Konan A, et al., J Nucl Med Radiol Radiat Ther 2017, 2: 008
DOI: 10.24966/NMRR-7419/100008

HSOA Journal of
Nuclear Medicine, Radiology & Radiation Therapy

Commentary

X-Ray Tubes Quality Control in the Optimization of Doses to Patients and Personnel in Conventional Radiology

Anhum Konan[1*], Idrissa Garba[1], Olivier Tra-Bi[1], Firmin Inago[2], Alionou Schécheou[1], Abdoulaye Touré[1], Ali Coulibaly[1], N'goranKouamé[1] and Anne-marieN'goan-Domoua[1]

[1]*Department of Radiology, Yopougon University hospital, Abidjan, Ivory Coast*

[2]*National Institute for Training of Health Workers of Abidjan, Ivory Coast*

Abstract

Objective: To report the place of the quality control of X-ray tubes in the search for optimization of doses delivered by these installations.

Materials and methods: Descriptive cross-sectional study carried out in the imaging departments of the Yopougon, Cocody and Treichville teaching centers in Abidjan from 06/15/2011 to 08/15/2011. All conventional radiology equipment of the various university hospitals, in working order during the study period, was surveyed. The quality control of the X-ray tubes concerned the technical characteristics of the acquisition and the quality of the radiation by alignment, collimation, linearity, accuracy, reproducibility and tube tension as well as focal spot and homogeneity of the x-ray beam. The means of evaluation were a RMI Beam model 162 A, a RMI Collimator model 161 B, a DIAVOLT Universal type 43014, a PTW-DensiX densitometer and a Focal test tool model 162 A. Tension and accuracy were measured and values compared to those displayed by the manufacturer. All other parameters have been compared with current international standards. These results were related to the age of the installations and the duration of activity.

Results: 4 posts were in operation during the study period. Post office 1 of the emergency department of Yopougon University Hospital and posts 2, 3 and 4 respectively of the outpatient clinics, the 3rd floor and the remote control room of Cocody University Hospital. The calibration of the devices, carried out by the vendor, deemed them to comply with European standards of functionality. None of the quality parameters of the emitted radiation were checked after the devices was switched on. The tubes displayed maximum voltages of 150 kilovolts (kV). Post 3, was the oldest at the time of the study with 14 years of age and 12 years of activity. The other items (1, 2 and 4) were respectively 3 years, 4 years, and 8 years of age and 2 years, 4 years and 3 years of activity. With the following parameters, 80 kilovolts (kV), 250 milliamperes second (mAs), 50 milliseconds (ms) and 100 centimeters (cm) focal-film distance, the three stations aged four years and older had failures related to the reproducibility of the current voltage across the tube. The one with the greatest number of years of activity (12 years) had, in addition, a lack of precision in tension and alignment of the X-ray beam. On the other hand, for the other two, a linearity defect of the x-ray beam was observed, with a dose delivered below the expected dose values when amperage was less than 250 milliamperes (mA).

Conclusion: Our study demonstrates the value of X-ray tube quality control for radioprotection in conventional radiology. In this way, the oldest installations will present, failures related to the reproducibility of the current voltage across the tub, lack of precision in tension and alignment of the X-ray beam and linearity defect of the x-ray beam. Failures increases with the duration of activity. All these things contribute to an excessive radiation exposure by increasing the scattered radiation and to the deterioration of the contrast and the resolution of the photographs responsible for many times.

Keywords: Optimization of doses; X-ray tubes control

***Corresponding author:** Anhum Konan, Department of Radiology, Yopougon University hospital, Abidjan, Ivory Coast, 21 BP 632 Tel: +225 08 328045; E-mail: anhum_konan@yahoo.fr

Citation: Konan A, Garba I, Tra-Bi O, Inago F, Schécheou A, et al. (2017) X-Ray Tubes Quality Control in the Optimization of Doses to Patients and Personnel in Conventional Radiology. J Nucl Med Radiol Radiat Ther 2: 008.

