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Dosimetric Evaluation of the Scanning Activity at the Regional Hospital of Kaolack (Senegal)

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Abstract

The aim of this study was to evaluate the dose delivered to patients during scannographic examinations at the Kaolack Regional Hospital (one of the 14 regions of Senegal located in the center-west of the country, 192 km from Dakar) and to compare these irradiation doses at diagnostic reference levels found in the literature in order to optimize our scanning protocols. To achieve this goal, we carried out a prospective study involving 218 CT scans. These examinations focused on cerebral, thoracic, abdominopelvic and lumbar spine acquisitions made in adults and cerebral only in children. We compared the median values of dosimetric indicators (CTDIvol and DLP) per acquisition with NRDs in the literature. During the course of this study, we found a dosimetric ratio lower than that of the NRDs for thoracic, abdomino-pelvic and lumbar spine CT scans in adults and a significant dosimetric exceedance for brain scans in adults and in children. These results encourage us to extend these dosimetric evaluations to other hospital structures in order to establish rigorous monitoring of dosimetric indicators and to respect the principles of radiation protection and good practice.

Keywords

Dosimetry, CT, DRL, Senegal

1. Introduction

Computed tomography is based on the fact that different tissues in the body achieve differential X-ray attenuation. The relatively homogeneous beam at the entrance becomes inhomogeneous. This information, called a radiant image, forms a real image with an appropriate sensor. These are obtained at the cost of a certain irradiation of the patient which leads to more or less long-term biological effects. This is why it seems judicious to respect the contraindications, and all reasonable technical means must be implemented to reduce these irradiation doses as much as possible while maintaining the good contrast of the image [1]. Nowadays, there is an increased demand for sometimes unjustified CT scans. This leads to deleterious effects, the most frequently encountered in medicine being the stochastic effects. We could not establish thresholds as these effects are at low doses and are also random [2]. These repeated doses, compatible with cell survival, are at the origin of DNA alterations resulting in carcinogenesis for somatic cells and transmissible genetic alterations for germ cells [3]. Two studies were carried out in Senegal concerning DRLs. One was carried out at the CHNU of FANN by DIOP [4] and collaborators and focused on conventional radiology. The other study concerned the X-ray scanner, and was carried out at CHN Aristide in Le Dantec by El Madrouchi and collaborator [5]. These two studies required supplementation with a choice of appropriate parameters to answer the question of radiation protection of patients with reference levels requiring optimization [6].

It is for this purpose that the International Atomic Energy Agency as well as other similar organizations in the world such as EURATOM, have laid down the general principles of the protection of patients exposed to ionizing radiation during an act for diagnosis purposes. In addition to explaining the steps necessary for the radiation protection of patients, it recommends, to member states, the development and use of diagnostic reference levels (DRLs) for radio-diagnosis examinations in particular CT scan [7].

The aim of our work was to compare the irradiation doses delivered to our patients with computed tomography NRD values found in the literature in order to make corrections to our protocols when necessary.

2. Materials and Methods

2.1. Material

This was a prospective, descriptive and analytical study carried out over a period of 3 months from February 17 to May 17, 2020. The data collection was done at the medical imaging department of the EL HADJ IBRAHIMA NIASS regional hospital of Kaolack, city situated in the central west of Senegal. During the study period, we received 288 patients for CT examinations and have adopted the criteria set by decision n˚ 2019-DC-0667 of the Nuclear Safety Authority (ASN) of April 18, 2019 relating to the methods for evaluating the doses of ionizing radiation delivered to patients during an act of radiology [8]. After applying the inclusion criteria, five types of scanners were studied, depending on the body area explored and the age category.

For the adult population, we performed 102 brain CT scans, 31 thoracic CT scans, 43 abdomino-pelvic and 32 lumbar spine CT scans.

For the pediatric population, we performed 10 brain CT scans in a population of children from 5 to 10 years old with a weight between 20 and 30 kg.

