Determination of Diagnostic Reference Levels (DRLs) in General Radiography in Latin America

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Abstract

The International Atomic Energy Agency (IAEA) through the International Action Plan on Radiation Protection of Patients and the International Commission on Radiological Protection have from some time carried out important efforts to assure that in the medical applications of the ionizing radiations, the optimization of radiological protection of patients is fundamental, to such a point that the IAEA includes it directly as a requirement for these practices (in its International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources - BSS – GSR Part 1, 2011)

For this reason, among the objectives of Regional Project RLA/9/057 and Regional Project RLA/9/067, the intention was to establish the dose references in conventional radiology for Latin America, for the purpose of determining if these doses comply with the requirements of the International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources (BSS) and to tend to improve practices, in order to minimize the dose received by the patients.

Introduction

The International Atomic Energy Agency (IAEA) and the International Commission on Radiological Protection have for some time carried out important efforts to assure that in the medical applications of the ionizing radiations, the optimization of radiological protection of patients is fundamental, to such a point that the IAEA includes it directly as a requirement for these practices (in its International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources (BSS)).

Work is normally performed with dosage guiding levels, which can then be used for institutions to compare with the dosages received by their patients, in order to review their working protocols and to optimize their practices to assure the effective protection on the patients involved.

For this reason, among the objectives of Regional Project RLA/9/57 and Regional Project RLA/9/67, the intention was to establish the dose references in conventional radiology for Latin America, for the purpose of determining if these doses comply with the requirements of the International Basic Safety

Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources (BSS) (1) and to tend to improve practices, in order to minimize the dose received by the patients.

This work is a continuation of the one carried out in project ARCAL LXXV "Pilot Exercise for the Determination of Guidance Levels in General Radiography and Mammography in Latin America", coordinated by the IAEA and PAHO.

The decision was taken to perform a sampling which would involve all of the countries and be divided in two phases:

In the first phase basic information was obtained on the characteristics of the radiology centers, the type of equipment, and the functioning characteristics with respect to personnel and technical controls. Data was also gathered on the exposure parameters for each selected technique and for the observance of image quality criteria.

In the first phase a total of 34 Health Centers participated from the following countries. These data appeared in Table 1

Table 1

Country	**Institutions**
Argentina	5
Brazil	7
Costa Rica	4
Cuba	2
El Salvador	1
Guatemala	3
Honduras	4
Mexico	1
Nicaragua	1
Dominican Republic	1
Uruguay	2
Venezuela	3

Table 1: Countries and corresponding Health Centers that participated in phase 1

During the second phase dose measurements were taken on conventional thoracic, spine and AP X-rays. As a total, 628 thoracic dose determinations and 350 spine dose determinations in X-rays were taken.

A total of 27 Health Centers from the following countries participated in this phase. This centers for each country appeared in Table 2

Table 2:

Country	Institutions
Argentina	5
Brazil	5
Costa Rica	5
Cuba	2
El Salvador	1
Guatemala	3
Mexico	1
Nicaragua	1
Peru	1
Venezuela	3

Table 2: Countries and corresponding Health Centers that participated in phase 2

Methodology

First phase

This phase lasted from March 2008 to December 2009.

The data collection for the first phase with regards to information on each Health Center and technical controls was performed through tables like the ones shown in Annex 1, which were completed by a person designated specially to this work in each center:

The surveyed institutions were classified according to the following types: private, public, small, medium, large, total amount of X-ray rooms, amount of equipment in the facility.

With respect to professional staff: information is obtained on the amount of medical radiologists, residents, technicians (with and without a radiology course), information is gathered with respect to the technician's years of experience, if there are any medical physicists, if quality controls are made and if a program of equipment maintenance exists.

An assessment of the radiologic equipment is made, also of the environmental conditions of the rooms, of the available resources of radiologic protection for the operator and the patient, and on the processing systems (analogical or digital).

Each institution was also requested to send the protocols employed for the thoracic and spinal techniques. Finally a request was made in this phase that the quality of the images obtained be evaluated by specialized professionals. An initial sample of 20 patients was requested, although this amount was not achieved by all participating institutions.

