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Radiation doses in diagnostic radiology and methods for dose reduction

Report of a co-ordinated research programme jointly organized by the International Atomic Energy Agency and the Commission of the European Communities (1991–1993)

INTERNATIONAL ATOMIC ENERGY AGENCY IAEA

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FOREWORD

It is well recognized that diagnostic radiology is the largest contributor to the collective dose from all man-made sources of radiation. Large differences in radiation doses from the same procedures among different X ray rooms have led to the conclusion that there is a potential for dose reduction. An exercise in dose reduction, while maintaining the quality of the diagnostic information in the image, is a genuine process of optimization associated with an improved use of the X ray equipment.

The CEC has been working since 1987 on assessing radiation doses and monitoring the image quality criteria at the same time.

A Co-ordinated Research Programme on Radiation Doses in Diagnostic Radiology and Methods for Dose Reduction, involving Member States with different degrees of development, was launched by the IAEA in co-operation with the CEC in order to spread knowledge of the potential for dose reduction and to further develop the techniques for achieving it.

The first Research Co-ordination Meeting was held 11–12 March 1991 in Vienna. At this meeting the objectives, methodology and programme of work were defined. During the second and final Research Co-ordination Meeting held in Vienna from 4 to 8 October 1993, the results were analysed and summarized and a report was drafted, which formed the basis for the present publication.

This programme of research has proved to be successful in that significant dose reduction has been achieved without any loss of diagnostic information.

EDITORIAL NOTE

In preparing this publication for press, staff of the IAEA have made up the pages from the original manuscript(s). The views expressed do not necessarily reflect those of the governments of the nominating Member States or of the nominating organizations.

Throughout the text names of Member States are retained as they were when the text was compiled.

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CONTENTS

1. INTRODUCTION

Radiation doses from diagnostic radiology are the largest contribution to the collective dose from all man-made sources of radiation [1].

Because most procedures causing medical exposures are clearly justified and because the procedures are usually for the direct benefit of the exposed individuals, less attention has been given to the optimization of protection in medical exposures than in most other applications of radiation sources (ICRP Publication 60) [2]. In addition to this expression of concern by the ICRP, two other statements are essential to an understanding of the subject [2]:

1. Dose differences of up to two orders of magnitude for the same type of examination have been reported in diagnostic radiology.

2. Consideration should be given to the use of dose constraints, or investigation levels, selected by the appropriate professional or regulatory agency, for application in some common diagnostic procedures and that they should be applied with flexibility to allow higher doses where indicated by sound clinical judgement.

The first statement suggests that there must be a large scope for dose reduction, which can be explored through pilot programmes on dose assessment and dose reduction.

The second statement suggests deriving guidance levels for patient doses based on wide-scale surveys. Alternatively, a pilot programme in exploring the applicability of existing guidance levels derived in a group of countries to other countries with different levels of development seems relevant to the establishment of international recommendations.

An overall approach to reduction of the collective dose consists of making a rational use of the imaging devices available and therefore of the X ray equipment. Comprehensive guidance on this subject can be found in WHO recommendations [3–5]. An example of efforts made at the national level [6] is the work done in the UK by a joint working party between the Royal College of Radiology and the National Radiological Protection Board (NRPB). A good summary of methods for dose reduction is given by the International Commission on Radiological Protection (ICRP) in its Publication 34 [7].

It is well recognized, that over-zealous reductions in patient doses can have deleterious effects on the diagnostic information of the image [8]. Therefore, any action on dose reduction should be associated to ensuring that, at least, no diagnostic information is lost in the process. (In some cases, dose reduction can even be obtained together with an improvement of the image). As an example, simple methods for monitoring the image are also given in Ref. [8].

In summary, a pilot programme can provide know-how and first hand experience to the participants, create awareness and motivation in the radiology staff involved, and lead toward a continuing process of optimization beyond the extent of this initial pilot programme.

In addition, a number of requests for the IAEA's technical co-operation projects as well as for research contracts on dose assessment, dose reductions and quality control in diagnostic radiology have been received by the IAEA from its Member States during recent years.

For all these reasons, it was considered convenient to optimize efforts and resources by conducting a Co-ordinated Research Programme on Radiation Doses in Diagnostic Radiology and Methods for Dose Reduction and to include this pilot study in the IAEA programme.

Since 1987, the CEC, under its Radiation Protection Research Action, had been running a number of projects on dose assessment (some examples are given in Refs [9–12]) and developing dose

reference levels and image quality criteria for common diagnostic examinations [13–16][1], which provided good background material for the programme[2]. Therefore, the Co-ordinated Research Programme (CRP) was launched in co-operation between the IAEA and the CEC. In future projects, it is expected that this co-operation will be extended to other organizations.

The fact that most radiological examinations (70%) are performed in health care level I countries (WHO classification) [17], does not reduce the usefulness of the pilot programme in developing countries. Dose reduction without loss of diagnostic information implies a successful process of optimization and quality assurance which leads to an improved used of the available X ray equipment and film.

A large part of dose reduction [6] can be achieved simply by excluding clinically unhelpful examinations, by improving the availability of previously taken films, by reducing the number of films per examination, and by reducing fluoroscopy time and tube current, as well as not pursuing the best image quality but the adequate one to detect pathologies. A typical example related to barium meal examinations consists of following the column of barium [6] intermittently and using memory devices. However, significant investments in equipment and long lasting efforts associated with improving the diagnostic expertise of the radiologists are far beyond the feasibility of the CRP conceived as a pilot programme.

2. OBJECTIVES OF THE PILOT PROGRAMME

Consistent with the statements made in the introduction, the CRP was mainly conceived as a 'pilot programme' on dose assessment and dose reduction for the patient. Doses to radiology staff were also to be monitored.

With regard to patients, the aim of the CRP was: to explore the potential for dose reduction in each individual X ray room for some types of examination, to assess whether available dose reference values could be applied worldwide, and to ensure that images obtained after the reduction of dose were satisfactory for diagnosis. For this latter area, the CEC image quality criteria were to be applied by the field radiologists.

A film rejection analysis was also included in the CRP in order to assess the global level of films routinely rejected in the participating X ray departments and the relative importance of causes leading to these rejects.

With regard to radiology staff, doses from the personal dosimetry were to be collected, classified into ranges, and analysed according to the type of work performed.

3. METHODOLOGY

The 'pilot programme' was carried out and completed in seven Member States from different continents. Three additional participant countries that started the pilot programme were unable to complete it for practical reasons.

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[1]As an example, Annex II includes two pages of the second edition of the CEC Working Document on Quality Criteria for Diagnostic Radiographic Images. These two pages (chest PA and lumbar spine) include the diagnostic requirement (image criteria), the criteria for good image performance and an example of good radiographic technique.

[2]Guidance levels on patient entrance surface dose are also provided in the draft of the International Basic Safety Standards for Protection Against Ionizing Radiation and for the Safety of Radiation Sources. However, they were not available while performing the pilot programme, and the CEC reference values were used. Nevertheless, the differences are not significant for the main scope of this pilot programme (chest and abdominal region, one projection).

TABLE I. GENERAL INFORMATION DESCRIBING THE CRP PILOT PROGRAMME

Country	Number of hospitals	Number of X ray rooms
Argentina	3	6
Brazil	3	19
Czech Republic	3	6
Ethiopia	2	4
Ghana	5	6
Iran, Islam. Rep.	2	4
Romania	2	7

To ensure a close interaction and co-operation with the radiology staff, a small number of hospitals was selected (see Table I and Appendix).

Comparisons are only possible if some examinations are common to all participants, and preferably belonging to those that make a significant contribution to the collective dose. In developed countries these examinations, in order of decreasing contribution, are computer tomography, lumbar spine, barium enema and barium meal, intravenous urography, plein abdomen, pelvis and chest (see examples in Ref. [8]). In developing countries this pattern may shift to the simple examinations.

For feasibility reasons, complex examinations (involving a combination of fluoroscopy and multiple spot films, changing beam size and position) were excluded from this initial pilot programme. It was decided to reduce the overall workload to be performed by each participating country to a small number of common X ray examinations and include only one single projection per examination for dosimetry purposes (one single field size and patient position).

The following X ray projections were considered: chest (PA), abdomen (AP or PA), lumbar spine (AP), lumbar sacral joint (lateral), pelvis (AP). Some participants included additional examinations such as mammography, intravenous urography (IVU) and skull.

With regard to the control of the diagnostic evaluation of the information of the images, it was initially agreed to perform a similar trial as the one carried out within the CEC. This would imply a centralized neutral evaluation of the images against the quality criteria by a panel of radiologists. However, for practical reasons the centralized evaluation became unfeasible and it was decided to leave the judgement to the field radiologists of each participant hospital as to whether there was any deterioration of the image information. As a tool, the CEC-image quality criteria were provided to them. This decision implied an intrinsic subjectivity.[3]

The neutral evaluation of the pictures has been recognized as a desirable feature of future pilot programmes. This should be in addition to and not in replacement of the use of test phantoms.

[3]During a large part of the duration of the pilot programme, the communication with some participants was very difficult. Sometimes, it took months to obtain a reply. This situation improved significantly towards the end of the project.

3.1. INDICATOR FOR DOSE ASSESSMENT

In order to be able to assess patient doses, to compare them with the reference dose values and to evaluate the patient dose reduction achieved, a dose indicator was used during the pilot programme.

For practical reasons such an indicator should:

- be simple to measure;
- preferably permit direct measurements on the patient during an examination;
- be representative of, or related to, the dose received by the patient in terms of effective dose.

The most reliable dosimetry quantities commonly used in diagnostic radiology to give an indication of the typical dose that is being delivered to an average adult patient are the patient entrance surface dose (ESD) including backscatter for simple X ray projections, and the dose area product (DAP) for complex examinations.

Since this CRP pilot programme was concerned only with simple X ray projections, the ESD was chosen as the most appropriate dosimetry quantity since it meets the three conditions indicated above. Such a quantity is also recommended by the CEC in the document on quality criteria for the most common radiographic images [15].