2.2. Methodology

The examinations were carried out on a multi-slice helical scanner from SIEMENS model 2010 (Muenchen, Germany), equipped with 16 strips.

The scanner incorporates an irradiation dose reduction technique (CARE Dose-4D) and the load can thus vary from 30 to 500 mA.

The CT presented in post-acquisition a dosimetric report on which appeared the doses delivered expressed in CTDI vol and in DLP for each acquisition and for the entire examination, as well as the length explored. The parameters that allowed the study to be carried out were voltage (kV), load (mA), acquisition thickness, rotation speed, collimation (mm) and expected length. These examinations were carried out according to predefined standard protocols. The voltage was set at 130 kV for adults and 110 kV for children. The load adopted was 220 mA for brain acquisition and other types of acquisitions with automatic milliamperage modulation. This could be lengthened or shortened on the topogram, compared to the length provided for in the protocol.

As for the dosimetric parameters, we studied the volumetric CT dose index (CTDI vol.). The length explored was modifiable as was the dose length product (DLP). Statistical analysis of these data was performed by dedicated statistical analysis software SPSS, version 18 and graphical representations made by Microsoft Excel 365 software

3. Results

3.1. Dosimetric Evaluation in Adults

3.1.1. Brain CT

The value of the flight CTDI was constant at 58.3 mGy. The median value of the lengths explored was 188.5 mm with extremes ranging from 159.5 mm to 341.5 mm with a ratio. The 75th percentile and the 25th percentile are estimated at 211.25 mm and 177 mm respectively, *i.e.* a 75th/25th percentile ratio estimated at 1.19. For DLP (**Figure 1**), the median was 1098.94 mGy·cm, with a standard deviation of 270.95 mGy·cm with extremes ranging from 929.87 to 1990.92 mGy·cm. The 75th/25th percentiles were estimated at 1257.07 and 1031.91 mGy·cm respectively, *i.e.* a 75th/25th percentile ratio of 1.21.

3.1.2. Thoracic CT

The median value of the flight CTDIs was 6.13 mGy with a standard deviation of 2.55 mGy and extremes of 2.85 and 14.4 mGy. The 75th/25th percentiles are respectively estimated at 8.22 and 5.19 mGy, *i.e.* a 75th/25th percentile ratio corresponding to 1.58. As for the median value of the lengths explored; it was estimated at 356.4 mm with a standard deviation of 97.4 mm and extreme values of

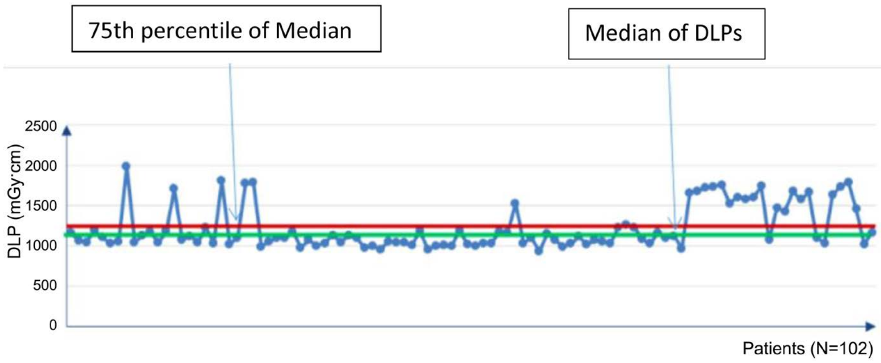

Figure 1. Distribution of PDL values for brain CT scan in adults.

269.4 and 734.7 mm. The 75th/25th percentiles are estimated at 384.7 and 330.9 respectively, *i.e.* a 75th/25th percentile ratio of 1.16.

For DLP (Figure 2), the median was 218.58 mGy·cm, with a standard deviation of 96.1 mGy·cm and extremes of 91.95 and 444.1 mGy·cm. The 75th/25th percentiles were estimated at 355.43 mGy·cm and 188.29 mGy·cm respectively, *i.e.* a 75th/25th percentile ratio of 1.88.