Finally, for the first phase, information was required on the image quality criteria for thoracic and spine X-rays in their AP and Lateral projections, following the recommendations of the European guidelines on quality criteria for diagnostic radiographic images (2)

The Image Quality Criteria for all three studies are summarized in the charts which appear in Appendix II, and were completed in each Health Center for the series of studies performed.

The information on the exposure parameters was obtained by requesting each Center to prepare tables in the X-ray rooms, for each practice performed. In this manner, the information was collected according to the patient's age and sex, their physical characteristics summed up in weight and thickness and also the exposure parameters: kVp, mAs, distance focus to X-ray film, distance focus to patient.

Second Phase: this phase lasted from March 2010 to December 2011

For the second phase, and beginning with the performance measurements of the X-ray tubes, the skin-entrance air kerma values were calculated for each technique, for a series of patients with anthropometric parameters (height, weight and thickness) within standard values.

For this purpose, calculation tables were used which allows us to obtain the X-ray tube's performance values, from which the kerma values for each procedure and patient are then calculated. As a total, kerma values were obtained for 978 procedures.

Data for entrance surface air kerma in μGy for the studies considered in this data collection within Regional Project RLA/9/57-67 were obtained from the calculation table mentioned in the Methodology section, based on the performance of the X-ray tubes.

The procedure used for the kerma determinations was similar to the one used in the work carried out by Project ARCAL LXXV, which was announced in the publication "Pilot Exercise for the Determination of Guidance Levels in General Radiography and Mammography in Latin America", which is transcribed below:

Selection of the patients and radiological studies

Samples were taken of a minimum of 10 patients per each participating X-ray room, with the required observance for image quality and 2 types of radiological tests were selected; one for thorax in its posteroanterior projection and one of the spine in its anteroposterior and lateral projections. The definition of patient type for the purpose of the study was for adult patients, men and women between a height of 1.65 and 1.75 meters and a weight between 65 and 75 kg.

Determination of entrance surface air kerma of the patient was performed following the Technical Report 457fro IAEA (3)

For the data collection, Excel sheets were prepared for the gathering of information and automatic calculation of entrance surface air kerma. This chart compiled data on age, sex, height and weight of patient. Also kVp, mAs, distance focus to X-ray film, distance focus to patient exposure parameters, size of X-ray film and entry dosage were requested.

Results

Not all of the countries which participated in the first phase did so in the second phase.

First Phase

Table 3 summarizes the results on the Health Centers surveyed, with respect to size, personnel and quality controls and equipment maintenance:

Country	#	Priv.	Publ.	Large	Med.	Small	Number of Radiologists	Technicians with Course	Medical Physicist	Quality Control	Maintenance
Argentina	5	3	2	3	2		35	183	0	3	5
Brazil	7	2	5	3	4		42	255	1	2	5
Costa Rica	4	1	3	3		1	21	83	0	0	3
El Salvador	2		2	1	1		6	33	0	2	2
Guatemala	3	1	2	3			15	78	0	1	2
Honduras	4	1	3	4			16	82	0	1	2
Nicaragua	2	2		1	1		7	13	0	2	2
Dom. Rep.	1	1				1	1	1	0	1	1
Uruguay	2		2	1	1		6	14	0	0	1
Venezuela	4	1	3	3	1		31	102	0	0	1
	34	12	22	22	11	2	180	844	1	12	24

According to this table, we can observe that 65% of the surveyed centers are public, and a similar percentage shows that there are centers with high workloads.

Only one of them has a Medical Physicist working in diagnostic radiology, and only 35% of the centers perform some type of quality control.

As a general norm, we can observe that the technicians that work at the surveyed centers, have approved some type of radiology course.