The ESD is related to the effective dose, which depends also on the field size, the X ray projection and position, the anatomy of patient, the beam quality and the focus to film distance. Therefore, the effective dose can easily be estimated for a standard-sized patient, provided that when measuring the ESD, the associated data on field size and position, distance and beam quality (kVp and filtration or half value layer (HVL)) are collected.

Moreover, the ESD is the quantity readily used for direct comparisons with reference dose values and between measurements.

To meet the conditions given in Ref. [15], the ESD was referred to striated muscle (except mammography where the ESD is referred to air). However, there is a trend to use absorbed dose to air (or air kerma) as an indicator instead of absorbed dose to muscle as thermoluminiscent dosimeters (TLDs) are usually calibrated in a manner which is traceable to a primary standard of air kerma [8]. Nevertheless, it does not influence the percentages of dose reduction and it is not significant for comparison with referent levels since the ratio

$$\frac{(\mu_{en}/\rho)_{muscle}}{(\mu_{en}/\rho)_{air}}$$

is approximately 1.06 $\pm$1% [18] for beams between 50 and 140 kVp.

3.2. REFERENCE VALUES

The reference values described in the CEC working document were determined on the basis of the 3rd quartile of patient dose distributions obtained in European surveys in recent years. Therefore, it seems sensible that, if 75% of X ray departments can operate satisfactorily below a certain dose level, the remaining 25% should be made aware of their less than optimal performance. This approach is consistent with the recommendations given in the ICRP Publication 60 [2], as mentioned in the introduction. These values are summarized in Table II.

Moreover, reference dose values developed under the above philosophy, could take the role of investigation levels in the sense that it is reasonable to investigate the reasons when the reference values are frequently exceeded with normal sized patients.

TABLE II. REFERENCE VALUES OF ESD (CEC WORKING DOCUMENT, JUNE 1990)

Examination type	ESD for a standard-sized patient (mGy)
Chest PA	0.3
Chest LAT	1.5
Skull PA	5.0
Skull LAT	3.0
Lumbar spine AP/PA	10
Lumbar spine LA	30
Lumbo-sacral junction LAT	40
Pelvis AP	10
Urinary tract AP	10
Breast (4.5 cm compressed breast)	7

Since a patient of exactly standard size (assumed to be 20 cm AP trunk thickness and 70 kg weight) is unlikely to be available, measurements on a statistically significant sample of patients (minimum of 10) of close to standard size are recommended. The mean value of these dose measurements can be taken as an estimate of the dose to a standard-sized patient for comparison with the reference dose value.

These conditions were not met for some of the rooms and examinations. For these reasons and others related to the standard deviations of the calibration factors for the TLDs, it was decided to accept as real dose reduction only differences greater than 20% between the values obtained in the first and second set of measurements.

With regard to mammography, it has been recognized that the risk for breast cancer is related to the mean absorbed dose in the glandular tissue. Moreover, the mean glandular dose can be used as an indicator and for comparison with reference values. Conversion factors from ESD to glandular dose for different beam qualities and breast thickness are given in Rosenstein, et al. [19]. Since, for this pilot programme, the CEC indicators and reference values were taken (referred only to 4.5 cm compressed breast), the actual thickness is to be taken into account when compared with the reference values. As an example, the mean thickness in the Islamic Republic of Iran, hospital/room number 2/2, was only 3 cm, and therefore the expected ESD must be lower.

3.3. DOSIMETERS AND CALIBRATION

Since TLDs do not provide a direct indication of absorbed dose, their response to radiation in the form of an emission of light has to be calibrated against a known standard of absorbed dose. It was therefore essential that all TLD systems used to carry out the measurements recommended in this CRP pilot programme be calibrated in the same manner and be capable of performing within the recommended levels of precision and accuracy. Individual LiF chips were chosen to estimate the ESD to patients during the selected X ray examinations.

Five out of seven countries were able to complete the calibration and intercomparison procedures which allowed an estimation of:

- energy response of TLD;
- linearity of TLD response with dose;
- minimum detectable dose.

Initially, after annealing procedures, TLDs of each participating country were sent to the X ray Dosimetry Laboratory of the National Institute of Public Health in Prague which was responsible for the calibration.

An X ray device ISOVOLT 400, Seifert and a ^{137}Cs source of 87 GBq were used for the irradiation of all the TLDs received.

Air kerma was estimated using two secondary chambers VICTOREEN 415A and VAK 253.

As for the evaluation of energy response, 3 sets of dosimeters per country (5 TLDs in each set) were irradiated at an air kerma of 50 mGy at 3 different tube potentials, and 1 set of dosimeters was irradiated at the energy of γ radiation of ^{137}Cs (662 keV).

As for the linearity of TLD response, 3 supplementary sets of dosimeters were irradiated at air kerma of 0.1, 5 and 50 mGy respectively at the same X ray energy value.

For intercomparison purposes of TLD systems, 3 sets of dosimeters per country were also irradiated at known X ray energies for unknown air kerma (only information of air kerma range was provided to the participants).

For background and transport dose evaluation a separate set of dosimeters was used.

Once the TLDs irradiated, they were mailed to the participants by the IAEA.

Tables III and IV report details of irradiation conditions for calibration and for intercomparison of the TLD systems respectively.

TABLE III. IRRADIATION CONDITIONS FOR CALIBRATION OF DOSIMETRIC SYSTEMS

Tube potential (kV)	Total filtration (mm)	Effective energy (keV)	Air kerma (mGy)
30	0.425 Al	15.7	50
60	2.0 Al	26.8	50
120	1 Al + 0.2 Cu	54.5	50
120	1 Al + 0.2 Cu	54.5	5
120	1 Al + 0.2 Cu	54.5	0.1
^{137}Cs	---	662	50

TABLE IV. IRRADIATION CONDITIONS FOR INTERCOMPARISON OF DOSIMETRIC SYSTEMS

Tube potential (kV)	Total filtration (mm)	Effective energy (keV)	Air kerma (mGy)
80	3.0 Al	32.75	15–25
100	0.15 Cu	43	0.3–0.5
60	2.0 Al	26.8	0.80–1.2

General technical characteristics of TLD systems are presented in the Table V. The great majority of the participants used Harshaw TL-readers, and all patient dose measurements were performed using natural LiF. From 1 to 5 dosimeters were used to measure patient ESD associated to each X ray projection.

TABLE V. TECHNICAL CHARACTERISTICS OF TLD SYSTEMS

Country	Argentina	Brazil	Czech Republic	Ethiopia	Iran, Islam.Rep.	Ghana	Romania
TL reader	Harshaw 2000	Harshaw	Victoreen	Vinten Solaro	Harshaw	Harshaw 2000	Harshaw 2000
TL material	LiF-TLD 100	LiF-TLD 100	LiF-TLD 100	LiF-TLD 100	LiF-TLD 100	LiF-TLD 100	LiF-TLD 100
SD of batch (%)	1.6	2	< 4	7	< 6	< 4.5	< 5
Annealing procedure	400°C/1h 100°C/3h	400°C/1h 100°C/2h	400°C/1h 80°C/16h	300°C/1,6h 80°C/17h	400°/1h 100°C/2h	400°C/1h 100°C/2h	400°C/1h 80°C/25h
Annealing after each reading (Y/N)	Y	Y	Y	Y	Y	Y	Y
Reading process: -T_{MAX} -time -N_2(Y/N)	300°C 15s Y	-- -- Y	256°C 23s Y	300°C 12s Y	280°C 25s Y	300°C 20s Y	240°C 30s N
Reading period after exposures (days)	1	1	3-10	1	1	1-2	~1
Calibration after each annealing procedure (Y/N)	Y	Y	Y	Y	Y	Y	Y
Source used for calibration	^{60}Co	^{60}Co	^{137}Cs	^{90}Sr	^{60}Co, ^{137}Cs	X ray (48) keV	^{137}Cs
Cleaning procedure (Y/N)	Y	Y	Y	Y	Y	Y	N

After each reading, the annealing procedures were performed according to manufacturer's recommendations and routine calibration using β, γ or X radiation was carried out by all the countries.

3.4. PLAN OF WORK

The work programme with regard to patient doses and dose reduction methods was the following:

1. To calibrate TLDs.
2. To measure individual patient dose and collect dosimetry related data (kV, mA · s, focus film distance (FFD), filtration, film-screen combination, etc.) (first set of measurement).
3. To analyse ESD values obtained and study correlation with the relevant parameters which may influence the ESD.
4. To start quality control tests and implement technical modifications suggested by the analysis performed in phase 3.
5. To perform a second set of measurements of the ESD and collect the same data as in the phase 2 for comparison.
6. To compare dosimetry results of the two sets of measurements with the reference dose values.
7. To identify modifications which led to the main dose reduction.

8. To organize the checking of the radiographic images using to the CEC quality criteria document.
9. To collect the occupational exposures data from the personnel dosimetry, and classify them in different ranges.

3.5. SCOPE FOR DOSE REDUCTION

Methods for dose reductions in diagnostic radiology are a subject of main concern due to the high dose contribution to the collective population dose from X ray procedures.

A list of methods for dose reduction can easily be obtained by reviewing the parameters which influence the effective dose. Some methods can be applied without having access to sophisticated equipment and may lead to substantial improvement in terms of dose reduction:

- select the most sensitive film/screen combination available consistent with good diagnostic quality (factor of 2 of reduction or higher).
- Operate film processor optimally (especially temperature) (factor up to 6 has been reported) [20].
- Collimate X ray beam to minimize size.
- Remove antiscatter grid during fluoroscopy or photofluoroscopy when field size or irradiated volume is small or detail not critical (factor of 2 of reduction or higher). The most relevant parameters to ESD for common radiographic examinations are briefly described below (Sections 3.5.1–3.5.5).

It is obvious that all these solutions require good knowledge about their effects and could not be practically implemented without education and training.

It is worth noting that not all methods for reduction of the ESD influence the effective dose in the same proportion. From this point of view, the methods can be classified into two categories:

1. Methods leading to a pure reduction of the mA · s without modification of the beam quality (e.g. improving the film developing conditions, reducing the optical density of the film or increasing the speed class of the film/screen combination). In these cases, the reduction of the ESD implies a reduction of the effective dose by the same factor since the relative dose distribution within the patient does not change.