Received: May 26, 2017; **Accepted:** August 08, 2017; **Published:** August 25, 2017

Introduction

The use of X-rays, for medical purposes contributes to the increase of human exposure to ionizing radiation. Maintaining human exposures in radiology, as low as reasonably achievable, taking social and economic factors into account, without altering the quality of the images is a challenge of radiation protection [1-5]. This desire to optimize doses to professionals and patients is dependent on human and material factors. The acquired physical facilities must allow the production of an image of sufficient quality to constantly show the appropriate diagnostic information at the lowest possible cost and with minimum irradiation of the patient and the staff. We report, through this work the failures of radiological facilities due to age and inadequate maintenance and their implications for the optimization of doses delivered in the radiology departments of the Abidjan University Hospitals.

Materials and methods

We conducted a prospective cross-sectional descriptive study in the radiology departments of the three University hospitals in Abidjan, representing the highest reference level of the health pyramid in Ivory Coast. It took place over a period of eight weeks from 06/15/2011 to 08/15/2011. The survey covered all the conventional radiology equipment of the various University Hospitals. The devices in working condition used for the production of X-rays during the study period were selected. Facilities not used and those used for purposes other than conventional radiology at the time of the survey were not included in the study. We are interested in the quality control of the X-ray tubes of these different installations. The investigation concerned the periodicity of the checks, the evaluation of the technical characteristics of the X-ray tubes, and the quality of X-ray emitted.

Measurements and controls were carried out by equipment supplied by the national public health laboratory. It was about RMI Beam alignment test tool model 162 A for alignment of the x-ray beam, RMI Collimator test tool model 161 B for the collimation of X-ray beams, DIAVOLT Universal type 43014 for linearity, accuracy and reproducibility of the X-ray tube, PTW-DensiX densitometer for homogeneity of the X-ray beam and Focal test tool model 162 A for focal spot size.

Quality of X-ray beam includes the following elements:

Alignment of the X-ray beam is evaluated by the concordance between the light and the X-ray beam and by orthogonality of X-ray beam and the image receptor through the calculation of the angle between the central axis of the X-ray beam and the image receptor plane.

Automatic collimation of the X-ray beam measured by the deviation of the X-ray beam from the focus-image receptor distance, on any side of the image receiver.

Linearity of the X-ray tube evaluated by the coefficient of proportionality between the dose delivered by the X-ray radiation and the intensity of the current at the control console.

Accuracy of the X-ray tube appreciated, in the case of repeated measurements, by the deviation of the tube voltage and the actual exposure times from the displayed values.

Reproducibility of the X-ray tube evaluated by the constant tension of the tube, the dose of irradiation and the exposure time. Here, we measured the deviations of voltage, exposure time and irradiation dose from the mean for identical repeated exposures with a given filtration. The standard parameters used were: 80 kV, 250mAs, 50ms and 100cm focal-film distance.

Focal spot showed limits of detestability of high contrast anatomical structures. Using a magnifying glass, different images, obtained with standard parameters, were examined for groups and the number of bars per group. The parameters used were 60 kV, 3.6mAs, 60cm distance between focus and film and a light field of 34mm x 34mm.

Homogeneity of the X-ray beam evaluated by the blackening differences after measurement of the optical density at the four corners and at the center of the film.

Results

4 non-digitized posts were used for conventional radiology examinations at the time of the study. It was post 1 of emergency lung bone post at Yopougon University Hospital, post 2 of lung bone post of the outpatient department of Cocody University Hospital, post 3 of lung bone post of the third floor of the Cocody University Hospital and post 4 of remote controlled station on the third floor of the Cocody University Hospital. Technical characteristics of these 4 radiology posts are shown in table 1.