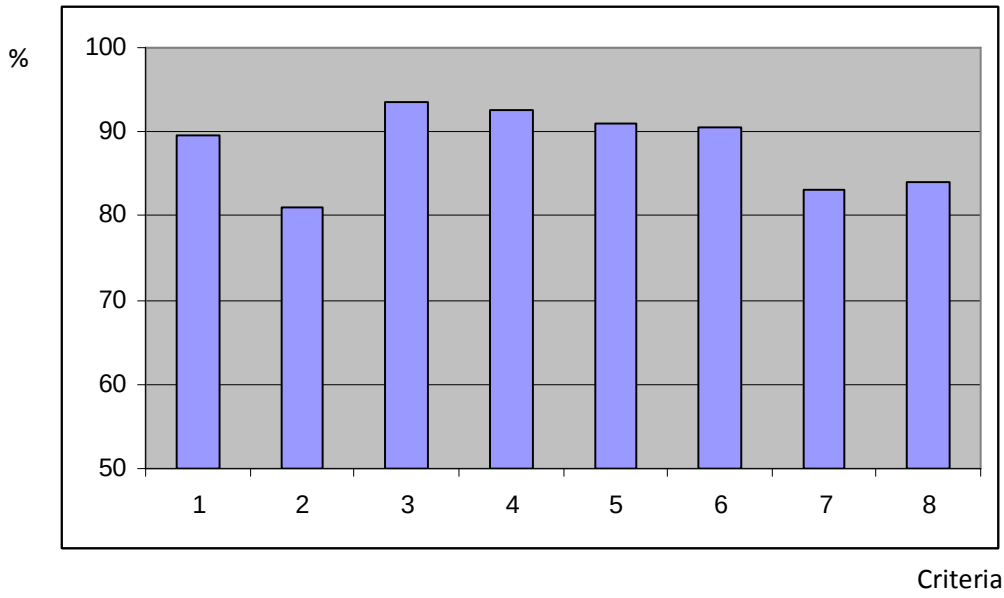
The following table (Table 4) shows the average values of the exposure parameters which emerged from the survey.

	kVp	mAs
THORAX	97	16
AP SPINAL	86	27

AL SPINAL	86	60

With respect to the degree of performance of the image quality criteria(2), as observed in Figure 1 for the case of thorax, it is true that although the performance percentage is above 80% for all criteria, 2, 7 and 8 are below 85%.

Figure 1: Performance percentage of the image quality criteria for Thoracic X-ray (see Annex 1).



In the case of the spine in its anteroposterior projection, criteria 1, 5 and 7 have the lowest performance (Figure 2), and for the lateral projection, the least satisfying criteria is 2 (Figure 3).

In general, we can affirm that in conventional radiology, positioning is vital for the good performance of image quality criteria.

Figure 2: Performance percentage of the image quality criteria for Spine X-ray in Anteroposterior Projection