2. Methods leading to modification of the dose distribution within the patient by modifying the beam quality (kV and/or filtration). In these cases, the penetration and scattering inside the patient are modified so the reduction of the ESD does not imply a reduction in effective dose by the same factor. In addition, a large variation of the distance from the X ray tube to the patient also modifies the dose distribution. A shorter distance leads to a higher ESD, given the same optical density on the film, which becomes critical when focus-patient distance decreases to 50 cm or less.

Vice versa, the effective dose can be influenced by the field size without necessarily modifying the ESD, once the field size is large enough to meet saturated scatter condition.

3.5.1. Filtering

Additional filtration[4] is needed to avoid unnecessary skin exposure due to low energy components of the X ray spectrum. The latter do not actually contribute to image formation but are absorbed by superficial layers of the tissues. Usually, a minimum total filtration of 2.5 mm of aluminum should be present in an X ray tube (except for mammography). The benefit of using thicker filters than those commonly used today (which in turn require increasing tube load by factor 1.2-2.0 compared to no added filter) is small since the dose reduction is most rapid for small values of added filters and the increase in tube load increases steadily with increasing filter thickness. More detailed recommendations can be found in ICRP Publication 33 [21].

3.5.2. Tube potential

A reduction of the ESD for the same overall optical density of the film can be achieved by increasing the 'penetration' of the X ray beam, e.g. by increasing the tube potential. The reduction of ESD in this case does not lead to a reduction of the effective dose by the same factor, for the reasons explained in Section 3.5. As an example, the reduction of 75% (Ethiopia, chest, hospital/room 2/2) leads to a reduction of about 60% in effective dose. (Calculated using Monte Carlo factors [18] for organ doses from ESD and ICRP Publication 60 tissue weighting factors.)

The optimal choice of energy spectrum depends primarily on patient thickness, contrasting detail, characteristics of anti-scatter grid used, receptor and display method.

In addition, the "high-kV technique" is desirable in some type of examinations. However, "high kV-techniques" cannot be recommended in cases where high contrast of the image is needed.

3.5.3. Screen-film combination

The quality of the image and the radiation dose depends on the characteristics and upkeep of the film/intensifying screen used. Therefore, it is important that the screens are carefully handled and kept clean using the manufacturer recommended products. In order to obtain an adequate level of patient dose and good image quality, screens must also be matched with the appropriate type of film (green or blue film). The sensitivity class of the screen-film combination used should be selected according to the type of examination. The higher the sensitivity class the lower the dose. However, a sensitivity class of more than 600 may not be appropriate for all types of examination since resolution is impaired.

3.5.4. mA · s product

Lowering the current x time product of the X ray tube (mA · s) while keeping other parameters unchanged may improve image quality (decrease of optical density).

It also reduces both ESD and effective dose accordingly.

This method should only be applied when the optical density of the film is too high, or the film processing is not adequate (e.g. too low temperature in automatic processor).

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[4]The total filtration of an X ray tube consists of the inherent filtration (the tube glass, the oil, the material of the beam exit window) and the additional filters.

3.5.5. Film processing

The processor is the most critical element in the imaging chain from the quality control point of view. During processing, the latent image captured on the film during the exposure is transformed into a visible, stable radiographic image. With today's automated processors, the film is transported through the processing sequence: developing, fixing, washing and drying. The constancy of the processor performance in each stage of processing must be assured with the greatest care, in order to avoid rapid degradation of the image quality (loss of contrast, of speed, and increase in base and fog, for example).

An important aspect of quality control is, therefore, to maintain a record of the variations in these three parameters over time on a control chart. The use of light sensitometry tests of the films is the most effective method for measuring such variations.

In some of the participants' countries only manual film processing was available. In these cases an optimization pilot programme [22] was possible using simple tools. However, in some cases the lack of fresh chemicals was a strong limitation to the optimization process.

3.6. Use of quality criteria for radiographic images

As discussed in Section 3, in order to ensure that the implemented ESD reductions did not result in a deterioration of the diagnostic information of obtained images, the CEC Quality Criteria for Diagnostic Radiographic Images were used by the field radiologists to score their own images.

These criteria were established in 1987 within the framework of the activities of the Radiation Protection programme of the Commission of the European Communities (DG XII) and published in a CEC working document in June 1990 [15].

The main objective of this document was to provide practitioners with a provisional list of radiological, technical and dosimetric criteria helpful in determining the quality of radiographs routinely undertaken in adult diagnostic radiology.

The following six common examinations were considered in the document: chest, skull, lumbar spine, pelvis, urinary tract and breast.

In order to validate and demonstrate the usefulness of such a document, two trials were conducted in 1988 and 1991 respectively on the European scale.

4. RESULTS

4.1. Calibration of dosimeters

The results, including energy dependence, variation coefficient (VC) of some dose values, and minimum detectable dose are reported in Table VI.

Among the different dosimetric systems used, the most important differences were found concerning VC of background dose values, VC of low dose values and minimum detectable dose values.

Two main reasons were responsible for poor characteristics observed: no proper handling of TLDs concerning cleaning procedures and not optimized procedures (e.g., absence of nitrogen flux in reading cycle and TL readers with low sensitivity).

TABLE VI. CHARACTERISTICS OF TLD SYSTEMS EVALUATED DURING THE CALIBRATION OF THE PILOT PROGRAMME

Energy response relative to 662 keV	Country				
	Czech Republic	Ethiopia	Ghana	Iran, Islam.Rep.	Romania
Effective energy (keV)					
26.8	1.36	1.36	1.32	1.48	1.44
54.5	1.18	1.38	1.26	1.26	1.29
662.0	1.00	1.00	1.00	1.00	1.00
Variation coefficient (%) of readings at					
50 mGy	3	5	4	5	4
1 mGy	6	14	12	15	5
0.5 mGy	10	9	10	5	17
0.1 mGy	21	21	33	30	54
Background (mGy) VC(%)	0.068 (18)	0.33 (20.5)	0.37 (16)	0.38 (2)	0.83 (20)
*M*inimum *D*etectable *D*ose MDD = 3 · VC · BG VC = Variation coefficient BG = Mean background value (mGy)	0.037	0.020	0.178	0.023	0.5

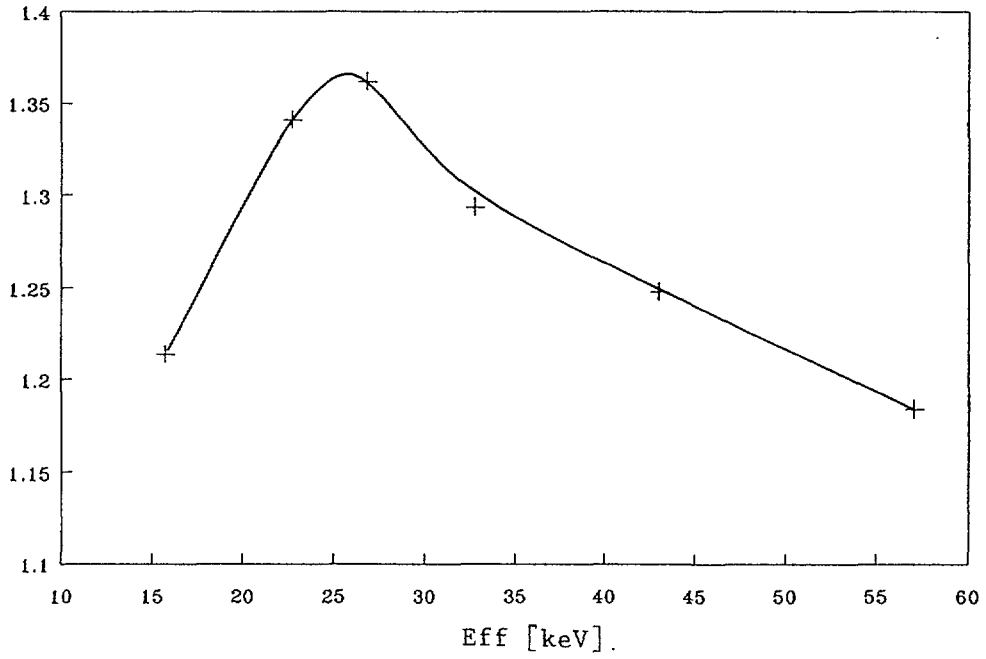

FIG. 1. Energy dependence of LiF TLD 100 when exposed free in air (air kerma of 50 mGy) normalized to ^{137}Cs radiation. Data reported by SSDL-NIPH, Prague.

A typical LiF phosphor energy response curve, estimated by the dosimetry laboratory in Prague, is given in Fig. 1.

Table VII reports the results of the intercomparison of the pilot programme.

TABLE VII. INTERCOMPARISON OF THE PILOT PROGRAMME OF TLD SYSTEMS

			Country				
			Czech Rep.	Ethiopia	Ghana	Iran, Islam.Rep.	Romania
TL group	Air kerma (mGy)	Effective energy (keV)	Evaluated air kerma (mGy) (VC) (%)				
B1	20.0	32.75	20.20 (2.2)	20.34 (3.7)	20.6 (3)	20.24 (3.3)	20.50 (3.2)
B2	0.41	43	0.44 (3.1)	0.387 (8.9)	0.3 (9.9)	0.36 (3)	0.29 (17.4)
B3	1.02	26.8	1.01 (6.6)	0.811 (14.6)	0.9 (12.2)	1.04 (15)	0.78 (5.5)

One observes that, depending on the dose level considered and on the country, dose measurement accuracy degree markedly varied (from less than 3% at 20 mGy to around 18% at 0.4 mGy). According to Fig. 1, energy response of TLDs varied up to 10% over the whole range of diagnostic X ray qualities.

Summarizing the results of calibration and intercomparison of the pilot programme, the dosimetric systems used in the CRP were able to measure doses of:

- 0.1 mGy with a variation coefficient from 20 to 33% (in one country up to 54%);
- 0.5 mGy with a variation coefficient from 10 to 20%;
- 1 mGy with a variation coefficient from 6 to 15%;
- 50 mGy with a variation coefficient below 5%.