Posts	**Post 1:** Emergency lung bone post at Yopougon University Hospital	**Post 2:** Lung bone post of the out patient department of Cocody University Hospital	**Post 3:** Lung bone post of the 3rd floor of Cocody University Hospital	**Post 4:** Remote controlled station on the 3rd floor of Cocody University Hospital
Mark	I.A.E Spa	I.A.E Spa	COMET AG	I.A.E Spa
Model	X 50 AH	RTM 782 HS	D171H-35/72-150	RTM 782 HS
Maximum Voltage Rating	150 kV	150 kV	150 kV	150 kV
Inherent Filtration (millimeter of aluminum mm Al)	1.2 mm Al	1.2 mm Al	1.0 mm Al	1.5 mm Al
Total Filtration (millimeter of aluminum mm Al)	1.5 mm Al	1.5 mm Al	2.5 mm Al	2.5 mm Al
Years of activity	2 years	4 years	12 years	3 years
Ages of tubes	3 years	4 years	14 years	8 years
Purchase control	Yes	Yes	Yes	Yes
Number of x-ray quality checks after purchase	0	0	0	0
Number of leaktightness tests on leaded sheaths	Daily	Daily	Daily	Daily

Table 1: Technical characteristics of the radiogenic tubes of the various University Hospitals.

There was no functioning post in the Radiology Department of Treichville University Hospital during the study period. When they were acquired, the post was calibrated by the vendor prior to commissioning and was found to comply with European functional standards. None of the quality parameters of X-ray beam were checked after posts was switched on. Post displayed maximum voltages of 150kV. The post 3 was the oldest at the time of the study with 14 years of age and 12 years of activity. The other posts (1, 2 and 4) were respectively 3 years, 4 years, and 8 years of age and 2 years, 4 years and 3 years of activity. Posts 1 and 2 showed a aluminum total filtration of 1.5 mm for 1.2 mm of inherent aluminum filtration. X-ray beam parameters are recorded in the following tables (Tables 2-5).

Post parameters	International Standards	Reference	Post data	Conformity
RX beam Alignment	< 3%	IPEM (2005a)	< 3%	+
RX beam Collimation	< 2%	EC (1997)	1.7%	+
RX beam linearity	< 15%	JORF (2007)	9%	+
RX beam homogeneity	< 10%	JORF (2007)	4%	+
Voltage reproducibility	< 5%	DRd (A)-2016	2.94%	+
Doses reproducibility	< 5%	DRd (A)-2016	1.6%	+
Pause times reproducibility	< 5%	IPEM (2005a)	51%	-
Focal spot for large slit	<1.6 lP/mm	JORF (2007)	1.6	+
Focal spot for small slit	<1.6 lP/mm	JORF (2007)	2.7	-
Voltage précision	< 10%	EC (1997) IPEM (2005a)	7.6%	+
Pause times précision	< 30%	IPEM (2005a)	75.4%	-

Table 2: Compliance of X-ray quality parameters at post 1.

Post parameters	International Standards	Reference	Post data	Conformity
RX beam Alignment	< 3%	IPEM (2005a)	< 3%	+
RX beam Collimation	< 2%	EC (1997)	0.3%	+
RX beam linearity	< 15%	JORF (2007)	21%	-
RX beam homogeneity	< 10%	JORF (2007)	10.2%	-
Voltage reproducibility	< 5%	DRd (A)-2016	8.3%	-
Doses reproducibility	< 5%	DRd (A)-2016	2%	+
Pause times reproducibility	< 5%	IPEM (2005a)	0.7%	+
Focal spot for large slit	<1.6 lP/mm	JORF (2007)	1.0	+
Focal spot for small slit	<1.6 lP/mm	JORF (2007)	0.9	+
Voltage précision	< 10%	EC (1997) IPEM (2005a)	6%	+
Pause times précision	< 30%	IPEM (2005a)	1%	+

Table 3: Compliance of X-ray quality parameters at post 2.