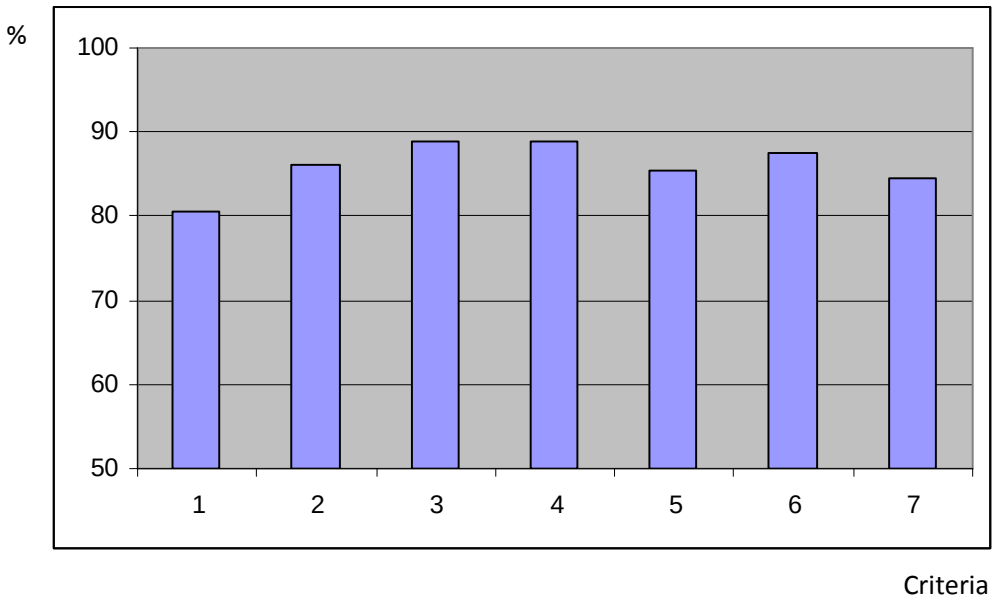
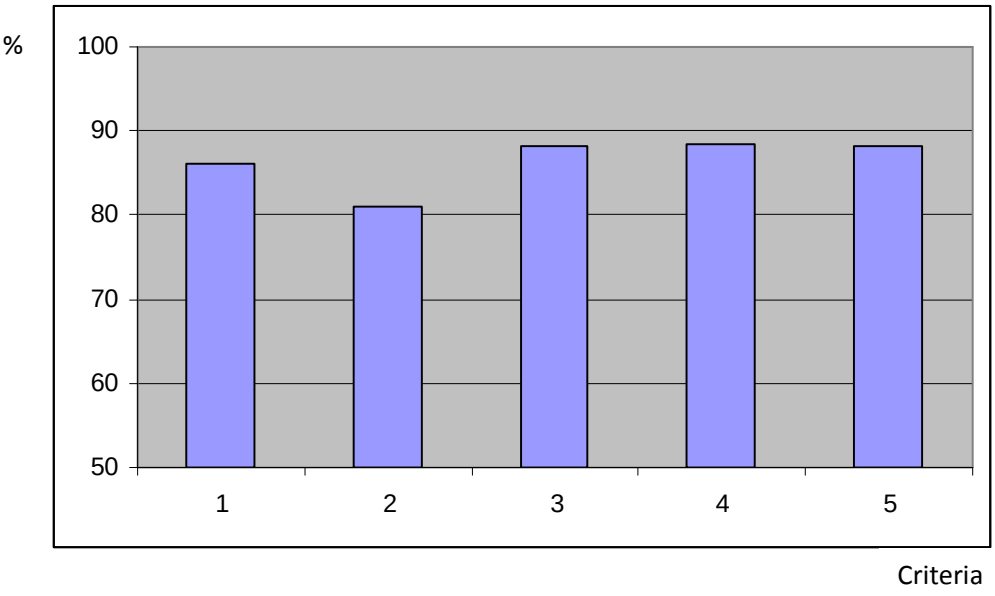


Figure 3: Performance percentage of the image quality criteria for Spine X-ray in Lateral Projection



Second Phase

The reference dose corresponding to the respective procedures was estimated as the percentile 75 of the data population.

In Table 5 the calculated values are presented, expressed in all cases as mGy, and the guidance levels of the Basic Norms.

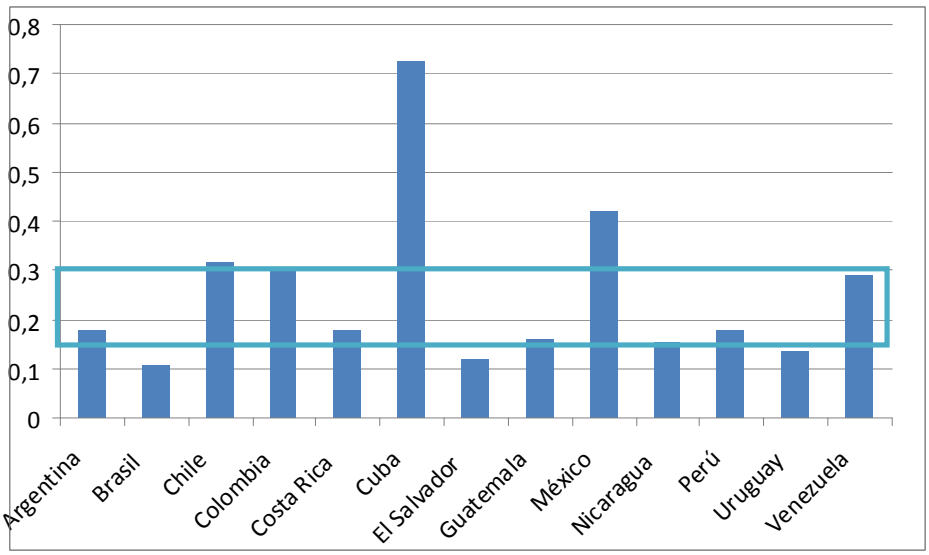
Table 5:

