen scanner sont adaptés à la région d'intérêt et à l'indication. Par conséquent, les NRD par région anatomique pourraient ne pas être adaptés à l'optimisation.
Objectif : Comparer les NRD basés sur l'indication clinique (CIB-DRLs) aux NRD basés sur la région anatomique (ARB-DRLs) sur les scanners de patients adultes afin d'optimiser les doses.
Méthodes : De janvier à juillet 2020, nous avons réalisé une étude transversale d'enquête dosimétrique. Les mesures de dose TDM des patients ayant des examens TDM de la tête, du thorax, du rachis lombaire, abdomino-pelvien et thoraco-abdomino-pelvien (TAP) ont été collectées prospectivement dans quatre structures sanitaires très fréquentées de Yaoundé. Treize indications cliniques les plus fréquentes ont été retenues (4 pour la tête, 3 pour le thorax, 3 pour l'abdomino-pelvien, 2 pour le rachis lombaire et un pour le thoraco-abdomino-pelvien) pour un total de 697 scanners. L'échantillonnage était consécutif et non exhaustif. Les NRD [75e percentile du produit dose-longueur (DLP)] ont été évalués pour chaque indication clinique principale dans une région anatomique donnée. Les NRD pour chaque région anatomique donnée (ARB-DRLs) ont été comparés aux NRD basés sur l'indication clinique (CIB-DRLs) sur cette même région. Cette étude a été approuvée par le comité d'éthique institutionnel de la FMBS.
Résultats : Sur les 697 examens TDM (55,4 % d'hommes), les examens TDM du cerveau, du thorax, des thoraco-abdomino-pelviens, abdomino-pelviens et du rachis lombaire représentaient respectivement 38,2 %, 25,5 %, 11,0 %, 10,6 % et 14,7 %. L'ARB-DRLs (mGy.cm) était de 1806,1 pour les scanners de la tête, 853,2 pour les scanners du thorax, 3038,7 pour les scanners abdomino-pelviens, 3050,5 pour les scanners thoraco-abdomino-pelviens et 844,7 pour les

scanners du rachis lombaire. Les CIB-DRLs étaient respectivement 11,6 % et 7,1 % plus élevés que les ARB-DRLs pour les processus expansifs intracrâniens et les céphalées chroniques ; ils étaient respectivement 30,7 % et 47,3 % plus bas pour les traumatismes crâniens et les accidents vasculaires cérébraux. Les CIB-DRLs étaient respectivement 84,0 % et 73,7 % plus élevés pour l'embolie pulmonaire et la tumeur pulmonaire, et 22,4 % plus faibles pour la pneumonie liée à la COVID-19 que pour les NRD thoraciques. Au niveau abdomino-pelvien, ils étaient respectivement 30,9 % et 8,1 % plus élevés pour la tumeur pelvienne et la masse hépatique, et 34,9 % plus faibles pour les calculs rénaux. Pour les scanners thoraco-abdomino-pelviens et lombaires, les CIB-DRLS étaient comparables aux ARB-DRLs (différence de 0,9 % à 5,0 %).
Conclusion : Les NRD basés sur l'indication clinique sont plus adaptés à l'optimisation que les NRD basés sur la région anatomique, en raison des variations importantes de dose entre les différentes indications pour une même région anatomique. Des mesures immédiates doivent être prises pour optimiser l'angiographie pulmonaire par tomodensitométrie. Il est pertinent de proposer des NRD nationaux basés sur l'indication clinique.

