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Research Article

Optimization of Conventional Radiology Doses During Adults Chests Examinations

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Abstract

The aim of this work is the implementation of an optimization process for the doses delivered to patients during frontal chest exams. The study was conducted at the clinic call Polyclinic of Deux Plateaux and involved 300 patients for the chest exam. For each patient exposed to X-ray, we recorded the exposure parameters (kV, mAs, focus-film distance), when the radiological images were acceptable for diagnosis. Then, the entrance dose (De) for each patient and the Dose-Area Product (DAP) using a formula has been calculated. The optimization processes involved modifying the exposure parameters (kV and mAs) while ensuring an acceptable image quality for diagnosis and a second dosimetric evaluation was done in the same manner as before. The median of the distribution of De and the DAP are respectively 0.60 mGy and 613.80 mGy.cm^2 with 112.12 kV and 6 mAs. After optimization, the results were 0.28 mGy and 286.31 mGy.cm^2 with 115 kV and 3.19 mAs. We observe that the medians of De and DAP have been approximately halved. This study has enabled a significant reduction in doses for the frontal chest exam performed in adults simply by acting on exposure parameters. The quality of the radiological images was maintained at a level allowing the examination to be carried out and interpreted.

Keywords

Optimization, Evaluation, DRL, Frontal, Chest, DAP, De

1. Introduction

To protect patients exposed to ionising radiation in radiodiagnostics, the ICRP recommends that Diagnostic Reference Levels (DRLs) be established for procedures where radiation protection is an issue. These include the most frequent and/or most irradiating procedures [1].

Numerous studies have shown that, thanks to DRLs, the doses delivered to patients during diagnostic and interventional medical procedures have been reduced while guaranteeing better image quality [2-4].

In Côte d'Ivoire, the DRLs have been defined at national level for conventional radiology by Issa Konaté and al [5] for frontal thorax and frontal lumbar spine examinations and are

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based on the distribution of dosimetry magnitudes of dose to the entrance surface (De) and Dose-Area Product (DAP) [6].

The aim of our study is to evaluate and optimize the doses delivered during frontal chest examinations in the conventional radiology department of the Polyclinic of Deux Plateaux in Abidjan. This is done by analytically determining the De and DAP doses [7, 8] for the examination studied and the median of each of these dosimetry quantities. The median is then compared with the national DRL for De and DAP [9].

The final objective is to set up an optimized protocol that provides the best possible dose for the patient.

2. Materials and Methods

2.1. Materials

Our study was conducted in the conventional radiology room of the Polyclinic of Deux Plateaux (P2P). The radiological device of the General Electric brand consists of a remote-controlled radiological table, equipped with an X-ray tube, a detector (screen-film couple), and a generator that operates at high frequency and can deliver a maximum voltage of 150 kV, and an acquisition console to set technical parameters such as voltage in kV, charge in mAs, and current intensity in mA. This device was installed in 2013. It includes, an image viewing console (VisionPACS), an image digitization console, a FUJUFILM type digitizer, and a RICOH brand printer.

2.2. Method

Within the framework of our study, an examination was evaluated: the adult frontal chest. The choice of this examination is based on its high frequency and the consideration of existing national diagnostic reference levels (DRL) [6] for this examination. Initially, 300 chest frontal exams [10] were recorded over a period of 7 months. After each examination, the operator in charge of the examination notes the acquisition parameters of the examination on a recording sheet that we have developed for this purpose. These parameters are the voltage, the charge, and the focus-skin distance (FSD) used for the examination. From these sheets, we enter the data into a standardized Excel spreadsheet. For chest exams, the irradiation area is 1522.2 cm^2, corresponding to the screen-film pair measuring 43.0 cm x 35.4 cm. For each patient, the De and the DAP have been calculated using formulas (I and II) then we determined the median entrance doses of the patient (Dem) and median Product Dose –Area (DAPm) and compared them to the DRL [6]. Subsequently, these results were presented to the operators and radiologists of the P2P radiology department, in order to optimize the dose delivered to patients. With the radiology department team, we implemented corrective actions by reducing the dose while ensuring that image quality is not compromised. These actions involved modifying acquisition parameters such as voltage and charge [11]. The realization of these exams with these new acquisition parameters was called the optimized protocol. Then, the study recorded again 100 frontal chest exams, including 50 exams with the first protocol called the initial protocol, and 50 other chest exams with the optimized protocol. The Dem and DAPm of each protocol were evaluated and compared to each other to verify the impact of the approach.