	Amount of centers	**Average dose (mGy)**	**Reference level (mGy)**	**Guidance level BSS (mGy)**
Thorax	50	0,19	0,28	0,15-0,30
AP Spinal	28	4,12	4,76	5,0-10,0
AL Spinal	25	9,47	10,49	15,0 -30,0

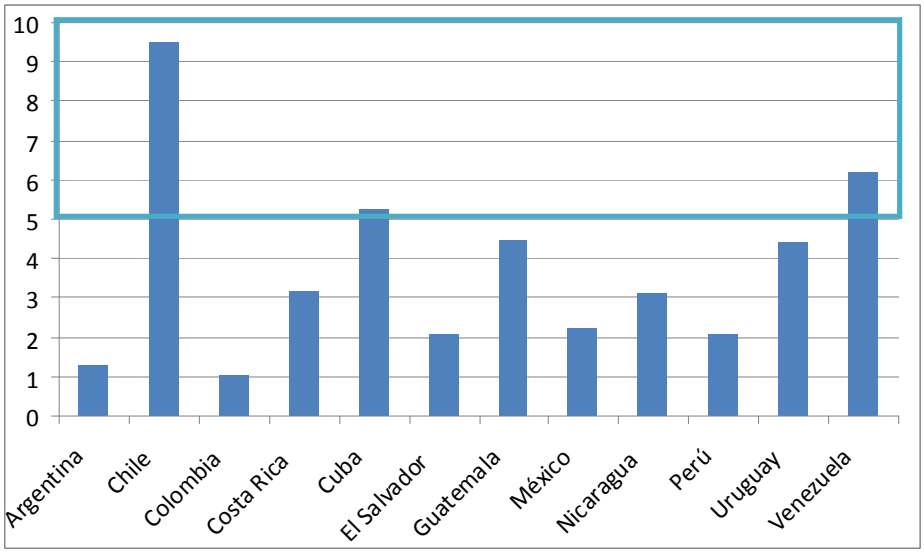
In Figure 4 (a, b and c) we can observe the values obtained by country, for thorax, AP spinal and AL Spinal, respectively.

Figure 4: Average values per country of entrance surface air kerma compared with the recommended dosage in the BSS, in mGy for

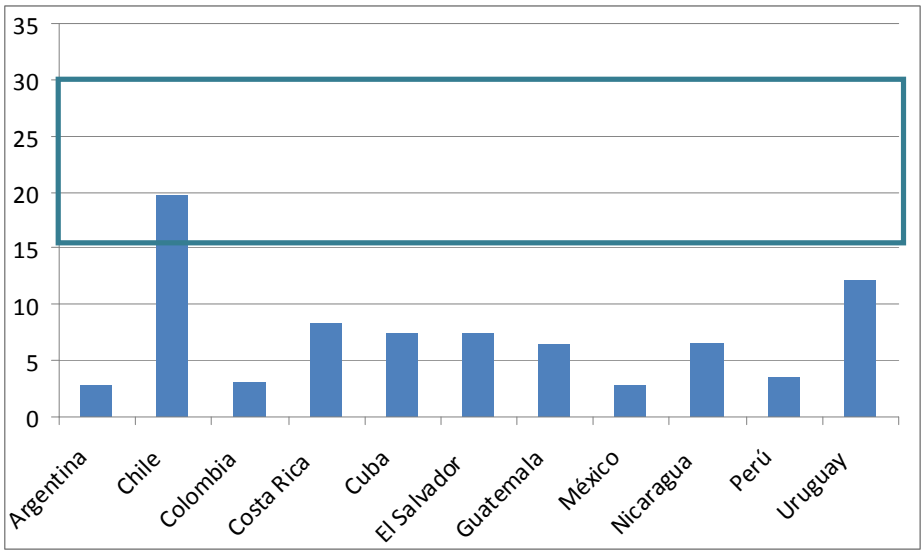
a: Thorax



b: AP Spinal



c: AL Spinal



Conclusions

When this survey was being made, digital technology was not widely spread, and for this reason only results of analogical equipment are presented.