Post parameters	International Standards	Reference	Post data	Conformity
RX beam Alignment	< 3%	IPEM (2005a)	> 3%	-
RX beam Collimation	< 2%	EC (1997)	0.7%	+
RX beam linearity	< 15%	JORF (2007)	2%	+
RX beam homogeneity	< 10%	JORF (2007)	6%	+
Voltage reproducibility	< 5%	DRd (A)-2016	8.8%	-
Doses reproducibility	< 5%	DRd (A)-2016	0.8%	+
Pause times reproducibility	< 5%	IPEM (2005a)	0.6%	+
Focal spot for large slit	<1.6 lP/mm	JORF (2007)	1.4	+
Focal spot for small slit	<1.6 lP/mm	JORF (2007)	1.5	+
Voltage précision	< 10%	EC (1997) IPEM (2005a)	13%	-
Pause times précision	< 30%	IPEM (2005a)	2%	+

Table 4: Compliance of X-ray quality parameters at post 3.

Post parameters	International Standards	Reference	Post data	Conformity
RX beam Alignment	< 3%	IPEM (2005a)	< 3%	+
RX beam Collimation	< 2%	EC (1997)	0.4%	+
RX beam linearity	< 15%	JORF (2007)	17%	-
RX beam homogeneity	< 10%	JORF (2007)	4%	+
Voltage reproducibility	< 5%	DRd (A)-2016	5.2%	-
Doses reproducibility	< 5%	DRd (A)-2016	0.07%	+
Pause times reproducibility	< 5%	IPEM (2005a)	0.8%	+
Focal spot for large slit	<1.6 IP/mm	JORF (2007)	1.5	+
Focal spot for small slit	<1.6 IP/mm	JORF (2007)	1.6	+
Voltage précision	< 10%	EC (1997) IPEM (2005a)	2.4%	+
Pause times précision	< 30%	IPEM (2005a)	2%	+

Table 5: Compliance of X-ray quality parameters at post 4.

Focal spot of the X-ray tube was correct in the 4 posts for large fireplaces. Detectability of bone structures and lung plaques, which constitute most of the explorations, was conserved. However, the focus was defective for the small focus at post 1. Post 2 exhibited a 10.2% density variation between center and 4 angles of the film exposed to ionizing radiation. For the other posts, variation was mower than 6%. All posts were well collimated. The deviation of the X-ray beam from the focus-image receptor distance was between 0.3 and 1.7 %. Normal rate is less than 2% [6,7]. Therefore, they had good functioning of diaphragms. A misalignment of X-ray beam was noted for post 3. Indeed, angle between central axis of X-ray beam and image receptor plane was greater than 3% for this post with 12 years of activity. Acceptable deviation must be less than 3% [6,7]. Dose delivered by posts 1 and 3 remains proportional to the current intensity. For current intensity values between 160 and 250 mA, posts 2 and 4 give dose values below the estimated dose. Post 1 had a pause time capped at 25 ms despite higher display values. He experienced a variation of more than 75% of the displayed time. Posts 2, 3 and 4 present voltage increase of more than 5% of the average value of the voltages applied to the terminals of the posts for 5 successive identical repeated exposures. Doses delivered showed a variation of less than 5% for all posts. The oldest post, post 3 showed a voltage increase of more than 5% between measured value and displayed one [6,7].

Totally posts 2, 3 and 4, aged four and over had failures related to reproducibility of the current voltage across the tube (Table 6), KV reproducibility fails beyond 2 years of activity and the failure increases with the duration of activity so, rate of photographs resumption increases with the time of activity. Post 3, with the longest activity also had a lack of accuracy in tension and alignment of the X-ray beam. Moreover, posts 2 and 4 had a linearity defect in the beam of X-ray, with an irradiation dose delivered below the expected dose values when the current currents were less than 250 mA. The post aged less than four years, failures related to the accuracy and reproducibility of pause times. The focal spot was also damaged.