2.2.1. Calculation of the Entrance Doses (De) to the Patient

The study determined the De from the exposure parameters, applying formula (1). In the absence of knowledge of the constant C, specific to the radiological installation, a standard value for high-frequency generators can be taken as C = 0.1 mGy m^2/mAs [12]. The backscatter factor F is 1.5, considering the size of the field at the entrance surface [13, 14].

$$De=C*(U/100)^2*Q* 1/r^2 *F \qquad (1)$$

With:

De: Dose at the patient's entrance surface in mGy

C: Local constant characteristic of the radiological installation in mGy m^2/mAs

U: Voltage in kV

Q: Charge in mAs

r: Focus-skin distance in m

F: backscatter factor

2.2.2. Determination of Dose - Area Products (DAP)

The Dose-Area Products (DAP) were determined using formula (II) based on the entrance doses De calculated and the irradiation area S, expressed in cm^2. As patient backscatter is not included in DAP, the associated correction is applied.

$$DAP = (De \times S) / BSF \qquad (2)$$

3. Results

3.1. Initial Protocol: First Analysis from February to August 2023 (7 Months)

In total, 300 standard patient data for adult frontal chest were analyzed. The median of the entrance dose (De) distribution and the Dose-Area Product (DAP) was established, and the results obtained are 0.60 mGy and 613.80 mGy.cm^2, respectively.

In Table 1 the DRL, the median of the examination evaluated in our study, and the positioning of the median in relation to the current DRL (% DRL) are presented.

Table 1. *Main statistical data of adult frontal chest exams.*

Evaluated exams	De (mGy)			DAP (mGy.cm^2)		
	DRL	median	%DRL	DRL	median	% DRL
Frontal chest	0.28	0.60	114.28%	574.7	613.80	12.06%

De: Entrance Dose; DAP: Dose-Area Product

3.2. Optimized Protocol: Second Analysis September 2023 (1 Month)

In total, 100 frontal chest exams were evaluated, including 50 patients with the initial protocol and 50 other patients with the optimized protocol. Figure 1 presents a comparison of the entrance doses to the patient between the initial protocol and the optimized protocol.

The average voltages and average charges used for the frontal chest exams with the initial protocol and the optimized protocol are presented in Table 2. The synthesis of the results of the data analysis of conventional radiology exams of the adult frontal chest, expressed in terms of entrance dose (De) and surface dose product (PDS) with the optimized protocol are presented in Table 3.