According to these characteristics:

- the estimation of ESD below 0.2 mGy (typical of optimized chest PA examinations) was performed, in certain countries, with low accuracy and precision;
- the estimation of ESD for chest PA (with ESD >0.5 mGy), abdomen, lumbar spine and mammography was performed with satisfactory accuracy and precision.

4.2. PATIENT DOSES

The corrective actions taken between the first and second set of the quality control measurements lead to a significant dose reduction in almost all X ray rooms. Figs 2 and 3 allow comparison to be made for the chest examination. Only those hospitals where a second series of measurement was possible are included in these figures.

TABLE VIII. ESD RANGES BY EXAMINATION

Examination type	Minimum (mGy)	Mean (mGy)	Maximum (mGy)	Maximum/Minimum
Lumbar spine AP	1.88	9.9	51.02	27
Pelvis AP	0.52	6.66	19.3	37
Chest AP	0.02	0.61	4.44	222
Abdomen AP	0.33	6.6	29.25	89
Breast CC	1.94	7.1	15.1	8
Breast LAT	4.1	5.98	8.9	2

4.2.1. Range of dose values

The overall statistics of the dosimetry measurements are given in Table VIII for each examination type.

One observes the large variations in dose, particularly for chest and abdomen examinations, as found in the recent CEC trial on the image quality criteria. Although these variations may partly be attributable to those in patient thickness, they raise the question of practically implementing dose reduction actions in daily radiological practice. Concerning the breast examination, only two hospitals were able to provide information for cranio-caudal projection and one hospital for lateral projection, respectively.

The range of doses for chest examinations are illustrated in Figs 2 and 3.

Mean dose values compare rather well with the CEC reference dose values for lumbar spine, pelvis and abdomen, while for chest examination, the mean value was twice as high as the reference value.

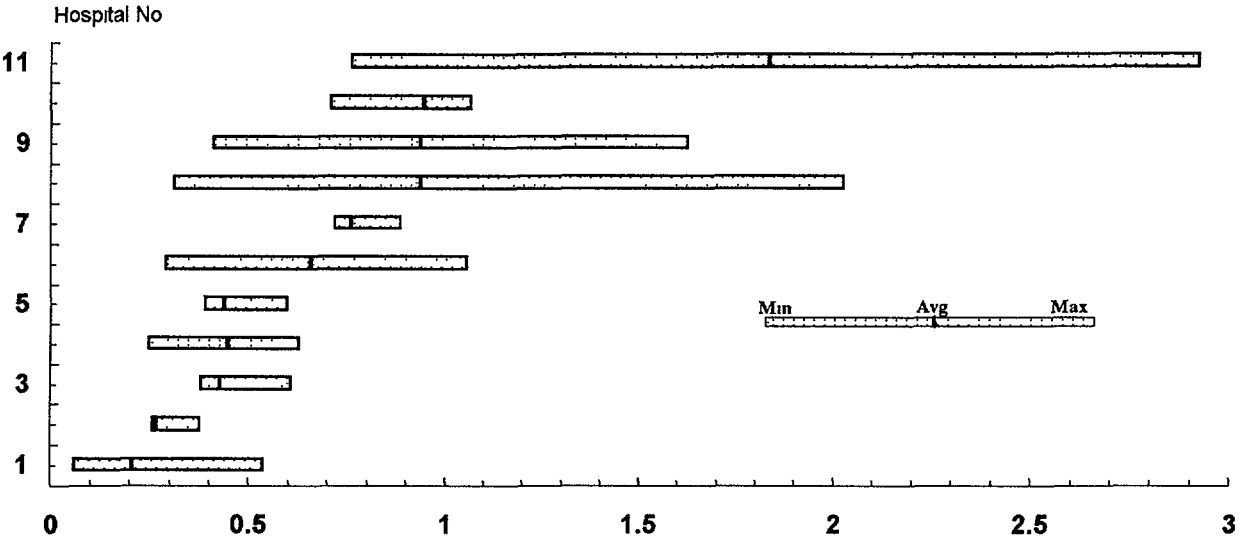

FIG. 2. Ranges and mean values of ESD for chest examinations by hospitals (first set of measurements).

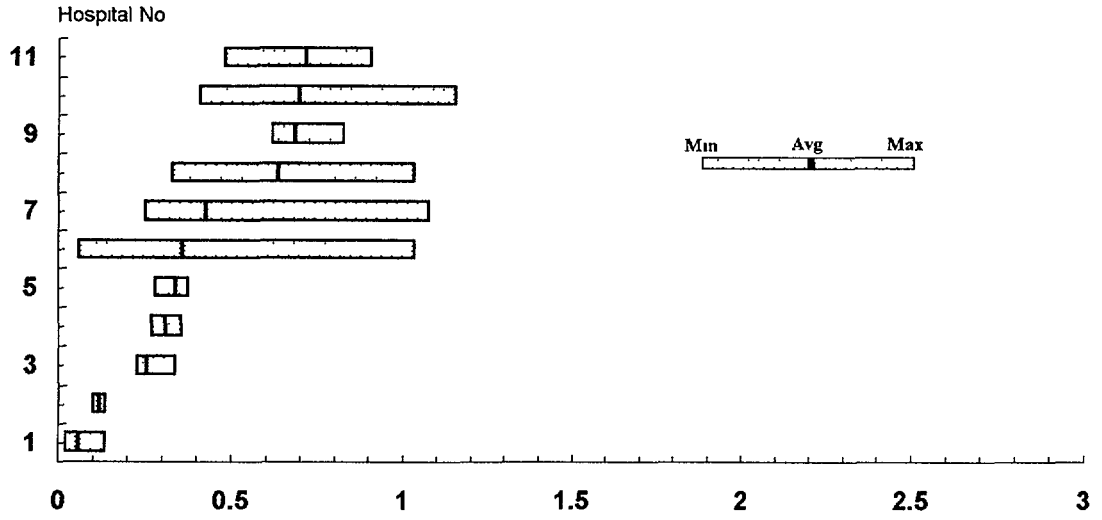

FIG. 3. Ranges and mean values of ESD for chest examinations by hospitals (second set of measurements).

As mentioned previously, breast information was gathered from two X ray departments where a variety of techniques (grid/no-grid) was used. Therefore, comparison with the CEC dose reference can only be made by X ray room.

4.2.2. Dose reductions

For practical reasons, some hospitals were not able to implement the corrective actions defined through the analysis of the results of the first set of dose measurements They were therefore excluded from the following analysis.

Table IX shows the percentage of X ray rooms where different kinds of technical actions were undertaken together with the overall dose reductions achieved.

TABLE IX RESULTS OF DIFFERENT DOSE REDUCTION ACTIONS

Dose reduction methods	X ray rooms where reduction methods were applied (%)	Average dose reduction (%)
Increased filtration	15	51
Increased tube potential	30	54
Increased screen-film sensitivity	30	48
Reduced mA · s*	6	57

*When the optical density of the film was too high

All examinations together, two dose reduction methods were more frequently implemented, namely, increasing tube potential and screen-film sensitivity. Filtration was added in several X ray rooms.

A few hospitals took action to lower film optical density by reducing mA · s.

All actions taken enabled a significant dose reduction to be achieved (a factor of 2 on average). The spread of these reductions, among the different X ray rooms, is shown in Fig. 4 for the four considered methods.

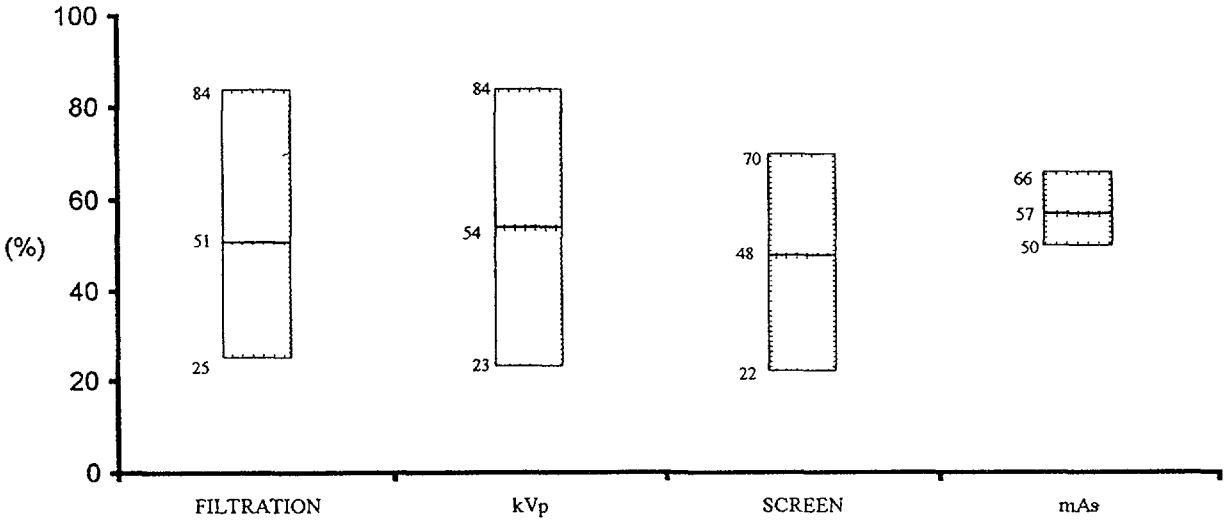

FIG. 4. Ranges and mean values (%) of ESD reduction by type of action.

