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Influence Of Image Quality On Dose Optimization In Conventional Radiology

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Abstract

The dose entering the skin (De) is the main parameter used to determine the irradiation that a patient receives during a radiodiagnostic examination. The dose entering the skin depends on parameters such as the charge (mAs), the tube voltage (kV), the focus-film distance (DFF), the focus-skin distance (DFP). Thus the objective of our work is to reduce as much as possible the dose at the entrance of the skin while taking into account the quality of the resulting image. This was done through the determination of the De of four (4) anatomical regions explored, the comparison of these doses obtained with the international diagnostic reference levels (NRD) adopted in Cameroon, then the comparison of the images obtained according to the dose at the entrance of the skin used. We conducted a prospective study over a period of five (5) months from May 24 to September 15, 2017 in the imaging department of the Garoua Regional Hospital (HRG). The data used come from 459 adult patients with a mass between 50 and 90 kg. The evaluation of the dose at the entrance to the skin of the patients was done through the Davies model and the determination of the quality of the image using the Michelson process and the Davies model, then the calculations of the 75th percentiles of the dose at the entrance and the analysis and processing of the data was done by Excel 2010 and Sphinx version 4.0. The doses at the entrance to the skin obtained in mGy were respectively 5.05 ± 0.4 for the thorax, 13.84 ± 0.5 for the pelvis, 21.00 ± 5.1 and 149.18 ±9.9 for AP and lateral views of the lumbar spine, 17.85 ± 2.5 for AP views / 10.52 ± 0.9 for skull profile. This study led us to understand that the 75ths the dose at the entrance to the skin varies very little with the DFF / DFP ratio (the value 1 which translates the absence of blur) and rather we obtain a maximum contrast with the values elevated by 75ths of the dose on the surface of the skin. The maximum contrast represents the visibility of each pixel in black and white, whereas with a small value of 75ths of the dose to the skin, the contrast is zero. The result of all these variations is that the quality of the image remains clinically diagnostic according to the values considered in our study.

Introduction:

Since the discovery by physicist Wilhelm C. Roentgen in 1895, X-rays have been used in medicine for diagnostic and therapeutic purposes. This discovery has fostered the development of several sectors such as magnetic resonance imaging, interventional imaging, angiography, scanner, conventional radiology, etc. Despite these innovations, conventional radiology occupies a place of choice in the treatment of certain pathologies. In France, 63% of radiographic procedures performed are standard radiology examinations estimated on a population of 74.6 million, whereas CT scans represent only 10.1% of procedures in this population (Maccia et al, 1990). Radiological examinations using ionizing radiation (IR) are irradiating. This is why the board of directors of Euratom 97/43 will recommend the protection of people against ionizing radiation for medical purposes in June 1997. Still in this momentum the International Atomic Energy Agency (IAEA, 2016) will emphasize the principle of optimization of radiation protection in radiology. However, it seems important to protect the patient while ensuring the quality of the diagnostic image. According to the 1987 survey (European Communities, 1999), image quality depends on the dose administered to patients during examinations, the ionization field and several other parameters. The quality of the image also depends on the measurement of the dose at the entrance, the details relating to the radiological equipment and the technical factors used (Maccia, 1997). In Cameroon, the National Radiation Protection Agency (ANRP) is responsible for ensuring the protection of people and the environment against ionizing radiation (IR), whether of natural or artificial origin. Thus since October 2002 (ANRP in Cameroon), several works have been carried out in conventional radiology on the radiation protection of personnel (Ongolo et al, 2011), on pediatric radiology (Mbo et al, 2015) but no study has further demonstrated the relationship between dose optimization and image quality. This is why this work will allow us to evaluate the minimum dose received by a patient allowing us to have a usable image. To achieve this, we will proceed to the enumeration of the dosimetric parameters intended for the evaluation of the quality of the radiological images, then to the determination of the optimal dose received by the patient after variation of the dosimetric criteria and finally to establish a comparison of the results of the 75th percentiles at DRLs. So to provide answers to these concerns we will present the generalities on X-rays; details on image quality and dosimetry in the literature review; the study setting and methods for determining the dose in the methodology; as results we will present the numerical values of the variation of the dose at the entrance (De) according to the dosimetric parameters. At the end we will discuss these different data obtained by calculation.

1-General objective

-Evaluate the minimum dose received by a patient to obtain a usable image.

2-Specific objectives

-List the dosimetric parameters intended for the evaluation of the quality of radiological images,

-Determine the optimal dose received by the patient after variation of the dosimetric criteria,

-Establish a comparison of the results of the 75th percentiles to the DRLs.