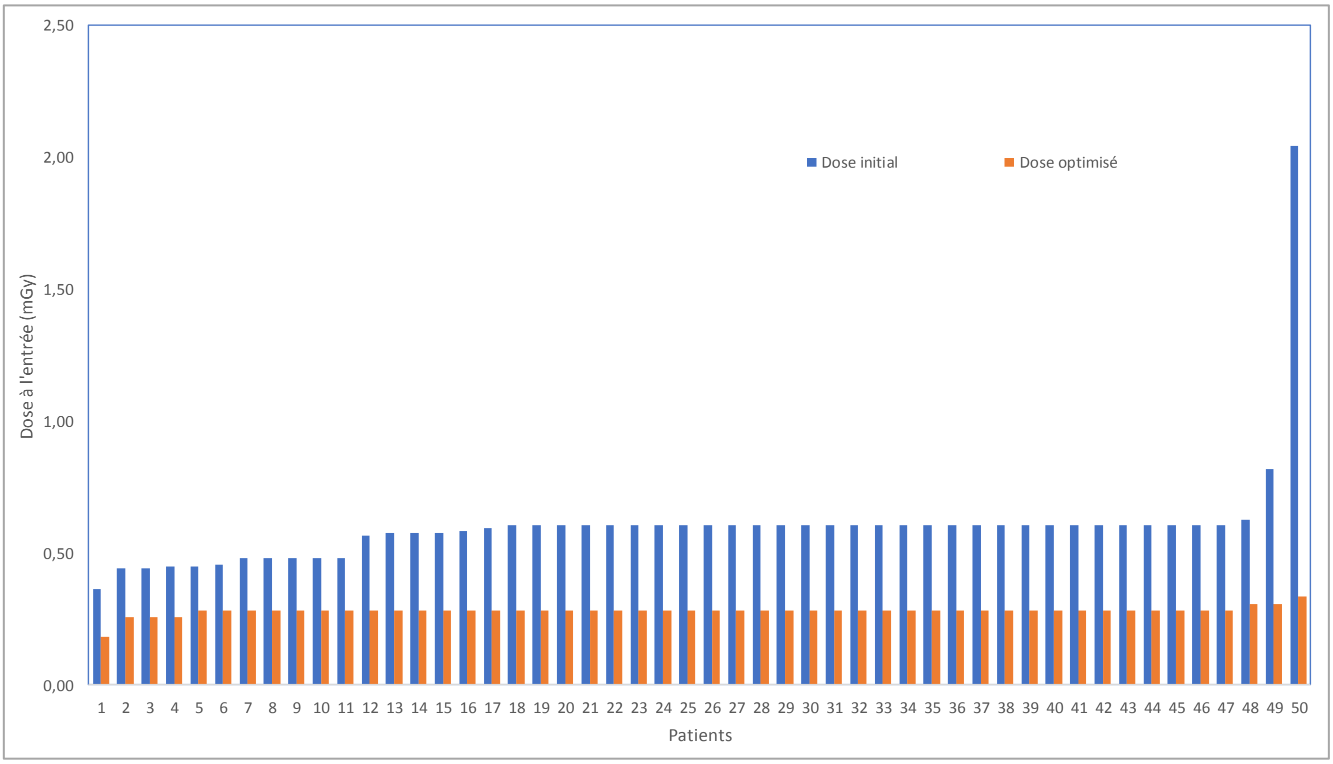

Figure 1. *Comparison of doses at patient entry between the initial protocol and the protocol Optimized for chest examination.*

Table 2. *Average voltage and load values.*

Initial protocol			Optimized protocol	
exam	High voltage (kV)	Charges (mAs)	High voltage (kV)	Charges (mAs)
Frontal chest	112.12	6	115	3.19

The average values of high voltages and charges were obtained considering 50 patients per protocol. These voltage values are taken when the image obtained allowed the diagnosis to be made.

Table 3. *Results of dosimetric evaluations of examinations in terms of De and DAP of the optimized protocol.*

exam	De (mGy)			DAP (mGy.cm^2)		
	DRL	median	%DRL	DRL	median	%DRL
Frontal chest	0.28	0.28	0%	574.7	286.31	-50.20%

4. Discussion

In the context of optimizing doses delivered to patients in conventional radiology, comparing the median to the DRLs published by the national study [6], the result showed that the median values of the entrance dose (De) and Dose-Area product (DAP) distributions for the chest are higher than the proposed national DRLs. Hence, there is a need to take corrective measures to optimize radiological practices [15].

Only parameters such as voltage (kV), charge (mAs), and focus-skin distance (DFP) were accessible to the medical imaging technician. For this study, and after discussions with medical imaging technicians and radiologists, the optimization focused on modifying the voltage and charge. Thus, for the frontal chest, the average voltage increased from 112.12 kV to 115 kV, and the average charge decreased from 5 mAs to 3.19 mAs after optimization. This is an increase in voltage of about 2.6% and a decrease in charge of 36.2%. These results confirm the compromise of the kV/mAs couple to adapt to have a quality image, allowing practitioners to make a diagnosis. Increasing the energy of X-ray radiation by using sufficient high voltages (kV) and decreasing the amounts of radiation by reducing charges (mAs) allowed, on one hand, to have a more penetrating beam, and on the other hand, to reduce the patient's entrance exposure. Indeed, in our study, we went from 0.60 mGy to 0.28 mGy, a reduction of about 53% (see tables 1 and 3) of the entrance dose for frontal chest procedures. Moreover, comparing our study's initial protocol with the national DRL value, there is an increase in dose of 114.28% for the frontal chest (see table 1). Note that the entrance dose of the optimized frontal chest protocol is equal to the national DRL, 0.28 mGy (see table 3). With the initial protocol, there is a significant variability in the doses delivered for the same diagnostic objective (figure 1, histogram in blue). Using standardized protocols in radiology, practices become uniform, and radiation doses remain under recommended levels, illustrated by figure 1.

Furthermore, knowledge of the Dose-Area Product (DAP) provides a dosimetric indication to the patient's skin. It is indeed the recommended dosimetric quantity in conventional radiology [16, 17]. The DAP also allows for an approximate value of the effective dose E (mSv), which is a risk indicator. The analysis of the dosimetric evaluation of DAP after modifying the voltage and charge shows that we have a dosimetric gain compared to the national DRL of DAP by a factor of 2. Comparing the initial protocol and the optimized protocol, we note a dosimetric gain by a factor of 2.2.

In general, whether with the entrance dose of the patient or the Dose-Area Product, this study revealed that radiographic exams of the frontal chest at the Polyclinic of Deux Plateaux were performed with higher doses compared to the available national data [6]. This can also be explained by the mode used to perform this examination in adults. Indeed, with this mode, it is impossible to adjust the diaphragm to the irradiation surface because the diaphragm automatically displays and conforms to the surface of the screen-film couple. This necessarily leads to a larger exposure area and thus a higher Dose-Area Product. Among the parameters influencing the dose received by the patient, the reduction of the diaphragm is not accessible to the operator for this installation. It is therefore appropriate to use the accessible parameters such as charge, voltage, and focus-skin distance in the optimization process to ensure the required image quality with a minimal dose of X-rays.