TABLE X. DOSE REDUCTIONS ACHIEVED BY COUNTRY AND BY EXAMINATION TYPE

Country Hospital/Room	Examination and Projection	Method	Reduction %
Argentina 1/1	Chest	Increased Filtration	29
Argentina 2/3	Chest	Increased filtration + increased kV	28
Czech 2/2	Chest	Screen-film with higher sensitivity	72
Ethiopia 1/1	Chest	Increased kV	26
Ethiopia 2/2	Chest	Increased kV	75
Ghana 5/1	Chest	Screen-film with higher sensitivity	49
Ghana 6/1	Chest	Screen-film with higher sensitivity	58
Iran, Islam.Rep. 1/1	Chest	Increased kV	79
Iran, Islam. Rep. 1/2	Chest	Increased kV	65
Iran, Islam. Rep. 1/3	Chest	Increased kV	74
Romania 1/1	Chest	Increased kV*	23
Czech 2/1	Pelvis AP	Screen-film with higher sensitivity	38
Czech 3/1	Pelvis AP	Screen-film with higher sensitivity	51
Czech 3/2	Pelvis AP	Screen-film with higher sensitivity	48
Brazil 1/8	Lumbar spine AP/PA	Screen-film with higher sensitivity old-new	70
Brazil 2/6	Lumbar spine AP/PA	Screen-film with higher sensitivity old-new	36
Czech 2/1	Lumbar spine AP	Screen-film with higher sensitivity	56
Czech 3/1	Lumbar spine	Screen-film with higher sensitivity	56
Argentina 1/4	Abdomen	Increased filtration	35
Brazil 1/3	Abdomen	Screen-film with higher sensitivity	22
Brazil 2/10	Abdomen	Increased filtration	60

TABLE X. (cont.)

Country Hospital/Room	Examination and Projection	Method	Reduction %
Brazil 3/2	Abdomen	Increased filtration	84
Iran, Islam. Rep. 1/1	Abdomen	Increased kV	43
Iran, Islam. Rep. 1/2	Abdomen	Increased kV	27
Iran, Islam. Rep. 1/3	Abdomen	Increased kV	65
Iran, Islam. Rep. 2/4	Abdomen	Increased kV	28
Romania 1/4	Abdomen	Reduced mA.s*	50
Argentina 3/5	Breast	Screen-film with higher sensitivity	32
Argentina 3/6	Breast	Screen-film with higher sensitivity	37
Iran, Islam. Rep. 2/4	Breast	Increased kV	21

* Reduced mA · s due to too high optical density of the film.

Concerning filtration, the highest reduction of dose was obtained in X ray rooms where additional filtration had not previously been installed.

Through the increase of tube potential, the most significant improvements were obtained for chest examinations. Almost all of these examinations were performed using very low kV-techniques (55–80 kV).

In only one out of 21 X ray rooms dedicated to chest examinations, a "high kV-technique" ($\geq$ 100 kV) was being used.

With regard to the screen-film sensitivity two different solutions were adopted. Too old screens were in some cases replaced by new screens of the same sensitivity class; in other cases, faster screens were introduced.

Table X gives the details of the dose reductions achieved in each X ray room by country and by type of examination.

4.2.3. Comparison with reference dose values

Table XI summarizes the overall findings of the pilot programme for each examination type.

The overall effectiveness of the CRP pilot programme is expressed by the increased percentage of X ray rooms where the mean dose values are in compliance with the reference values for each examination type.

By observing the last column, some conclusions can be drawn.

TABLE XI. COMPLIANCE WITH THE CEC REFERENCE DOSE VALUES

Examination type	First set of measurements	Second set of measurements
	X ray rooms complying with the CEC reference dose value (%)	X ray rooms complying with the CEC reference dose value (%)
Lumbar spine (PA)	20	75
Pelvis	100	100
Chest (PA)	29	36
Abdomen	75	100
Breast (4.5 cm)	0	100

Most of the cases show a significant improvement which results in a total compliance with CEC requirement (pelvis, abdomen and breast).

In the case of chest PA, the reference value for ESD of 0.3 mGy was defined for "high kV technique", and therefore for high penetration of the X ray beam. Most of the hospitals participating in this pilot programme used "low kV technique", thus leading to a higher ESD even after optimization.

In summary, it seems that it is possible to develop reference values for wide applications of common examinations and use them as investigation levels. For the chest it is necessary to specify that the reference values apply only for "high kV technique" and will often be exceeded when the "low kV technique" is used.

4.3. IMAGE QUALITY ASSESSMENT

The CRP pilot programme also included an evaluation of the image quality through the use of the image quality criteria defined in the CEC working document. For practical reasons, it was not possible to get and analyse centrally neither individual radiographic films nor the individual answers provided by the field radiologist for each examined patient. (However, the images produced in each X ray department were scored by the field radiologists according to these criteria.) Therefore, general considerations are made hereafter concerning the image quality evaluation and their compliance with the image quality criteria, based on this score.

When available, detailed results for each participating country may be found in the tables of the Appendix.

The field radiologists used a qualitative rating: poor, satisfactory and good. Such a rating system was applied to each image criterium for each examination type and was mostly performed after the second set of measurements in order to make sure that there was no deterioration of the image in the process of dose reduction.

Concerning chest examinations, two specific criteria (Nos. 5 and 6) were particularly difficult to be seen (criterion 5: Reproduction of the vascular pattern in the whole lung, particularly the peripheral vessels. Criterion 6: Visually sharp reproduction of (a) the trachea and proximal bronchii, the borders of the heart and aorta, and (b) the diaphragm and costophrenic angles).

It is interesting to note that the same finding was obtained in the 1991 CEC image quality criteria trial and this confirms the need for improving the wording of these two criteria in order to avoid any ambiguity in their interpretation [14]. Concerning lumbar spine, a variety of scores was obtained among the different hospitals which pointed out the difficulty of seeing criteria 5 and 6 at a satisfactory level.

In a great majority of cases the visibility of criterion 6 was even scored as poor. As for the other examinations, it was not possible to come to any relevant conclusion due to the lack of data.

Finally, although trials carried out by others have shown that there was no clear correlation between dose and image quality, this pilot programme has demonstrated that it was possible to achieve significant dose reduction without introducing adverse factors on image quality, as judged by the field radiologists.

Note: A few cases of too low ESD values may deserve further investigation/confirmation as to whether the images meet the diagnostic needs. Examples from Annex I are the values of around 2.0 mGy for abdomen without grid and 0.05 mGy for chest PA. However, some low ESD values found for mammography are consistent with low breast thickness (3 cm) and with no use of grid.

4.4. FILM REJECTION

Analysis of rejected films is a subjective evaluation of image quality. Those images judged to be of inadequate quality are then categorized according to cause, which may related to competence of the technical personnel, equipment problems, specific difficulties associated with the examination, or some combination of these elements.

A film reject analysis also acts as a link between an X ray department's quality assurance efforts and the consistency of its image quality. However, due to the subjectivity of the analysis, it is possible that a given hospital may be approving the consistent production of images of poorer quality than those which could be achieved by the installed equipment.

Constraints such as shortages of radiology personnel, lack of equipment maintenance and service, and logistic problems concerning X ray films and chemicals may interfere with effectiveness of quality control approach.

More generally, the wide range of different local circumstances encountered within this CRP pilot programme made it difficult to draw comparisons between one participating hospital and another.

Tables XII and XIII give respectively the overall and detailed reject rate results recorded during the CRP pilot programme. The results, broken down by cause for rejection and by type of examination, are presented in the histograms (Figs 5 and 6).

As can be seen from Table XIII, reject rates related to abdomen and lumbar spine examinations varied from 2.3% to 19.2% while, for mammography, the corresponding figures were significantly lower: from 0.5% to 2% respectively.

As far as the causes of these reject rates are concerned (see Table XIV), large variations were found depending on the X ray room considered as well as on the average performance of the equipment used in the participating hospitals.

TABLE XII. GENERAL REJECT RATE RESULTS BY EXAMINATION TYPE

Examination	Mean reject rate (%)	Standard deviation (%)	Number of X ray rooms considered
Chest	7.6	3.9	19
Abdomen	11.6	4.9	8
Lumbar spine	6.7	3.7	7
Mammography	1.5	0.9	3

TABLE XIII. REJECT RATES AND FILM USAGE BY X RAY ROOM AND BY COUNTRY

Country Hospital/Room	Examination and projection	Reject rate (%)	Films/year
Argentina 1/1-1/2	Chest	8.5	2 500
Brazil 1/D	Chest	13.6	13 000
Brazil 2/D	Chest	6.1	26 000
Czech 1/1	Chest	3.3	16 000
Czech 2/2	Chest	2.8	28 000
Czech 3/1 and 3/2	Chest, Pelvis AP and Lumbar spine	3.7	52 500
Czech 4/1	Chest, Pelvis AP and Lumbar spine	9.6	34 000
Ghana 1/1	Chest	5.7	2 000
Ghana 2/1	Chest	5.1	5 200
Ghana 2/2	Chest	6.5	2 000
Ghana 3/1	Chest	4	5 700
Ghana 5/1	Chest	11.2	3 100
Ghana 6/1	Chest	6.5	3 000
Iran, Islam. Rep. 1/1	Chest and abdomen	15	30 000
Iran, Islam. Rep. 1/2	Chest and abdomen	5	7 200
Iran, Islam. Rep. 1/3	Chest and abdomen	15	36 000
Romania 1/1	Chest	7.4	4 300
Czech 2/1	Pelvis AP and lumbar spine	3.4	22 000
Ghana 1/1	Pelvis AP and lumbar spine AP	5.7	2 000
Ghana 2/2	Pelvis AP	6.5	2 000
Brazil 1/B-2/6	Lumbar spine AP	6.1	26 000
Ghana 3/1	Lumbar spine AP	4	5 700
Argentina 1/4	Abdomen	10	1 500
Brazil 1/3	Abdomen	13.6	13 000
Brazil 2C	Abdomen	6.1	26 000
Brazil 3/2	Abdomen	19.2	9 500
Romania 1/4	Abdomen	9	1 200
Argentina 3/5-3/6	Breast	2	50 000
Iran, Islam. Rep. 2/4	Breast	0.5	40 000