Posts	Posts age	workload exams/week	Years of activity	Deficiencies identified	International Standards	Post data	Resume Rate
Post 1	3 years	220	2 years	Pause time reproductibility	< 5%	51%	
				Pause time précision	<5%	75.4%	11%
				Focal spot for small slit	<1.6 IP/mm	2.7	
Post 2	4 years	200	4 years	RX beam linearity	< 15%	21%	14.3%
				Voltage reproductibility	< 5%	8.3%	
Post 3	14 years	195	12 years	RX beam Alignment	< 3%	> 3%	21%
				Voltage reproductibility	< 5%	8.8%	
				Voltage précision	< 5%	6.5%	
Post 4	8 years	205	3 years	RX beam linearity	< 15%	17%	17%
				Voltage reproductibility	< 5%	5.2%	

Table 6: Ages, years of activity and deficiencies identified by post.

Comments and discussion

The observations made during this work allowed us to identify the following particularities: Concerning the intrinsic performances of X-ray tubes, all posts were able to deliver a maximum voltage of 150 kV. The application of such high voltages leads to a reduction in the dose delivered to the patient. Indeed, the dose parameters to the patient, which are the dose at the entry and the dose-surface product, are reduced by 15 to 20% for a voltage increase of 115 to 140 kV [8-10]. Posts 1 and 2, due to insufficient additional filtration, each showed a total filtration of 1.5 mm aluminum. Manufacturers recommend a minimum total aluminum filtration of 2 mm or 2.5 mm copper for tube voltages of 60 to 120 kV. Posts 1 and 2 thus provided excessive irradiation to patients because optimal filtration allows a reduction of the dose at the patient's entrance and the dose-surface product by removal of the highly irradiating components of low energy [11,12].

All posts had small and large foci with dimensions of 0.6 to 1.2 mm, respectively. Their powers of resolution were satisfactory [9].

Machines surveyed in the course of our work carried the CE logotype certifying they had been subjected to the procedures for checking and verifying conformity of technical characteristics provided for in the directives of the European Union. Our investigation revealed an inadequate total filtration, insufficient for post 1 and 2 due to low additional filtration. It should be noted that at the time of the investigation, there was no formally identified state structure responsible for performing radiation protection, nuclear safety and security checks. Indeed, it was after the law of 10 October 2013, bringing safety and nuclear safety and radiation protection against ionizing radiation in Ivory Coast, that was created by decree, in June 2014, the authority for radiation protection, safety and nuclear safety authorities responsible for these nuclear regulatory and oversight missions [13].

Concerning the quality of the emitted radiation. The parameters studied were reproducibility, precision, alignment and linearity of the tube and homogeneity and collimation of the X-ray beam.

After 5 identical and successive exposures with the following acquisition parameters 80 kV, 250 mAs, 50 ms and 100 cm focal-film distance, we observed with posts over four years of age, an increase of 5.2 to 8.8% in measured voltages. Since the tolerance threshold set by the manufacturers was less than 5%, the reproducibility of the voltage of these tubes was not in conformity. An increase in scattered radiation, causing excessive irradiation, was responsible for this increase in voltage and the production of images whose contrast was deteriorated. This resulted in a significant number of reprints of pictures between 14 and 21%. A systematic check of the lead tube of the tubes was recommended. We noted also a non-significant dose variation with deviations of less than 1% between successive measured values. A difference of less than 5% being tolerated by the manufacturers, the reproducibility of doses delivered was acceptable [1,11,14]. Post 3 after 12 years of activity, showed a lack of accuracy of the voltage applied to the tube terminals with an average deviation of 5.3% of variation between the displayed tension and the measured voltage. The increase in scattered radiation was also the cause. This also led to deterioration in the contrast of the images generated, which resulted in the highest rate of image recovery. The other posts were considered accurate with variations less than 5%. Indeed, the 5% threshold between the value of the displayed and measured voltages is usually tolerated [9,10,12,14].