5. Conclusion

The optimization process is not the responsibility of a single person. By working together, conducting a dosimetric study, and changing certain acquisition parameters such as voltage and charge, we have managed to reduce the doses of X-rays used and to come back under the indicator defined by the national DRLs. This study allowed for a significant reduction in the De by 53% and a dosimetric gain of DAP with a factor of 2.2 for frontal chest exams in adults with acceptable image quality. This work proves that medical imaging technicians can reduce the dose received by patients by acting only on the voltage and load they choose to perform the examination. It must be continued in all standard radiology rooms with a view to giving good examination practices to practitioners to optimize the doses received by patients.

Abbreviations

kV	kilovoltage
mAs	milliampère seconde
De	Entrance Dose
DAP	Dose Area Product
DRL	Diagnostic Reference Level
mGy	milli Gray
mGy.cm^2	milligray square centimeter
ICRP	International Commission of Radiation Protection
P2P	Polyclinic of Deux Plateaux

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Author Contributions

Ouattara Tofangui Alain: Conceptualization, Writing, Ressources
Koua Aka Antonin: Supervision
Konate Issa: Investigation, Methodology
Oka N'Guessan Guy Leopold: Formal Analysis
Dossa Gerald: Data Curation
Gnahore Gbo Firmin: Software

Conflicts of Interest

The authors declare no conflicts of interest.

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Biography

Konate Issa is an assistant professor and lecturer at University Félix Houphouët Boigny (UFHB) of Abidjan, Sciences of Structure of Matter and Technology (SSMT) Training and Research Unit. He is a permanent member of the Physics Department, Laboratory of Sciences of Matter, Environment and Solar Energy, Nuclear Energy and Radiation Protection team. He acquired his Doctorate in Nuclear Physics from University of Abidjan (now UFHB) in 2018. Since 2019, he is teaching different courses (Nuclear Physics, mechanic, electricity etc.) at UFHB. He is actually an Associate Professor, and he's been the advisor of many students during their Master of Nuclear Sciences and Techniques in the same institution in Côte d'Ivoire. He is the author of several publications in different research fields.

Oka N'Guessan Guy Leopold is a nuclear physicist by training and a Qualified Expert in Radiation Protection. He is currently the Deputy Director of Nuclear Safety and Security of the Radiation Protection, Nuclear Safety and Security Authority (ARSN, Regulatory Body for Nuclear Safety and Security of Côte d'Ivoire) and Sworn Inspector of ARSN. He is also a Research Associate at the Laboratory of Nuclear Energy and Radiation Protection of the Institute for Research on New Energies of the University of Nangui-Abrogoua. He was Head of Radiation Protection Services at the Sub-Directorate of Protection against Ionizing Radiation (SDPRI) of the National Public Health Laboratory (LNSP) from 2002 to 2008 and then Manager of the "Radiation Protection and Environment Consulting" consultancy from 2009 to 2013.

Koua Aka Antonin is a teacher-researcher professor specializing in nuclear physics and radiation protection at the Félix Houphouët Boigny university of cocody in abidjan, côte d'ivoire. He is the director of radiation protection at the french radiation protection authority for nuclear safety and security in côte d'ivoire. He has published several scientific articles in several journals in the field of nuclear physics.

Ouattara Tofangui Alain is a medical physicist by training. He worked as a medical physicist at the National Center for Radiotherapy and Medical Oncology (CNRAO) from 2020 to 2021. He was head of the department in charge of dosimetry at the French Nuclear Protection, Safety and Security Authority (ARSN, Nuclear Safety and Security Regulatory Body of Côte d'Ivoire) from 2022 to 2024. He obtained his master's degree in medical physics at the University of Tours (France) in 2016. Since 2020, he has been teaching the radiotherapy course at the National Institute for the Training of Health Workers (INFAS). He is currently a PhD student in physics at the University Félix Houphouët Boigny (UFHB) in Abidjan, Training and Research Unit in Structural Sciences, Matter and Technology (SSMT).

Dossa Gerald is a radiologist and head of the radiology department at the Polyclinique des Deux Plateaux. He is head of the medical imaging competence division within the Novamed group, which includes 6 clinics spread between Abidjan, San-Pedro, Bouaké and Ouagadougou. He is a member of the Ivorian Society of Medical Imaging (SIIM), the Radiology Society of Francophone Black Africa (SRANF) and the French Society of Radiology (SFR). He obtained his doctorate in medicine at the University of Abidjan (now UFHB) in 2006, then his diploma of specialized studies in Medical Imaging and Radiology in 2016. He holds a diploma of medical training specialized in medical imaging at Paris V (DFMS – Pierre and Marie Curie) and a university diploma (DU) in whole-body MRI at Paris Descartes He has completed several internships in various hospitals in Paris including KLEMLIN BICETRE, COCHIN and INSTITUT CURIE. He is the author of several publications in different fields of Radiology Research. Award of best poster in 2013 at the SRANF Radiology Congress in Brazzaville

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