ABSTRACT

Background : CT-scan is the major source of population exposure in diagnostic x-rays radiology. DRLs is one of the main optimization tools, initially established by anatomical region. CT examination protocols are adapted to the region of interest and to the indication. Therefore, DRLs by anatomical region may not be well appropriate for optimization.
Objective : To compare clinical indication-based DRLs (CIB-DRLS) to anatomical region-based DRLs (ARB-DRLS) in adult patients CT-scans for better doses optimization.
Methods: From January to July 2020, we carried out a cross-sectional dose-survey. CT dose metrics of patients undergoing head, chest, lumbar spine, abdomino-pelvic, and thoraco-abdomino-pelvic (TAP) CT examinations were collected prospectively in four highly attended health facilities in Yaounde. Thirteen most frequent clinical indications were retained (4 for head, 3 for chest, 3 for abdomino-pelvic, 2 for lumbar spine and one for thoraco-abdomino-pelvic) for a total of 697 scans. The sampling was consecutive and not exhaustive. The DRLs [75th percentile of Dose Length Product (DLP)] were assessed for each main clinical indication in a given anatomical region. DRL for each giving anatomical region (ARB-DRLS) were compare to DRLs based on clinical indication (CIB-DRLS) on that same region. This study was approved by the Institutional Ethical Review Board of the FMBS.
Results: Of the 697 CT-examinations (55.4% men), the brain, chest, thoraco-abdomino-pelvic, abdomino-pelvic and lumbar spine CT-examinations represented respectively 38.2%, 25.5%, 11.0%, 10.6% and 14.7%. The ARB-DRLS (mGy.cm) was 1806.1 for head, 853.2 for chest, 3038.7 for abdomino-pelvic, 3050.5 for thoraco-abdomino-pelvic and 844.7 for lumbar spine CT-scans. CIB-DRLs were 11.6% and 7.1% higher than ARB-DRLs for intracranial space occupying lesion and chronic headache; it was 30.7% and 47.3% lower for head trauma and stroke. CIB-DRLs were 84.0% and 73.7% higher for pulmonary embolism and lung tumor; and 22.4% lower for covid-19 pneumonia than chest DRL. On the abdomino-pelvic region, it was 30.9% and 8.1% higher for pelvic tumor and hepatic mass ; and 34.9% lower for renal stones. For thoraco-abdomino-pelvic and lumbar spine CT-scans, CIB-DRLS were comparable to ARB-DRLs (difference of 0.9% to 5.0%).
Conclusion: Clinical indication-based DRLs are more adapted for optimization than anatomical region-based DRLs because of large dose variations between different indications for the same anatomic region. Immediate actions should be taken for optimization of CT-pulmonary angiogram. Suggestion of national clinical indication-based DRLs is relevant.

1. Introduction

CT examination is the most irradiating imaging tool (contributing to about 50% of the collective effective dose from diagnostic x-rays imaging) [1] despite the general decrease of doses per CT examination due to advanced technology, improvement of radiology guidelines and the establishment of Diagnostic reference levels. This is mainly due to increased number of CT devices and CT examinations, worldwide [2], especially in Cameroun (3). Thus there is need for constant improvement of dose optimization [1]. The Diagnostic Reference Levels (DRLs) are one of the main optimization tools in CT. They are defined as the 75th percentile of dose levels for typical examinations, on groups of patients and for broad categories of facilities. DRLs intended to help in the optimization of patient doses, by indicating a level which should not generally have to be exceeded to obtain acceptable image quality [2].

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This concept was first introduced in 1996 by the International Commission on Radiological Protection (ICRP) in publication 73 and revitalized by the Bonn call in 2012 for the strengthening of patients' radiation protection [3, 4]. They are established by anatomical region and stand as one mandatory radiation protection regulation for each State. The ICRP stated in the 2017 report that "different clinical indications for an examination may require different image qualities, and therefore different amounts of radiation", addressing the need to implement clinical indication-based DRLs [3]. Despite this recommendation, most large scale of patient's dose survey are from European countries [5] and are mostly based on anatomical regions.

In 2017 the first CT DRLs in Cameroon was establishing for anatomical regions [6]. In clinical practice, CT examinations protocols are adjusted to the anatomical region and the clinical indication for an appropriate image quality. Thus, patients' doses in one anatomical region may fluctuate following the CT indication and DRLs by anatomical region may not be appropriate for proper optimization. The aim of this study was to compare clinical indication-based DRLs (CIB-DRLS) to anatomical region-based DRLs (ARB-DRLS) in adult patients CT-scans in one sub-Saharan country to improve local dose optimization in adults at CT.

2. Material and methods

2.1 Study design, study period and variables

From January to July 2020, we conducted a descriptive cross-sectional dose-survey in four highly attended health facilities using CT scan in Yaounde (**Table I**). From the statistics of a 2017 study done in Cameroon, the most frequent adults CT-examinations were identified: CT of the head, chest, lumbar spine, combined abdomen/pelvis, and chest/abdomen/pelvis [6]. We circumscribed data collection to adults (18-year-old and more) undergoing one of these CT-investigations.
The following information were collected in each facility: center name, anatomical region, CT clinical indication, $CTDI_{vol}$, DLP and patient age, gender, height and weight. The DRL was calculated as the third quartile (75th percentile) of the distributions of mean doses as required by the ICRP [3].