With a measured pause time, capped at 25 ms in spite of higher posted times, a variation of 75.4%, post 1 was considered imprecise. Indeed, the accuracy of the pause time is good, for manufacturers, when the variations between displayed and measured times remain less than 5% [1,6,7,9,10,12,14]. This observation, reported to the establishment managers, allowed for a successful maintenance mission. Indeed, the reprints of photographs were observed for the examinations requiring a long pause time.

In our series, post 3, the oldest, showed a lack of alignment between the light field and the radiation field. He was off-center. This finding is consistent with data from the literature. Indeed, there is a deaxation of the X-ray tubes over the years, due to a deposition of target material inside tube window and the rigidification of the tube [11,15,16]. On this post, excessive radiation was noted in relation to an increase in the surface dose product because a misalignment exposes to ionizing radiation a wider area than the region of interest [9].

We noted with, posts 2 and 4, aged over than four-year and with more than two years of activities, a linearity fault for intensity values between 160 and 250 mA. Indeed, the measured dose values were lower than the expected doses. There was no proportionality between current intensity and delivered dose [12,14,17]. This reduction in doses due to tube saturation by electronic flow limitation was responsible for poor quality images due to deterioration in resolution. The numerous induced recoveries eventually increased the dose of irradiation.A uniformly distributed irradiation dose on the receiver defines a homogeneous beam. According to the manufacturers' recommendations, a variation in dose density between the 4 corners and the center of the film is tolerated when it remains less than 10% [12,14,18]. This in homogeneity responsible for uneven irradiation of the exposed surfaces, impacts the quality of X-ray images. We observed that post 2 with a dose variation of 10.2% did not meet standards. The use of locating cones has been proposed to solve this problem.

All posts had well collimated beams, indicating the diaphragms were functioning correctly. Adjusting the opening of the diaphragm to the anatomical limits of the region to be explored will eventually reduce the irradiated volume and hence the dose-surface product. Indeed, when passing from an irradiated surface of 36 × 43 Square centimeter (cm^2) to 30 × 40 cm^2, the dose-surface product decreases by 30% [8,9,12,14].

Totally, we observed through this work that the failures caused by the aging and insufficient or uncontrolled installations concerned voltage applied to the tubes in all cases. This is due to a lack of precision and reproducibility of tension responsible for a highly irradiating scattered radiation and negatively impacting the contrast of the rendered images. KV reproducibility fails beyond 2 years of activity and the failure increases with the duration of activity. The reprints representing 11 to 21% of the photographs. The quality of electrical installations and the recurring electricity supply cuts would be at stake.

Llinearity of the tube in two thirds of cases. There was a decrease in measured dose values compared to expected doses. This reduction in doses due to tube saturation was responsible for poor image quality due to deterioration in image resolution. The numerous induced recoveries eventually increased the dose of irradiation [12,14,17].

Alignment of the tube and the homogeneity of the X-ray beam, less frequently in one third of cases. Excessive irradiation was noted in relation to an exposed area wider than the region of interest and uneven irradiation of the exposed surfaces, further degrading the quality of the X-ray images and causing numerous occasions [9].

As for the post aged less than four years, the shortfalls concerned the pause time due to its cap at 25 ms. The focal spot was also damaged for the small focus with a partial limit of detectability of high contrast structures such as bone and lung.

Conclusion

Our study demonstrates the value of X-ray tube quality control for radioprotection in conventional radiology. In this way, the oldest installations will present, in our working context and in order of frequency, current voltage increases, decreases in measured dose values compared to the expected doses, and wider exposures than regions of interest and patchy irradiation of exposed surfaces. Failures increases with the duration of activity. All these things contribute to an excessive radiation exposure by increasing the scattered radiation and to the deterioration of the contrast and the resolution of the photographs responsible for many times. We recommend making functional the radiation protection services of all radiology units.