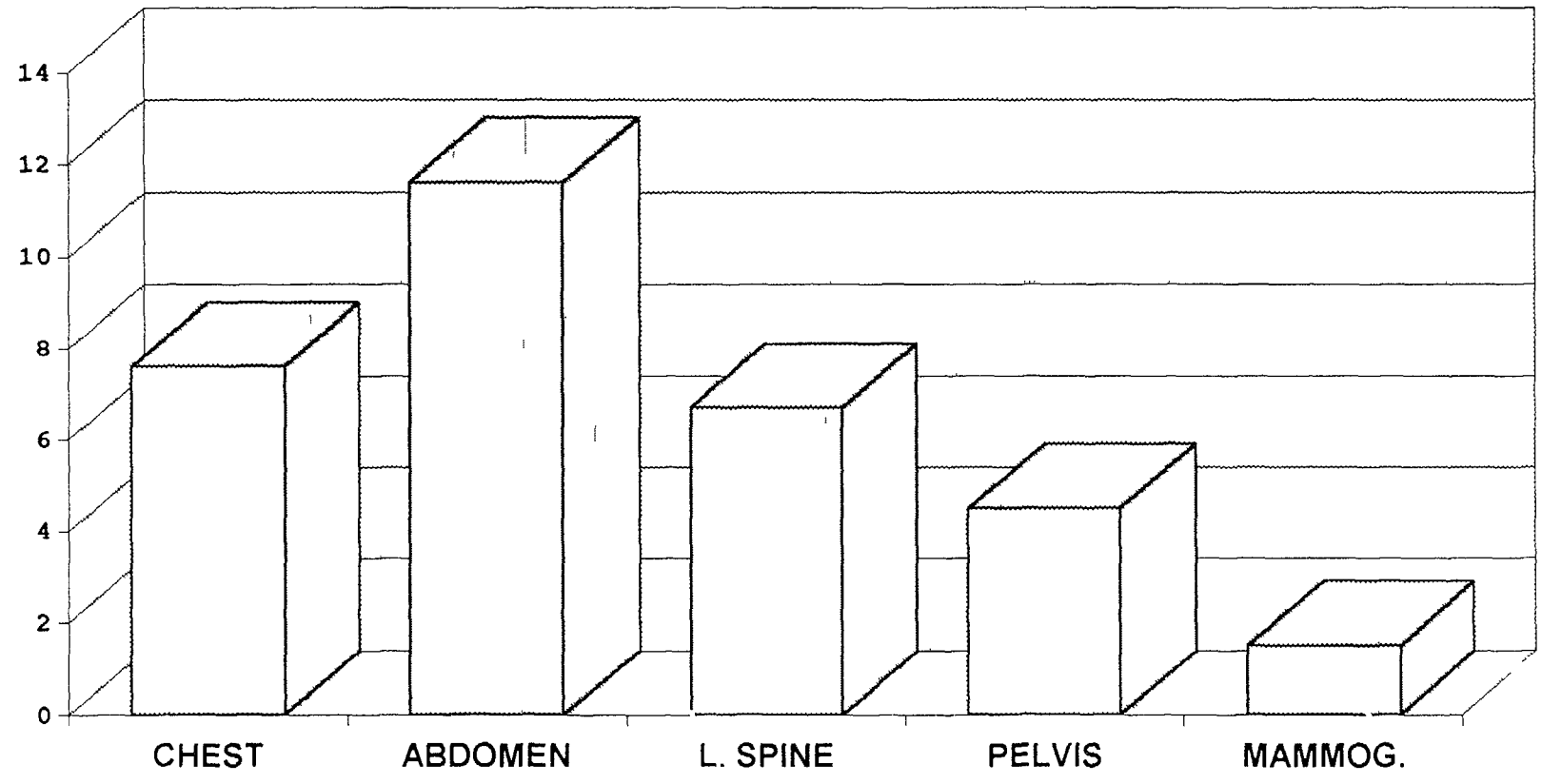

FIG. 5. Rejected films in percentages of the total number of films per examination.

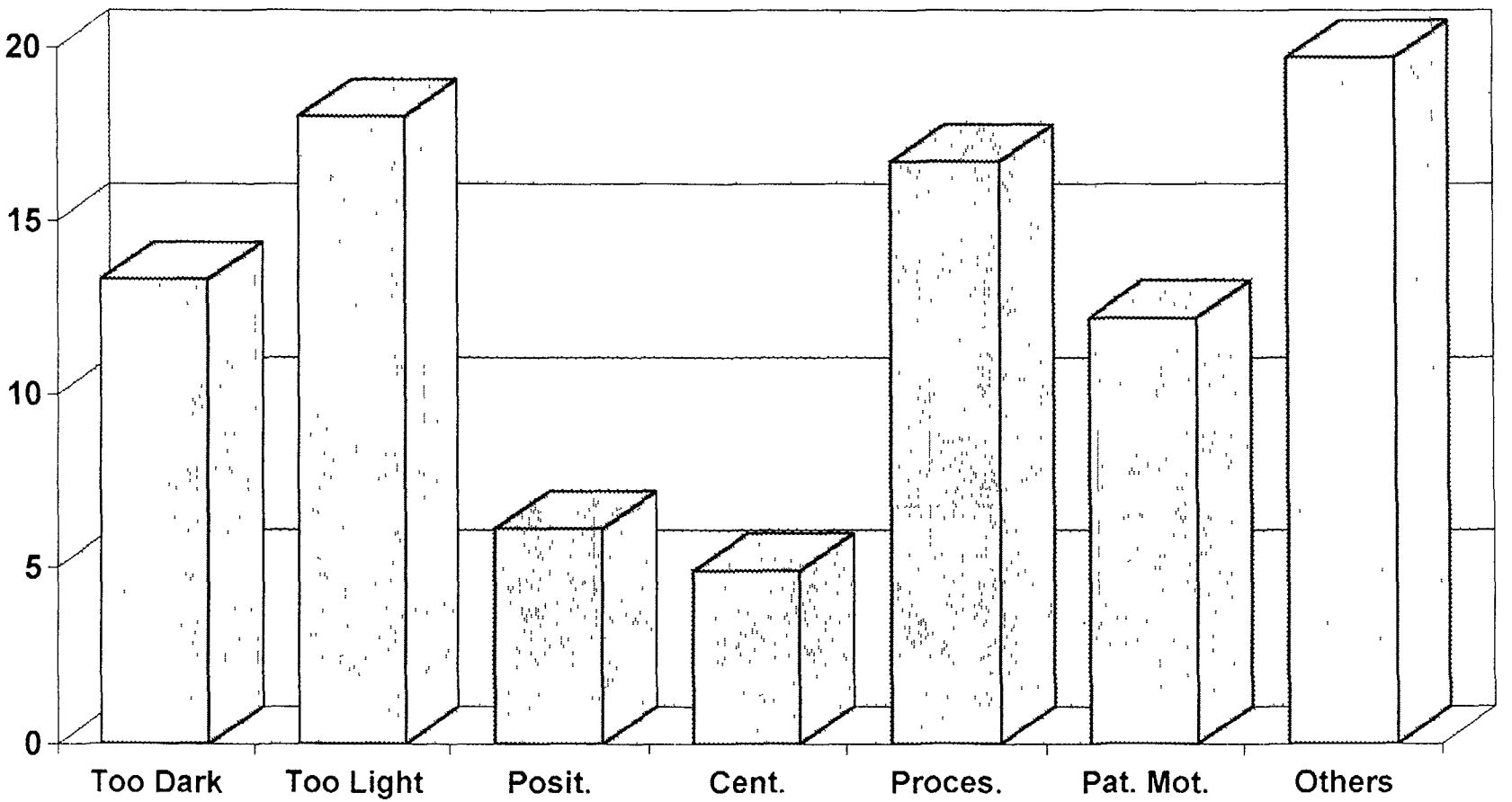

FIG. 6. Rejected films (relative percentages) averaged over 22 rooms in six countries.

TABLE XIV. REJECT RATES BY CAUSE AND BY COUNTRY

Country Hospital/Room	Too dark (%)	Too light (%)	Positioning (%)	Centering	Film processing	Patient movement	Other
Argentina (chest)	23	31	3.8	3.8	19	12	11.2
Argentina (abdomen)	50	33	8.3	8.3	--	--	0.4
Argentina (breast)	15	15	60	10	--	--	--
Brazil	28	28	15	--	--	11	18
Czech 1/1 (chest)	13	34	7.2	11	7.2	3.4	22.5
Czech 2/2 (chest)	18	38	8.8	21	12	2.3	--
Czech (pelvis) + (lumbar spine) 2/1	21	26	14	15	6.4	2.4	15.2
Czech (chest) + (pelvis) 3/1-3/2	17	18	1.6	8.5	14	3.8	37.1
Czech (chest) + (pelvis) + (lumb. spine) 4/1	16	25	19	2.3	9	2.2	26.5
Ghana 1/1 (chest) + (pelvis) + (lumb. spine) 1/1	11	21	--	11	19	38	--
Ghana (chest) + (pelvis) 2/1	5.6	12	--	--	16	18	48.4
Ghana (chest) + (pelvis) 2/2	7.7	6.5	2 000	--	--	--	--
Ghana (chest) 3/1	5	15	--	--	20	40	20
Ghana (chest) + (spine) 5/1	7.1	7.1	--	--	34	41	10.8
Ghana (chest) 6/1	6.3	19	--	--	25	25	24.7
Iran, Islam. Rep. (chest) + (abdomen) 1/1-1/2	--	--	50	--	30	10	10
Iran, Islam. Rep. (chest) 1/3	--	--	40	--	20	12	28
Iran, Islam. Rep. (mammography)	--	--	38	--	43	15	4
Romania (chest)	15	15	2	2	15	3	48
Romania (abdomen)	16	16	5	5	15	6	22

Among the most important causes of reject, one observes inadequate setting of physical parameters which lead to too dark or too light films (from 13% to 18%), processing malfunctions (16.7%), patient movement and positioning of patient.

4.5. Doses to staff

According to the general occupational radiation protection rules, doses received by the different personnel categories involved in the CRP pilot programme were monthly recorded in all participating hospitals.

Three ranges of doses were considered: below 0.3 mSv, between 0.3 mSv and 0.5 mSv, between 0.5 mSv and 1 mSv.

Within a specific X ray department, no simple correlations were found between actual occupational received doses and the radiological activity performed in the different X ray rooms. Almost all personal dosimeters recorded dose values below 0.3 mSv.

5. CONCLUSIONS

Despite some practical limitations inside the pilot project, and the obvious difficulties connected to the starting of a new programme in countries from different continents and with different levels of radiological and radiation protection infrastructures, the results have shown that it is possible to achieve dose reduction at little or no cost. The basis has been established for a wider approach to the problem of patient dose reduction diagnostic radiology.

The pilot programme has specifically confirmed that there is usually a considerable scope for dose reduction in diagnostic radiology and that simple and low-cost methods can be used to achieve significant dose reductions, without loss of diagnostic information of the X ray images.