3.1.3. Abdomino-Pelvic Scanner

The median value of the flight CTDIs was 5.61 mGy with a standard deviation of 1.3 mGy and extremes of 4.26 and 9.65 mGy. The 75th and 25th percentiles are respectively estimated at 6.78 and 4.26 mGy, *i.e.* a 75th/25th percentile ratio corresponding to 1.3. As for the median value of the lengths explored; it was estimated at 498.7 mm with a standard deviation of 44.84 mm and extreme values of 438.2 and 679.2. The 75th/25th percentiles are estimated at 520.7 and 470.7 mm respectively, *i.e.* a 75th/25th percentile ratio of 1.1.

For the DLP (Figure 3), the median was 281.91 mGy·cm, with a standard deviation of 71.45 mGy·cm and extremes ranging from 200.27 to 503.38 mGy·cm. The 75th/25th percentiles were estimated at 333.3 mGy·cm and 241.74 mGy·cm respectively, *i.e.* a 75th/25th percentile ratio of 1.37.

3.1.4. CT Scan of the Lumbar Spine

The median value of the flight CTDIs was 10.39 mGy with a standard deviation of 3.45 mGy and extremes ranging from 5.05 to 21.09 mGy. The 75th/25th percentiles are respectively estimated at 11.82 and 8.91 mGy, *i.e.* a 75th/25th percentile ratio corresponding to 1.32. As for the median value of the lengths explored; it was estimated at 285.45 mm with a standard deviation of 112.79 mm and extreme values varying from 230.2 to 616 mm. The 75th and 25th percentiles are estimated at 327.82 and 268.3mm respectively, *i.e.* a 75th/25th percentile ratio of 1.22.

For DLP (Figure 4), the median was 310.55 mGy·cm, with a standard deviation of 159.12 mGy·cm and extremes ranging from 169.04 to 876.43 mGy·cm. The 75th/25th percentiles were estimated at 426.32 mGy·cm and 245.09 mGy·cm respectively, *i.e.* a 75th/25th percentile ratio of 1.73.

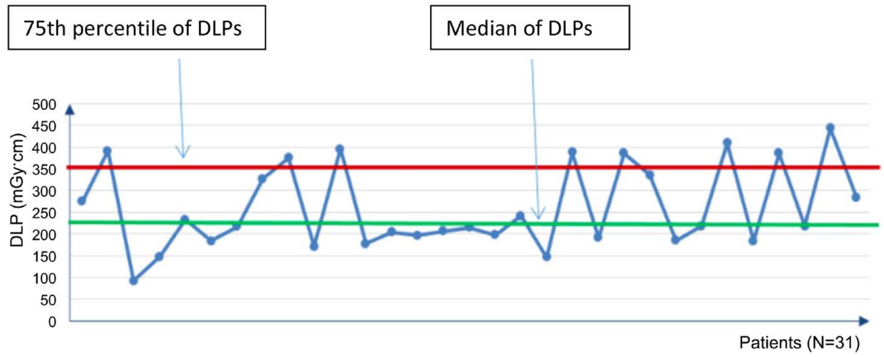

Figure 2. Distribution of DLP for chest CT scan in adults.

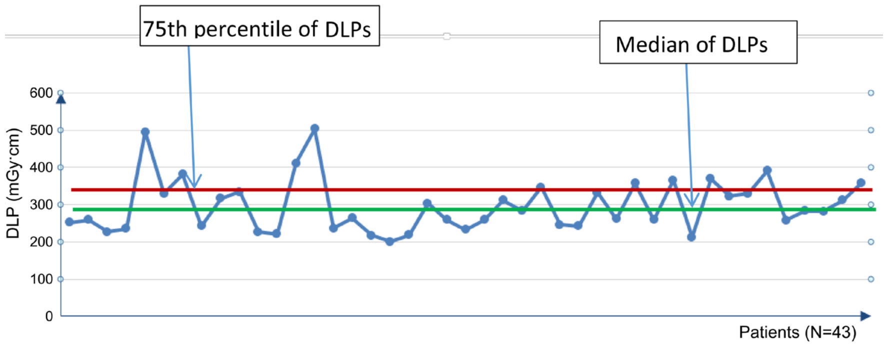

Figure 3. Distribution of DLP for abdominopelvic CT scan in adults.