The analysis carried out on the exposure parameters of the three types of radiological studies displayed a large statistical dispersion, which suggests that the use of a wide variety of criteria was employed by the radiological technicians, while working with the same equipment and even for centers of the same country, the large variation in the technical factors generate a dispersion in percentile 75. This is indicative that efforts should be made to optimize radiographic techniques.

The same is suggested with respect to the anthropometric characteristics of the patients.

Analyzing the dose reference values for Latin America obtained in this work, a decrease can be observed with respect to those obtained in the sample of Project ARCAL 75 (see Table 5), which suggests that this type of actions tend towards a decrease of the doses received by the patients. Although during the period of our study, we notice a dosage decrease in the referenced centers, we must not forget that in our work we include some institutions that employ fast screens, while the BSS reference values are considered for slow screens.

Table 5

	PERIOD UP TO 2009 DRL (mGy)	**2009-2011 DRL (mGy)**
THORAX	0,38	0,28
AP SPINAL	5,91	4,76
AL SPINAL	12,31	10,49

Annex 1: Tables used for the information survey of the Centers

Type of institution
Private
Public
Small
Medium
Large
Total amount of X-ray rooms

Total amount of equipment in the institution
Fixed conventional X-ray
Portable conventional X-ray
Mammography
Tomography
Fluoroscopy
Processer

Number of professionals in the institution
Medical Radiologists
Medical Residents
Technicians **WITH** radiology course
Technicians **WITHOUT** radiology course
Amount of technicians with experience in radiology?
- how many with experience < 2 years
- how many with experience of 2 - 5 years
- how many with experience of 5 -10 years
- how many with experience > 10 years
Does the facility have a Medical Physicist?
Is there a Quality Control program implemented?
- Is it performed by the Medical Physicist?
- Is it performed by the technician?
- Is it performed by an external engineer?
Is IAEA protocol used?
Is ACR protocol used?
Is Spanish protocol used?
Other?

Assessment of radiological equipment
Equipment brand
Equipment model
Tube brand
Tube model
Year of manufacture
Installation date
Range of kV
Range of mAs
Is the equipment analogical?
Is the equipment digital?
Automatic exposure control ?
Focal spot marked on housing?
Is the total filtration value indicated?
Is there an audible or luminous indication on the command console to reveal radiation emission?
Is it possible to see and maintain contact with the patient?
Is the luminous indication of the radiation field functioning?

Equipment Maintenance
Is there a preventive maintenance program?
Is it internal?
Supplied by the manufacturer or representative?
Supplied by an external company?
Is there a contract?
Maintenance frequency: biannual?
Maintenance frequency: anually?
Maintenance frequency: every 2 years?
Other?

Environmental Conditions of the Room
Is there air conditioning in the mammography equipment room?
Is the air conditioning functioning?
Does the room have reinforcement?
Are the doors reinforced?
Is there a luminous indicator on the door?

Is there a radioprotection sign on the door?

Protection measures for the operator and the patient
Is there a fixed barrier or window lead shielding?
The barrier is made of what material?
Are there protection aprons in the room?
How many?
Do technicians use a personal dosimeter?
- Is it a film dosimeter?
- Is it TLD?
Other dosimeters?

Assessment of processing systems
Do you use an X-ray film to obtain image?
Do you use CR to obtain image?
Do you use DR to obtain image?
In the case of Digital Radiology:
Model of CR cassettes?
Brand of CR cassettes?
Model of DR detector?
Brand of DR detector?
Can the images be extracted?
In *"for processing"* format?
In *"for processing"* format?
Brand of the workstation monitor?
Model of the workstation monitor?
Is the workstation monitor CRT type?
Is the workstation monitor LCD type?
Matrix size of workstation monitor?
Does the software of the monitor belong to the workstation?
In the case of Radiographic Film?
Brand?
Model?
Type of screen?
Is the process of the film manual?
Is the process of the film automatic?
Brand of processer?
Model of processer?
Developer temperature?