It seems possible to choose reference levels of dose that are valid world wide for common examinations. Furthermore, it has been shown that it is possible and advisable to use them as investigation levels in the sense that it is reasonable to investigate the reasons when they are frequently exceeded with normal sized patients.

The pilot programme has proven to be valuable as a learning process for those taking part and has also provided them with hands-on experience, which can also add effectiveness to practical training programmes on radiation protection in diagnostic radiology.

This kind of pilot programme is considered a good and cost effective start for national projects on radiation protection and quality assurance in diagnostic radiology in developing countries. The awareness gained through these pilot programme should contribute to a better use of technical co-operation assistance and improve the safety and lifetime of X ray equipment.

Lessons learned and recommendations for future pilot programmes:

1. To ensure a neutral evaluation of the diagnostic information of the pictures. This should be in addition to and not in replacement of test phantoms on contrast/detail detectability.

2. To improve the selection of TLDs, and the quality control of the TLD readers, to reduce the standard deviation of the readings.

3. To improve the uniformity of the sample of patients, ensuring that the minimum of ten patients for each set of measurements is available.

4. To extend the pilot programme to more complex examinations involving fluoroscopy and computed tomography where available.

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Appendix

SUMMARY OF REPORTS BY PARTICIPANTS

This appendix deals with individual patient dose data and quality control measurement results obtained by each country participating in the CRP.

It provides the reader with information on practical implementation of the quality control protocol established at the beginning of the CRP and describes the framework within which the field measurements were actually carried out by the participants.

Where available, the following items are included:

- hospitals and rooms (coded);
- Type of X ray equipment;
- Parameters controlled;
- Compliance with the CEC image criteria.

For reasons of simplicity, country related data are presented in alphabetical order.

ARGENTINA

Chief investigator and research team:

Chief investigator:	J.J. Skvarca
Research team:	A. La Pasta
	P. Buda

Institution(s):

Ministerio de Salud
Secretaría de Salud
Dirección Nacional de Regulación y Control
Dirección de Control Ejercicio Profesional
Departamento Equipamiento Médico Sanitario (Radiofísica)

Names of the hospital(s):

Centro de Diagnóstico "Dr. Di Rienzo"
Centro de Investigaciones Mamarias "Dr. Manuel Cymberknoh"
Hospital Central de Mendoza

Radiology staff involved in the pilot programme:

A. di Rienzo
M. Cymberknoh
V. Ugarte

TABLE I. SUMMARY OF THE MEASUREMENTS OF PATIENT ENTRANCE SURFACE DOSE (ARGENTINA)

HOSPITAL	X RAY ROOM	EXAMINATION	DOSE PRIOR TO QC (mGy)	DOSE AFTER QC (mGy)	DOSE REDUC-TION IF ANY (%)	CORRECTIVE ACTIONS
1	1	Chest PA	0.48	0.34	29	Increase of filtration : 1 mm Al.
1	2	Chest PA	0.24	--	--	Replacement of X ray tube
2	3	Chest PA	0.43	0.31	28	Use of high voltage technique
1	4	Abdomen	5.10	3.31	35	Increase of filtration : 1 mm Al.
3	5	Breast	11.20	7.61	32	Increase of speed class of film/screen combination and reduction of kV
3	6	Breast	10.95	6.91	37	Increase of speed class of film/screen combination and reduction of kV

TABLE II. QC PARAMETERS CONTROLLED (ARGENTINA)

PARAMETERS	HOSPITAL 1 X RAY ROOM 1	HOSPITAL 1 X RAY ROOM 2	HOSPITAL 2 X RAY ROOM 3	HOSPITAL 1 X RAY ROOM 4	HOSPITAL 3 X RAY ROOM 5	HOSPITAL 3 X RAY ROOM 6
Film Processing Conditions	A	A	A	A	A	A
kV Accuracy (10%)* kV Reproducibility (4%)* kV Consistency (10%)*	A A A	A A A	A A A	NA NA A	A A A	A A A
HVL, mm of Al (measured at 80 kV)	1.6 NA	73.0 NA	2.7 A	2.0 NA	0.3** A	0.3** A
Timer Accuracy (10%)* Timer Reproducibility (5%)*	A A	A A	A A	A A	A A	A A
mA · s Linearity, Consistency	NA	A	A	A	A	A
Output (mGy/mA · s) (5%)* Consistency	0.075 A	0.017 NA	0.056 A	0.049 A	0.037 A	0.036 A
Light/Radiation Beam Alignment (deviation at 1 m) (+2%)*	NA	A	A	NA	A	A

* Tolerance **Measured at 28 kVp A = Acceptable NA = Not acceptable NM = Not measured

TABLE III. COMPLIANCE WITH THE CEC IMAGE CRITERIA. CHEST (PA) (ARGENTINA)

IMAGE CRITERIA	HOSPITAL 1 X RAY ROOM 1	HOSPITAL 1 X RAY ROOM 2	HOSPITAL 2 X RAY ROOM 3
Performed at deep inspiration and with suspended respiration	+++	+++	+++
Symmetrical reproduction of the thorax	+++	++	+++
Medial border of the scapulae to be outside the lung fields	+++	++	+++
Reproduction of the whole rib cage above the diaphragm	+++	++	+++
Reproduction of the vascular pattern in the whole lung, particularly the peripheral vessels	+++	++	++
Visually sharp reproduction of the trachea and proximal bronchi, the borders of the heart and aorta and the diaphragm and costo-phrenic angles	++	++	+++
Visualization of the retrocardiac lung and the mediastinum	++	++	+++

+ Poor ++ Satisfactory +++ Good

TABLE IV. COMPLIANCE WITH THE CEC IMAGE CRITERIA. BREAST (CRANIO-CAUDAL) (ARGENTINA)

IMAGE CRITERIA	HOSPITAL 3 X RAY ROOM 5	HOSPITAL 3 X RAY ROOM 6
Visually sharp reproduction of the whole glandular breast	++	+++
Visually sharp reproduction of the cutis and subcutis	++	++
Nipple should be parallel to the film	+++	+++

+ Poor ++ Satisfactory +++ Good

BRAZIL

Chief investigator and research team:

A.M. Campos de Araujo
J.C. Passos
L.C. Ribeiro
J.T. Farias

Institution(s):

Instituto de Radioproteçáo e Dosimetria
Comissáo Nacional de Energia Nuclear

Names of the hospital(s):

Hospital Universitário Clementino Fraga Filho (1)
Hospital Geral de Bonsucesso (2)
Hospital Universitário Pedro Ernesto (3)
Hospital Raphael de Paula Souza (4)

Radiology staff involved in the pilot programme:

A. Arantes do Nascimento (1)
V. de Lucas (2)
B. Pellisaro (3)
A. Resende (4)

(Note: These are the Heads of the radiological staff in each hospital)

TABLE I. SUMMARY OF THE MEASUREMENTS OF PATIENTS ENTRANCE SURFACE DOSE (BRAZIL)

HOSPITAL	X RAY ROOM	EXAMINATION	DOSE PRIOR TO QC (mGy)	DOSE AFTER QC (mGy)	DOSE REDUCTION IF ANY (%)	CORRECTIVE ACTIONS
1	C	Chest PA	0.65	0.64	0	None
2	D	Chest PA	0.29	0.28	0	None
4	0	Chest PA	0.17	--	--	None
1	3	Abdomen PA/AP	5.72	4.51	21	New screens
2	C	Abdomen PA/AP	8.70	3.46	60	Increase of filtration
3	2	Abdomen PA/AP	15.25	2.46	84	Increase of filtration
1	B	Lumbar Spine PA/AP	14.83	4.36	70	Increase of filtration
2	6	Lumbar Spine PA/AP	14.57	9.28	36	New intensifying screens
1	5	Urography AP	6.00	8.65	44	Unknown
2	8	Urography AP	6.61	--	--	None
3	3	Urography AP	9.11	5.79	36	Increase of filtration and new intensifying screens
1	B	Skull PA/AP	5.24	4.49	14	Increase of filtration
1	6	Skull PA/AP	3.72	3.08	17	Unknown
2	9	Skull PA/AP	6.01	4.74	21	Increase of filtration
2	6	Skull PA/AP	3.69	3.11	16	Unknown
2	2	Skull PA/AP	7.34	--	--	None
1	A	Hip AP/PA	16.08	4.35	73	Increase of filtration
2	2	Hip AP/PA	14.08	6.20	56	Increase of filtration and new intensifying screens
3	5	Hip AP/PA	11.93	--	--	Increase of filtration and new intensifying screens

TABLE II. QC PARAMETERS CONTROLLED (BRAZIL)

PARAMETERS	HOSPITAL/X RAY ROOM NUMBER												
	1/C	2/D	4/0	1/B	1/6	2/9	2/6	2/2	1/3	2/C	3/2	1/A	3/3
Film processing conditions	A	A	A	A	A	A	A	A	A	A	A	A	A
kV Accuracy (10%)*	A	A	A	A	A	A	A	A	A	A	A	A	A
kV Reproducibility (4%)*	A	A	A	A	A	A	A	A	A	A	A	A	A
kV Consistency (10%)*	A	A	A	A	A	A	A	A	A	A	A	A	A
HVL, mm of Al (measured at 80 kV)	2.7	3.5	3.4	2.7	2.7	2.0	3.3	1.6	3.4	2.3	1.7	2.2	2.5
Timer accuracy (10%)*	A	A	A	A	A	A	A	A	NA	A	A	A	A
Timer reproducibility (5%)*													
mA·s linearity, consistency	A	A	A	A	A	A	A	A	A	A	A	A	A
Output (mGy/mA·s) (5%)*	0.08	0.10	0.05	0.07	0.05	0.10	0.06	0.09	0.08	0.09	0.10	0.07	0.09
Consistency	A	NA	A	A	A	A	A	A	NA	A	A	NA	A
Light/radiation beam alignment (deviation at 1 m) (+2%)*	A	A	A	NA	A	A	A	A	A	A	A	NA	A

*Tolerance A = Acceptable NA = Not acceptable NM = Not measured

TABLE III. COMPLIANCE WITH THE CEC IMAGE CRITERIA. CHEST (PA) (BRAZIL)