Table I. Characteristics of CT-machines included in the study.

Health facilities	Manufacturer	Model	Number of detector rings	Acquisition type	Year of commissioning
HGOPY	PHILIPS	Neusoft	16	Helical	2018
CMC	TOSHIBA	Aquilion CX	128	Helical	2017
HCY	SIEMENS	Somatom emotion duo	2	Helical	2008
PBS	TOSHIBA	Aquilion TSX	16	Helical	2016

HGOPY : Hôpital Gynéco-Obstétrique et Pédiatrique de Yaounde ; CMC : Centre Médical la Cathédrale ;
HCY : Hôpital Central de Yaounde ; PBS : Promoteurs de la Bonne Santé

2.2 Statistical analysis

Stata software version 15.1 was used for statistical analyses. Qualitative variables were described using frequencies, and quantitative variables using mean, median (50th percentile), first quartile (25th percentile) and third quartile (75th percentile).

Anatomical region-based DRLs (ARB-DRLS) were calculated for anatomical region of head, chest, lumbar spine, abdomino-pelvic, and thoraco-abdomino-pelvic (TAP). Clinical indication-based (CIB-DRLS) were calculated for thirteen selected most frequent clinical indications (4 for head, 3 for chest, 3 for abdomino-pelvic, 2 for lumbar spine and one for thoraco-abdomino-pelvic CT-scans). DRL for each giving anatomical region were compare to DRLs based on clinical indication on that same region (relative deviation and ratio). The sampling was consecutive and not exhaustive.

2.3 Ethical considerations

Prior to this study, an ethical clearance was obtained from the institutional ethical review board of the Yaounde faculty of medicine and biomedical sciences. Five health facilities, from the public and private sector, operating in the locality were invited to participate on a voluntary basis and four responded positively. Patients were invited to sign an informed consent form and all the information collected from participants was anonymous.

3. Results

3.1 Study population.

A total of 697 patient CT-examinations data were collected. Head CT-scan was the most represented with 38.2% (**Table II**).

Table II. Distribution of the study data per anatomical region in each participating facility

CT-scan examinations Site	Anatomical region Head	Chest	Abdomino-pelvic	TAP	Lumbar spine	Total
HGOPY \ Neusoft	45	21	11	34	20	131
CMC \ Aquilion CX	45	67	38	12	17	179
HCY \ Somatom emotion duo	76	17	17	20	31	161
PBS \ Aquilion TSX	100	73	8	11	34	226
Total	266	178	74	77	102	697
Percentage (%)	**38.2**	**25.5**	**10.6**	**11.0**	**14.7**	**100**

HGOPY : Hôpital Gynéco-Obstétrique et Pédiatrique de Yaounde ; CMC : Centre Médical la Cathédrale ; HCY : Hôpital Central de Yaounde ; PBS : Promoteurs de la Bonne Santé ; TAP : Thorax/Abdomen/Pelvis

The median age of participants was 50 years with and interquartile range of 23, the male gender represented 55.4 % (**Table III**).

Table II. Distribution of data according to sex and age group.

Characteristics		Number	(%)
Sex/gender	Male	386	**55,4**
	Female	311	44,6
Age groups (years)	[18-28[	73	10,4
	[28-38[	110	15,7
	[38-48[	152	**21,7**
	[48-58[	141	20,5
	[58-68[	111	15,9
	≥68	110	15,8

3.2 Anatomical region-based DRLs (ARB-DRLS) and clinical indication-based DRLs (CIB-DRLS)

The anatomical region-based DRLs dose metrics are summarized in **Table IV** while the clinical indication-based DRLs are in **table V**. The most irradiating CT-examination was thoraco-abdomino-pelvic with DRLs of 3050,5 mGy.cm while the exposition dose for chest CT-scans was the lesser with DRLs of 853,2 mGy.cm.