Total processing time?
Is the variation between the value of measured time and the one indicated on the equipment acceptable? **(Tolerance: < ± 3% with respect to the value indicated by the manufacturer)**
If you have a thermometer measure the temperature of the developer
Is the variation between the measured value and the one indicated on the equipment acceptable? **(Tolerance: ± 0,5 with respect to the value indicated by the manufacturer)**
Is there evidence of stains or scratches in the films after the process?

Darkroom Inspection
Is there a ventilation system?
Is it functioning?
Is the floor non-slip, waterproof and anticorrosive?
Is the room clean?
Can you perceive a strong odor of liquid developer?
Is there an extractor fan?
Is the white light switch located in places where it cannot be activated involuntarily?
Is the safety light at a distance of more than 120 cms from the surface?
Is the power of the safety light lower or equal to 15 watts?
Are there signs of infiltration or dampness on the walls?
Are the boxes of film in vertical position and organized?
Are there entries of light in the darkroom?
Are the films organized by their expiry date?

Amount of negatoscopes
Can you observe stains at a first glance?
Are there luminosity differences in the negatoscope?
Is there a magnifying glass?
Can you vary the intensity of the negatoscope?
Can you disguise the image of the X-ray?
Can you vary the intensity of the observation room?
If you have a photometer, measure the luminance of the negatoscope
Is the measured value acceptable? (**Tolerance:** Luminance: **15**00 cd/ m^2)
Uniformity of the negatoscope
Is the measured value acceptable? (**Tolerance:** Uniformity: <15%)
Illumination of the viewing room
Is the measured value acceptable? (**Tolerance**: Illumination**:** <100 lux)

Annex II: Image quality criteria for thoracic and spine X-rays in their AP and Lateral projections, following the recommendations of the European guidelines on quality criteria for diagnostic radiographic images

QUALITY CRITERIA-Thorax
1- Image performed in deep inspiration, evaluated from (6 anterior and 10 posterior) ribs above the diaphragm and holding breath
2-Symmetrical reproduction of the thorax shown by the central position of the spinous process between the medial clavicular heads
3- Medial aspect of the scapula outside of the lung parenchyma
4- Complete reproduction of the thoracic cage above the diaphragm
5- Clear visualization of the vascular pattern in all the lung, particularly the peripheral vessels
6- Clear visualization of: a) trachea and principal bronchial tubes
b) borders of the heart and aorta
c) diaphragm and costophrenic angles
7- Visualization of the retrocardiac lung and mediastinum
8- Visualization of the spine through the heart shadow

QUALITY CRITERIA- AP Spinal View
1- Clear visualization of the surface of the superior and inferior vertebral endplates, as a single line, in the central part of the X-ray beam
2- Clear visualization of the pedicles
3- Visualization of the intervertebral spaces
4- Visualization of the spinous and transverse processes
5- Clear visualization of the cortex and the trabecular structures
6- Visualization of adjacent soft tissue, particularly of the psoas muscle
7- Visualization of the sacroiliac articulation

QUALITY CRITERIA- Lateral Spinal View
1- Precise visualization of the surface of the superior and inferior vertebral endplates, as a single line, with visualization of the intervertebral space
2- Total superposition of the posterior borders of the vertebrae
3- Visualization of the pedicles and of foramina
4- Visualization of the spinous processes
5- Precise visualization of the cortex and the trabecular structures

References

1) IAEA Safety Standards: Radiation Protection and Safety of Radiation Sources. International Basic Safety Standards. International Atomic Energy Agency. Vienna, 2011

2) European guidelines on quality criteria for diagnostic radiographic images. EUROPEAN COMMISSION. Directorate-General XII: Science, Research and Development, Luxembourg: Office for Official Publications of the European Communities, 1996.

3) Technical Reports Series No. 457 **,** International Atomic Energy Agency, Vienna, 2007.