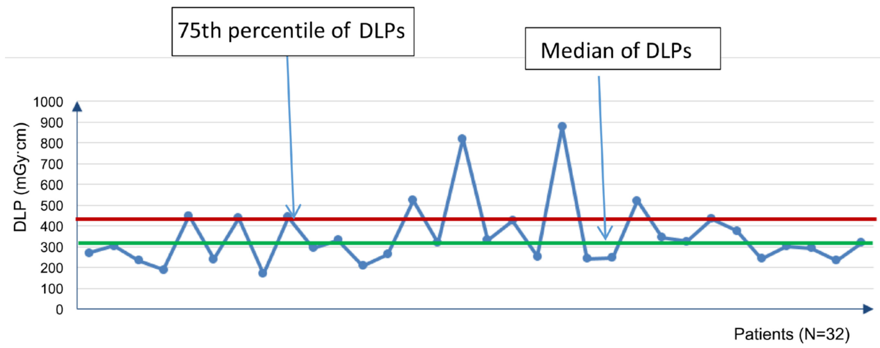

Figure 4. Distribution of PDL for CT scan of the lumbar spine in adults.

3.2. Dosimetric Evaluation of the Brain Scan in Children

The distribution of CTDI-vol values by brain scan acquisition had a median value of 25.93 mGy with a standard deviation of 3.31 mGy and extreme values of 22.94 and 31.52 mGy. The values of the 75th/25th percentiles were respectively estimated at 29.32 and 23.73 mGy, *i.e.* a 75th/25th percentile ratio corresponding to 1.23.

As for the median value of the lengths explored; it was estimated at 290.1 mm with a standard deviation of 41.38 mm and extreme values varying from 199.6 to 316.1 mm. The 75th/25th percentiles are estimated at 304.72 and 262.97 mm respectively, *i.e.* a 75th/25th percentile ratio of 1.15.

For DLP (Figure 5), the median was 743.57 mGy·cm, with a standard deviation

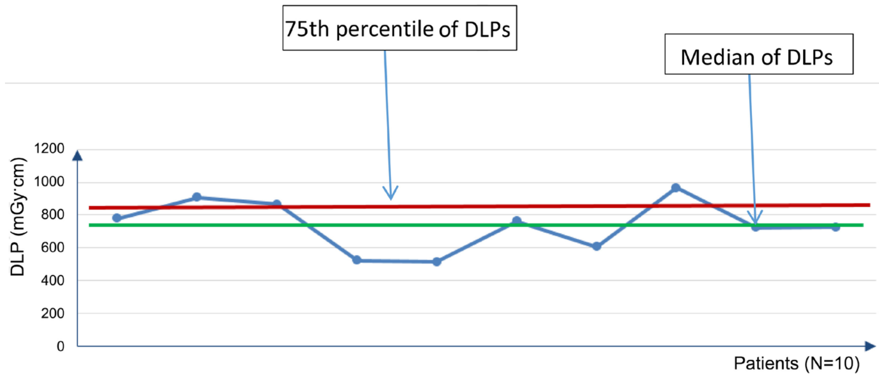

Figure 5. Distribution of DLPs for the brain scan in children.

of 153.87 mGy·cm and extremes ranging from 513.63 to 964.76 mGy·cm. The 75th/25th percentiles were estimated at 843.41 mGy·cm and 633.89 mGy·cm respectively, *i.e.* a 75th/25th percentile ratio of 1.33.