For head CT-scans, the irradiation dose was higher for the investigation of intracranial space occupying lesion (ICSOL) with a DRL of 2015.9 mGy.cm. For chest CT-examinations, the radiation dose was higher for suspected pulmonary embolism with a DRL of 1570.1 mGy.cm. In the abdomen-pelvis region CT-examinations, the radiation dose metrics was higher for the investigation of pelvic tumors with a DRL of 3977.2 mGy.cm. For chest-abdomen-pelvic anatomical region, cancer extension workup was the only clinical indication retained. For lumbar spine CT-examinations, radiation dose metrics for lumbosciatica and lumbago clinical indications were very close.

Table IV. Anatomical region-based DRLs (75th percentile of medians of CTDIvol and DLP of the four sites broken down by anatomical region).

Anatomical region	75th percentile		DLP percentile
	CTDIvol (mGy)	**DLP** (mGy.cm)	[25th ; 50th]
Head	75,8	1806,1	[439,6 ; 644,9]
Chest	22,3	853,2	[247,7 ; 396,2]
Abdomino-pelvic	175,0	3038,7	[806,0 ; 2152,6]
Thoraco-abdomino-pelvic	163,6	3050,5	[860,7 ; 2373,2]
Lumbar spine	23,3	844,7	[282,0 ; 484,2]

Table V. Clinical indication-based DRLs (75th percentile of medians of CTDIvol and DLP of the four sites broken down by indication per anatomical region).

Anatomical region	Clinical indication	75ème percentile		PDL percentile
		$CTDI_{vol}$	**DLP**	[25th ; 50th]
Head	ICSOL	85.1	2015.9	[622.5 ; 931.3]
	chronic headache	81.6	1934.9	[635.0 ; 824.9]
	Head trauma	42.2	1252.5	[446.7 ; 597.8]
	Suspected stroke	42.2	952.6	[325.4 ; 452.2]
Chest	Pulmonary embolism	78.0	1570.1	[555.1 ; 692.1]
	Lung tumor	73.0	1482.1	[456.8 ; 656.1]
	Pneumonia	18.0	662.3	[192.6 ; 364.6]
Abdomen-pelvis	Pelvic tumor	222.5	3977.2	[1030.7 ; 2750.8]
	Hepatic tumor	171.9	3283.4	[618.6 ; 1938.4]
	Kidney stones	21.6	1059.9	[369.3 ; 807.4]
Chest/abdomen/pelvis	Tumor extension assessment	183.9	3196.1	[856.7 ; 2295.5]
Lumbar spine	Lumbosciatica	22.9	836.7	[271.0 ; 458.5]
	Lumbago	23.3	802.8	[289.9 ; 499.0]

$CTDI_{vol}$ is expressed in mGy and DLP in mGy.cm ICSOL : IntraCranial Space Occupying Lesion

3.3 Comparison between anatomical region-based DRLs (ARB-DRLS) and clinical indication-based (CIB-DRLS)

The relative difference and the ration between ARB-DRLS and CIB-DRLS are summarized in **table VI**. CIB-DRLs were 11.6% higher than ARB-DRLs for intracranial space occupying lesion; 30.7% and 47.3% lower for head trauma and stroke. CIB-DRLs were 84.0% and 73.7% higher for pulmonary embolism and lung tumor; and 22.4% lower for covid-19 pneumonia than chest DRL. On the abdomino-pelvic region, it was 30.9% higher for pelvic tumor 34.9% lower for renal stones. For thoraco-abdomino-pelvic and lumbar spine CT-scans, CIB-DRLS were comparable to ARB-DRLs (difference of 0.9% to 5.0%).

Table VI. Comparison of anatomical region-based DRLs (ARB-DRLS) to clinical indication-based (CIB-DRLS).

Anatomical region	ARB-DRLs (mGy.cm)	Clinical indication	CIB-DRLs (mGy.cm)	DRL Difference [CIB-ARB] (mGy.cm)	DRL Ratio CIB/ARB (%)
Head	1806.1	ICSOL	2015.9	209.8	111.6%
		Chronic headache	1934.9	128.8	107.1%
		Head trauma	1252.5	-553.6	69.3%
		Suspected stroke	952.6	-853.5	52.7%
Chest	853.2	Pulmonary embolism	1570.1	716.9	184.0%
		Lung tumor	1482.1	628.9	173.7%
		Covid-19 pneumonia	662.3	-190.9	77.6%
Abdomen-pelvis	3038.7	Pelvic tumor	3977.2	938.5	130.9%
		Hepatic tumor	3283.4	244.7	108.1%
		Kidney stones	1059.9	-1978.8	34.9%
Chest/abdomen/pelvis	3050.5	Tumor extension assessment	3196.1	145.6	104.8%
Lumbar spine	844.7	Lumbosciatica	836.7	-8.0	99.1%
		Lumbago	802.8	-41.9	95.0%