References

1. The Council of the European Union (1997) Council Directive 97/43/Euratom of 30 June 1997 on health protection of individuals against the dangers of ionizing radiation in relation to medical exposure, and repealing Directive 84/466/Euratom. Official Journal of the European Communities No: L 180/22.

2. Kramer R, Khoury HJ, Vieira JW, Lima VJ (2006) MAX06 and FAX06: update of two adult human phantoms for radiation protection dosimetry. Phys Med Biol 51: 3331-3346.

3. ICRP (1996) Radiological Protection and Safety in Medicine. ICRP, Ottawa, Ontario, Canada 26: 73.

4. United Nations Scientific Committee (2000) Sources and effects of Ionizing Radiation. United Nations Scientific Committee on the Effects of Atomic Radiation. UNSCEAR 2000 Report to General Assembly, United Nations Publication, New York, USA.

5. AFSSAPS (2006) Study of the project to implement the quality control of radio diagnostic facilities. Practical internship TSIBH, AFSSAPS, France.

6. Marimbert J (2007) Décision du 24 septembre 2007 fixant les modalités du contrôle de qualité de certaines installations de radio diagnostic. NOR Pg no: 17501.

7. European Commission (2012) Radiation Protection N° 162 - Criteria for Acceptability of Medical Radiological Equipment used in Diagnostic Radiology, Nuclear Medicine and Radiotherapy. Luxembourg, European Union.

8. Ullman G, Sandborg M, Dance DR, Hunt RA, Alm Carlsson G (2006) Towards optimization in digital chest radiography using Monte Carlo modelling. Phys Med Biol 51: 2729-2743.

9. United States Nuclear Regulatory Commission (USNRC) (1995) Part 20-standards for protection against radiation. Code of Federal Regulations, United States Nuclear Regulatory Commission, Washington, DC, USA.

10. Frigren S (1996) Criteria for acceptability of radiological (including radiotherapy) and nuclear medicine installations – Radio Protection No 91. Luxembourg, European Commission.

11. Strauss KJ (1996) Radiographic Equipment and Components: Technology Overview and Quality Improvement. In: Gould RG, Boone JM (eds.). Syllabus: a Categorical Course in Physics: Technology Update and Quality Improvement of Diagnostic X-ray Imaging Equipment. Radiological Society of North America (RSNA), Oak Brook, IL, USA. Pg No: 35.

12. Jean-Paul D, Elisabeth M (2009) A Guide to Medical Imaging and Radiotherapy Technologies. Elsevier Masson, Paris. Pg no: 389.

13. ARSN (2014) Decree No. 2014-361 of 12 June 2014 on the organization and functioning of the Radiation Protection, Nuclear Safety and Security Authority, ARSN, Ivory Coast.

14. Minister of Health (2008) Radiation Protection in Radiology - Large Facilities: Safety Procedures for the Installation, Use and Control of X-ray Equipment in Large Medical Radiological Facilities - Safety Code 35. Department of Health, Minister of Health, Canada.

15. Lin PP, Kriz RJ, Stortzum R (1982) An Alignment Testing Device for Compliance Testing of PBL Automatic Collimators. In: Paul P-J, Lin (eds.). Acceptance Testing of Radiological Imaging Equipment, Proceedings of the AAPM/ACR/SRE Symposium, Co-sponsored by American Association of Physicists in Medicine, American College of Radiology, and Society for Radiological Engineering, American Institute of Physics, New York, USA. Pg no: 183.

16. Shepard SJ, Lin Pei-Jan P, Boone JM, Cody DD, Fisher JR, et al. (2002) Quality Control in Diagnostic Radiology. AAPM, Alexandria, Virginia, USA.

17. Claude R (1997) Approach for quality control of the imaging chain in conventional radiology. UTC, France.

18. Gislason AJ, Davies AG, Cowen AR (2010) Dose optimization in pediatric cardiac x-ray imaging. Med Phys 37: 5258-5269.