4. Discussion

4.1. Dosimetric Evaluation in Adults

4.1.1. Brain Scanner

The value of the flight CTDI was constant at 58.3 mGy, higher than the NRD value in the USA [9] which is 56 mGy, that in Belgium [10] which is 50 mGy and that in France [8] which is 46 mGy. The median value of DLP was 1098.94 mGy·cm, higher than the NRD value in the USA [9] which is 962 mGy·cm, that in Belgium [10] 800 mGy·cm and that in France [8] 850 mGy·cm.

As in our study and with this type of brain examination carried out in adults, the only parameter modifiable by the manipulator technician was the length explored and, moreover, the irradiation dose reduction software (CARE Dose-4D) did not work, this could explain the superiority of our values of CTDI and DLP compared to those found in the literature. We also observed that the median value of the lengths explored was 188.5 mm and is much greater than the length provided for by the predefined protocol (150 mm), with an inclusion in the field of exploration of anatomical areas not interested in the desired study, hence the need for compliance for this type of examination. For this, it seems judicious to us to limit ourselves to the irradiation field, to the anatomical zone useful for the study and also to study the possibility of integrating the dose reduction software for this type of examination.

4.1.2. Thoracic, Abdominopelvic and Lumbar Spine Scans

The median values of CTDIvol were lower than the values of NRDs in the USA, Belgium and France.

The median values of the lengths explored were relatively high compared to the length provided for by the protocol, especially for scans of the lumbar spine where several of our examinations went back to the dorsal vertebral level or covered the entire pelvis.

We insisted with the manipulator technicians on the importance of respecting the acquisition lengths. The normal height of acquisition for the lumbar spine should extend from the twelfth dorsal vertebra to the sacroiliac joints.

The median DLP values were lower than the NRD values in the USA, Belgium and France.

Although the lengths explored are relatively high, the use of the irradiation dose reduction software (CARE Dose-4D), allowing the automatic modulation of the load according to the different regions crossed by the X-ray beam, means that the median values of the vol and DLP CTDIs remain lower than the NRD values [11].

4.2. Dosimetric Evaluation of the Brain Scan in Children

The median value of CTDIvol was 25.93 mGy, lower than the value of NRD in Canada [12] which is 51.5 mGy, that in Belgium [8] which is 40 mGy and also that in France [8] which is 26 mGy.

The median value of the lengths explored was 290.1 mm, much too high compared to the length provided for by the protocol (150 mm).

The median value of DLP was 843.41 mGy·cm, higher than the value of NRD in Canada [12] which is 692 mGy·cm, that in Belgium [10] which is 660 mGy·cm and also that in France [8] which is 470 mGy·cm.

Despite the use of radiation dose reduction software (CARE Dose-4D) for this type of scanner, the DLP was significantly higher than the NRD values. This can be explained by a lack of training of our technicians, whether for acquisition techniques, with inclusion in the field of exploration of anatomical areas not interested in the desired study, or radiation protection rules for the patient.

5. Conclusions

The improvement of the scanning practice requires, first of all, a good knowledge of the fundamental principles of radiation protection applied to the medical field: the justification of the clinical indication and the choice of the radiological examination, optimization by informed management acquisition parameters to achieve the compromise between lower dose of irradiation and better image quality, known by the acronym "ALARA" (As Low As Reasonably Achievable) and finally substitution when the limitation is not beneficial to the patient.

In Senegal, it would be useful to introduce legislation that requires an assessment of the radiation doses delivered to patients during diagnosis and interventional radiological examinations against national reference values. These evaluations would be periodic and monitored and corrective actions would be imposed as needed.

The transposition of the dosimetric record in our reports should be compulsory. Relevant information is DLP for any exposure and CTDIvol for pelvic exposures in women of childbearing age and in pregnant women after justified exposure.

The initial and continuing training in radiation protection of the various stakeholders must be an ethical or even legal obligation.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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