4. Discussion

The aim of this cross-sectional study was to reinforce adults' dose optimization during CT-examinations in Yaounde. The indication-based DRLs obtained in our study were globally higher than those available in the European publications except for suspected stroke where the UK DRLs dose metrics are slightly higher than ours (table VII). This can be explained by the fact that CT dose optimization greatly depends on the thorough implementation of optimized protocols [10]. This is not the case in our country where the establishment and standardization of CT protocols are still pending. This is a strong indicator that more can still be acquired in relations to dose optimization in our settings. This dose reduction goal is achievable regarding a feasibility study published in 2009 [2].

The 2017 report of the ICRP insisted on the need to establish indication-based DRLs at regional, national and local regions for accurate dose optimization [3]. Few data are available on the African continent on DRLs and most of them are focused on anatomical regions [5, 6, 11, 12]. This study was the first of its kind in our country to access CT DRLs based on clinical indication.

Besides this observations, the distribution of our study population was similar to the results obtained in a 2017 survey in Cameroon where on a similar sample size, the mean age of participants was 52 ± 15 years and the male gender was the most represented (55.9%).

The average dose variations between participating facilities differed with the CT-examination. It ranged from 3.9 folds for chest CT examinations to 7.3 for combined abdomen and pelvis CT-examinations, with the extremes being held by the 2 and 128 detectors rings CT equipment. These large variations can't be justify by the differences in Automated Exposure Control software or the differences in patients' sizes. They rather indicate that there are different levels of optimization among participating facilities and call for a need to homogenize our radiation protection policies. This results are close to that of Salama et al. where chest CT had the lowest dose variations (4.1) and the combined abdomen and pelvis the largest (10.4) [5]. Based on this variations, it might be interesting to establish a separate DRLs for high detector ring CT equipment.

This study had some limitations. Firstly, the diagnostic quality of CT images were not assessed. Secondly, due to limited resources, the exactitude of the CTDIvol and DLP displayed by the CT machines were not accessed. Thirdly, due the coronavirus pandemic restrictions, the attendance of our CT units dropped thus restraining our population size. In spite of these limitations, this survey has given us the opportunity to have an overview of the radiation protection practices in our locality. It's a starting point, demonstrating that we can achieve more in our CT dose optimization process. Moreover, there is a necessity to standardize CT protocols in other to limit large dose variations for identical CT indications in our CT facilities.

Table VII. Indication-based DRLs from our study, compared to selected indication-based DRLs of other countries

Anatomical region	Clinical indication	PDL in mGy.cm			
		Yaounde, this study	Finland [7]	UK [8]	Switzerland [9]
Brain	ICSOL	2015.9	–	–	–
	chronic headache	1934.9	–	–	–
	head trauma	1252.5	–	–	–
	suspected stroke	952.6	–	970	–
Chest	pulmonary embolism	1570.1	–	440	207
	Lung tumor	1482.1	430	610	–
	Pneumonia	662.3	–	–	223
Abdomen-pelvis	Pelvic tumor	3977.2	–	–	–
	Hepatic tumor	3283.4	–	910	289.4
	Kidney stones	1059.9	330	460	339.5
Chest/abdomen/pelvis	Tumor extension assessment	3196.1	–	1000	–
Lumbar spine	Lumbosciatica	836.7	–	–	–
	Lumbago	802.8	–	–	–

5. Conclusion

Clinical indication-based DRLs are more adapted for optimization than anatomical region-based DRLs because of large dose variations between different indications for the same anatomic region. Immediate actions should be taken for optimization of CT-pulmonary angiogram. Suggestion of national clinical indication-based DRLs is relevant. Our clinical indication-based DRLs are globally higher than that of European countries. It's an indicator of the large potential for radiation dose optimization in our settings. More so, large dose variations among participating facilities indicates the need of harmonizing and standardizing our radiation protection protocols.

Conflict of interest

The authors declare that they have no conflict of interest.

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