Materials and methods

Target population

Any adult aged 21 to 90 received for a standard X-ray examination at the Radiology Department of the Garoua Regional Hospital was considered. Inclusion criteria; Any adult over 20 years old and weighing between 50 and 90 kg received for an examination of the thorax, skull, pelvis or lumbar spine in the department consenting to the study was included. Also included were images with good contrast and sharpness and the DFF/DFP ratio. Exclusion criteria; were not excluded any patient with little information (age, weight etc.), pregnant women, and we excluded images with poor sharpness. Sampling is non-probability; the 547 patients were randomly selected

Data collection technique

We started by consulting the exam reports, checking if the age, sex and weight were marked there and then seeing the exam request; complete the notebook and questionnaire sheet relating to the device and the patient; choose parameters relating to the requested examination. Finally position the patient then launch the automatic exposure after sufficient heating of the tube. After patient exposure, the dosimetric (tube voltage, load) and geometric (DFF(m) and DFP(m)) parameters were recorded as the patient's number increased; store the image obtained in a support taking into account the marking of the patient's identity and the date of the said examination. Finally assist in the interpretation of the pictures; conclude whether the image is of good quality or poor quality.

It should be noted that the basic accuracy of the parameters displayed before exposure on the console is (3%, +2 kV) for the kilovoltage; (10%, +0.2mAs) for load; (15%) for milliamperes; (10%, +1ms) for milliseconds.

Dose determination methods: Davies model

According to Davies, the calculation of the dose at the entrance to the skin must integrate technical parameters directly involved in carrying out the examination. For this purpose, the dose entering the skin would be a function of (Davies, 1997)

- The yield of the O x-ray tube (mR): This is one of the main characteristics of the installation. If the maximum voltage at the terminals of the tube is high, the better the production of the quantity of R_X because it acts on the quantity of electrons produced, therefore the Bremsstralhung will be higher, this would lead to a very energetic production of the RX. We could also obtain images at low doses.

-The dose at the entrance to the skin is directly a function of the voltage at the terminals of the tube U (kV) quantity because it causes a strong acceleration of the electrons consequently Bremsstralhung.

- The increase in charges Q (mAs) leads to an increase in the dose at the entrance to the skin and conditions the quality of the radiological image. However, according to the International Atomic Energy Agency (IAEA, 2016), by convention, the scattered radiation factor BSF is set at 1.35 in adults and 1.30 in children.

The Davies model is represented by this equation

$$\mathrm{D_e} = \mathrm{O(mR)}\left(\frac{\mathrm{U}}{80}\right)^2 \mathrm{Q}\left(\frac{100}{DFP}\right)^2 \ \mathrm{BSF}$$

Or

D_e (mGy), the dose entering the skin;

O (mR) (mGy/mAs), the power (output) of the X-ray tube, at 80kV for a distance fixed at 100cm for 10mAs, O=0.29 mGy / mAs

U (kV), the voltage applied to the tube for carrying out the examination;

Q (mAs), the charge passing through the tube;

DFP (cm), distance-focus-skin and

BSF, the radiation backscatter factor. Under this formula, it is equal to 1.35 for adults.

II.4.2- Image quality assessment methods

Contrast determination

In the particular case of a black and white image:

- For zero contrast, the observed image is entirely gray (C=0)

- For maximum contrast, each pixel in the image is either black or white (C=1)

Thus according to Michelson the global contrast is defined by (Rachida, 2015)

$$C = \frac{L_{max} - L_{min}}{L_{max} + L_{min}} = \frac{I_{max} - I_{min}}{I_{max} + I_{min}}$$

Where L denotes the luminance and I the luminous intensity. This Michelson contrast is between 0 and 1.

According to the Davies model;

Image quality is highly dependent on Distance-Focus-Patient (DFP) and Distance-Focus-Film (DFF):

- Thus for $\frac{\mathrm{DFF}}{\mathrm{DFP}} < 1$, the image is of good quality.

-And for $\frac{\mathrm{DFF}}{\mathrm{DFP}} = 1$, no blur but the size of the focal point causes a geometric blur (darkness) when the film moves away from the object.

Results

we conducted our study on four types of radiology examinations.It is noted that the examination of the thorax is carried out the most with 48% and patients whose age is between 21-30 years are in the majority, i.e. 11%; follow-up of patients coming for the lumbar spine with 39%.

-The distribution of the 75th percentiles of the dose entering the skin of the thorax in mGy (5.05 ± 0.4) in postero-anterior incidence.

- The ratio (De Min / De Max) of the lumbosacral spine in frontal view is 0.71 and in profile this value is 0.13. Table 16 presents the 75th percentiles (17.85±2.6) in postero-anterior incidence of the skull and (10.52±0.9 for the profile of the skull; The 75th percentiles of the lumbosacral spine is (21.00±5.1) for the anteroposterior face and (149.18±9.9) for the profile.

- The pelvis ratio in antero-posterior incidence presented in table 18 is 0.15. While the value of the 75th percentiles in table 20 is (13.84±0.5)

Table 1:Determination of contrast and geometry according to the radiological parameters of the thorax

Dose differences	luminescence intensity		geometry parameter		contrast	spatial resolution
	I_{min}	I_{max}	DFF	DFP	C	DFF/DFP
D_{max}	16	32	1,85	1,60	0,3	1,1
D_{min}	0	16	1,50	1,22	1	1,2
D_{moy}	0	25	1,67	1,41	1	1,1

For all the loads present in table 1 the values of DFF/DFP tend towards 1. The contrast of the minimum and average loads converges towards 1 whereas for the maximum load this value tends towards 0.

Table 2: Determination of contrast and geometry of the neurological system according to radiological parameters

Dose differences		luminescence intensity		geometry parameter		contrast	spatial resolution
		I_{min}	I_{max}	DFF	DFP	C	DFF/DFP
Crane	D min	0	400	1,0	0,64	1	1,5
	D m	0	400	1,07	0,75	1	1,4

	D max	400	400	1,15	0,87	0	1,3
SL F	D min	0	320	1,0	0,65	1	1,5
	D m	0	320	1,12	0,72	1	1,5
	D max	320	400	1,25	0,80	0,1	1,5
SL P	D min	0	250	1,0	0,65	1	1,5
	D m	0	400	1,12	0,72	1	1,5
	D max	250	200	1,25	0,80	-0,1	1,5

For all the loads present in table 2, the DFF/DFP values tend towards 1. The contrast of the minimum and average loads converges towards 1 while for the maximum loads for the skull and the lumbosacral spine tend towards 0.

Table 3: determination of contrast and geometry according to the radiological parameters of the pelvis

Dose differences		**luminescence intensity**		**geometry parameter**		**contrast**	**spatial resolution**
		I_{min}	I_{max}	DFF	DFP	C	DFF/DFP
Bassin	D_{min}	0	400	1,07	0,76	1	1,4
	D_{moY}	0	320	1,08	0,84	1	1,2
	D_{max}	400	320	1,10	0,92	0,1	1,2

Dm= average distance, Dmin= minimum distance and Dmax the maximum distance.

For all the loads present in table 23, the values of DFF/DFP tend towards 1. The contrast of the minimum and average loads converges towards 1, whereas for the maximum load, this value tends towards 0.

Discussion

Table 1 presents the thoracic region, in fact the determination of the quality of the image depends on its geometry (the special resolution), noise and contrast; this forming the criteria of an objective method. The subjective method, in addition to being common, depends on the visual perception and the training of the observer, it allows the estimation of the intrinsic characteristics of the collected image (SFC, 2015).

Here the determination of the image varies according to the DFF (m) and the DFP (m); at a DFF=1.67 m and a DFP=1.41, the DFF/DFP ratio tends towards 1. For a DFF=1.85m and a DFP=1.60m, the DFF/DFP ratio always tends towards 1. So we see that for all the values of DFF and DFP used, the DFF/DFP ratio tends towards 1, which provides information on the absence of blurring of the image according to the Davies model (Davies, 1997).

The contrast here is a function of the luminescence intensity which is closely linked to the charge considered. For the values of I_max=25mA and I_min=0 according to Michelson's formula

C=(I_max-I_min)/(I_max+I_min)=1. The contrast is also equal to 1 for I_max=16mA and I_min=0. Whereas for I_max=32mA and I_min=16mA, the contrast tends towards 0.

We can see that for the minimum (16mA) and average (25mA) values of Imax, the contrast gives 1, which is considered as a maximum contrast where each pixel of the image is either black or white. With an I_min=32mA and an I_min=16mA, the contrast tends towards 0, the value of zero contrast with an entirely gray image (Rachida, 2015).

In Table 2,In the cranial region as elsewhere the determination of the image varies according to the DFF (m) and the DFP (m). For all the different respective values of DFF let 1.0; 1.07 and 1.15m for the different DFP values (0.64; 0.75 and 0.87), the DFF/DFP ratio tends towards 1.

So we see that for all the values of DFF and DFP used, the DFF/DFP ratio tends towards 1, which informs about the absence of blurring of the image according to the Davies model (Davies, 1997).

The contrast is a function of the luminescence intensity which is closely linked to the charge considered. For the values of I_max=400mA and I_min=0 according to the Michelson formula

C=(I_max-I_min)/(I_max+I_min)=1, Whereas for I_max=400mA and I_min=400mA, the contrast tends towards 0 with an entirely gray image.

In Table 3, the geometry of the basin determined in this part shows that all the DFF/DFP ratios tend towards 1, which defines the obtaining of an image without geometry blur.

The contrast reveals that for the values I_min=0mA and I_max=400 and 320 mA we have a maximum value for the contrast while this value tends to 0 for I_max=320 mA and I_min=400 mA

For a value of 0.45mGy, the 75th percentiles of the dose at the entry surface of the skin of the thoracic region, the contrast is maximum with a black and white image (1); whereas for the value of 0.8 mGy as the 75th percentile of the dose at the entrance surface of the skin of the thorax, the contrast becomes zero with an image entirely in gray.

We can conclude that the greater the 75th percentiles of an anatomical region, the more the image tends towards maximum contrast. According to Kwong et al. (2008), the quality of the image produced by a constant tube voltage and a variable current intensity in the presence of a filter gives significant differences in terms of images for the shots of the same field of view, but no clinically significant difference in terms of diagnostic quality of the images.

The DFF/DFP ratio tends towards 1 for all the values of DFF and DFP considered. It appears that the geometric parameters (DFF, DFP) of the image vary very little whatever the values of DFF and DFP and this ratio depends very little on the variation of the 75th percentiles of the dose at the entry surface of the skin. . Kwong et al (2008), also concluded that tube voltage, geometric parameters and milliamperage did not affect the overall diagnostic quality of the image.

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