IMAGE CRITERIA	HOSPITAL 1 X RAY ROOM C	HOSPITAL 2 X RAY ROOM D	HOSPITAL 4 X RAY ROOM --
Performed at deep inspiration and with suspended respiration	++	+++	+++
Symmetrical reproduction of the thorax	++	+++	+++
Medial border of the scapulae to be outside the lung fields	++	++	+++
Reproduction of the whole rib cage above the diaphragm	++	+++	+++
Reproduction of the vascular pattern in the whole lung, particularly the peripheral vessels	++	+++	+++
Visually sharp reproduction of the trachea and proximal bronchi, the borders of the heart and aorta and the diaphragm and costo-phrenic angles	++	+++	+++
Visualization of the retrocardiac lung and the mediastinum	++	+++	+++

+ Poor ++ Satisfactory +++ Good

TABLE IV. COMPLIANCE WITH THE CEC IMAGE CRITERIA. LUMBAR SPINE (AP/PA) (BRAZIL)

IMAGE CRITERIA	HOSPITAL 1 X RAY ROOM B	HOSPITAL 2 X RAY ROOM 6
Linear reproduction of the upper and lower-plate surfaces in the centred beam area and visualization of the intervertebral spaces	++	+
Visually sharp reproduction of the pedicles	++	+
Visualization of the intervertebral joints	++	+
Reproduction of the spinous and transverse processes	++	+
Visually sharp reproduction of the cortex and trabecular structures	++	+
Reproduction of the adjacent soft tissues, particularly the psoas shadows	++	+

+ Poor ++ Satisfactory +++ Good

TABLE V. COMPLIANCE WITH THE CEC IMAGE CRITERIA. SKULL (PA/AP) (BRAZIL)

IMAGE CRITERIA	HOSPITAL 1 X RAY ROOM B	HOSPITAL 2 X RAY ROOM 6	HOSPITAL 2 X RAY ROOM 9
Symmetrical reproduction of the skull, particularly cranial vault, orbits and petrous bones	+++	++	+
Projection of the apex of the petrous temporal bone into the centre of the orbits	+++	++	+
Visually sharp reproduction of the frontal sinus, ethmoid cells and apex of the petrous temporal bones and the internal auditory canals	+++	++	+
Visually sharp reproduction of the outer and inner tables of the cranial vault	+++	++	+

+ Poor ++ Satisfactory +++ Good

TABLE VI. COMPLIANCE WITH THE CEC IMAGE CRITERIA. ABDOMEN (AP) (BRAZIL)

IMAGE CRITERIA	HOSPITALS		
	HOSPITAL 1 X RAY ROOM 3	HOSPITAL 2 X RAY ROOM C	HOSPITAL 3 X RAY ROOM 2
Symmetrical reproduction of the pelvis	+	++	+
Visualization of the sacrum and its intervertebral foramina	+	++	+
Visualization of the pubic and ischial rami	+	++	+
Visualization of the sacroiliac joints	+	++	+
Reproduction of the necks of the femora which should not be distorted by foreshortening or rotation	+	++	+
Reproduction of spongiosa and corticalis, and visualization of the trochanters	+	++	+

+ Poor ++ Satisfactory +++ Good

CZECH REPUBLIC

Chief investigator and research team:

Chief investigator:	O. Kodl
Research team:	I. Zachariašova
	V. Klener
	O. Vojtisek

Institution(s):

National Institute of Public Health

Names of the hospital(s):

Teaching hospital: Department for Internal Diseases, Prague
Teaching hospital: Orthopedic Clinic, Prague
Teaching hospital: Central Radiodiagnostic Department, Prague
City hospital: Radiodiagnostic Department, Prague

Radiology staff involved in the pilot programme:

J. Ort
K. Zizkovska
V. Brezina
J. Sprindrich
J. Husakova

TABLE I. CHARACTERISTICS OF X RAY DEVICES (CZECH REPUBLIC)

HOSPITAL	X RAY ROOM	X RAY UNIT*					PROCESSOR	
		TYPE	INSTALLATION DATE	GENERATOR (PULSES)	TOTAL FILTRATION (mm AL)	FOCUS SPOT SIZE (mm) S/L	TYPE	INSTALLATION DATE
1	1	CHIRALUX 1	1985	6	1.5	1.2/2.0	MARF 120L	1985
2	1	TELEMAX 850	1980	HF	3	--	MARF 120L	1980
2	2	CHIRALUX 2	1987	6	3	1.2/2.0	MARF 120L	1987
3	1	DUROLUX	1966	6	3	1.2/2.0	MARF 120L	1982
3	2	CHIRODUR 125	1978	2	3	1.2/2.0	AR 510/HOPE	1979/1991
4	1	CHIRALUX 2	1988	6	3	1.2/2.0	MARF 120L	1989

*All X ray units were equipped with an antiscatter grid.

TABLE II. SUMMARY OF THE MEASUREMENTS OF PATIENT ENTRANCE SURFACE DOSE (CZECH REPUBLIC)

HOSPITAL	X RAY ROOM	EXAMINATION	DOSE PRIOR TO QC (mGy)	DOSE AFTER QC (mGy)	DOSE REDUC-TION IF ANY (%)	CORRECTIVE ACTIONS
1	1	Chest PA	0.99	--	--	Reorganization of workplace
2	2	Chest PA	0.45	0.13	71.1	Increase of speed of film screen combination
3	2	Chest PA	0.11	0.1	--	
4	1	Chest PA	0.08	--	--	Reorganization of workplace
2	1	Lumbar Spine AP	10.76	4.74	55.9	Increase of speed of film screen combination
3	1	Lumbar Spine AP	8.74	3.87	59.1	
3	2	Lumbar Spine AP	5.56	--	--	None
4	1	Lumbar Spine AP	8.39	--	--	None
2	1	Pelvis AP	5.59	3.28	41.3	Increase of speed of film screen combination
3	1	Pelvis AP	6.91	3.12	53.5	Increase of speed of film screen combination
3	2	Pelvis AP	5.98	3.09	48.2	Increase of speed of film screen combination
4	1	Pelvis AP	6.99	--	--	None

TABLE III. QC PARAMETERS CONTROLLED (CZECH REPUBLIC)

PARAMETERS	HOSPITAL 1 X RAY ROOM 1	HOSPITAL 2 X RAY ROOM 1	HOSPITAL 2 X RAY ROOM 2	HOSPITAL 3 X RAY ROOM 1	HOSPITAL 3 X RAY ROOM 2	HOSPITAL 4 X RAY ROOM 1
Film Processing Conditions	CHIRALUX 1 NA	TELEMAX550 A	CHIRALUX 2 NA	DUROLUX NA	CHIRODUR 5 NA	CHIRALUX 2 NA
kV Accuracy (10%)* kV Reproducibility (4%)* kV Consistency (10%)*	4.6 2.4 NM	7.0 1.5 1.7	10.5 2.1 8.0	8.7 2.3 10.6	5.1 1.5 1.8	3.0 0.3 7.0
HVL, mm of Al (measured at 80 kV)	2.4	3.1	3.1	3.2	3.0	3.3
Timer Accuracy (10%)* Timer Reproducibility (5%)*	2.3 0.8	4.5 0.2	7.3 0.01	12.3 3.6	1.5 0.9	6.6 0.3
Output (mGy/mA · s) (5%)*	2.4	3.2	1.5	2.5	1.4	1.4
Light/Radiation Beam Alignment (deviation at 1 m) (+2%)*	A	A	NA	NA	A	A

* Tolerance A = Acceptable NA = Not Acceptable NM = Not Measured

TABLE IV. COMPLIANCE WITH THE CEC IMAGE CRITERIA. CHEST (PA) (CZECH REPUBLIC)

IMAGE CRITERIA	HOSPITAL 1 X RAY ROOM 1	HOSPITAL 2 X RAY ROOM 2	HOSPITAL 3 X RAY ROOM 2	HOSPITAL 4 X RAY ROOM 1
Performed at deep inspiration and with suspended respiration	+++	+++	+++	+++
Symmetrical reproduction of the thorax	+++	+++	+++	+++
Medial border of the scapulae to be outside the lung fields	+++	+++	+++	+++
Reproduction of the whole rib cage above the diaphragm	+++	+++	+++	+++
Reproduction of the vascular pattern in the whole lung, particularly the peripheral vessels	+++	+++	+++	++
Visually sharp reproduction of the trachea and proximal bronchi, the borders of the heart and aorta and the diaphragm and costo-phrenic angles	+++	+++	+++	++
Visualization of the retrocardiac lung and the mediastinum	+++	+++	+++	+++

+ Poor ++ Satisfactory +++ Good

TABLE V. COMPLIANCE WITH THE CEC IMAGE CRITERIA. LUMBAR SPINE (AP/PA) (CZECH REPUBLIC)

IMAGE CRITERIA	HOSPITAL 1 X RAY ROOM 1	HOSPITAL 2 X RAY ROOM 2	HOSPITAL 3 X RAY ROOM 2	HOSPITAL 4 X RAY ROOM 1
Linear reproduction of the upper and lower-plate surfaces in the centred beam area and visualization of the intervertebral spaces	+++	+++	+++	+++
Visually sharp reproduction of the pedicles	+++	+++	++	++
Visualization of the intervertebral joints	++	++	++	++
Reproduction of the spinous and transverse processes	+++	+++	++	++
Visually sharp reproduction of the cortex and trabecular structures	++	+++	++	++
Reproduction of the adjacent soft tissues, particularly the psoas shadows	+++	++	+	+

+ Poor ++ Satisfactory +++ Good

TABLE VI. COMPLIANCE WITH THE CEC IMAGE CRITERIA. PELVIS (AP) (CZECH REPUBLIC)

IMAGE CRITERIA	HOSPITAL 1 X RAY ROOM 1	HOSPITAL 2 X RAY ROOM 2	HOSPITAL 3 X RAY ROOM 2	HOSPITAL 4 X RAY ROOM 1
Symmetrical reproduction of the pelvis	+++	+++	+++	+++
Visualization of the sacrum and its intervertebral foramina	++	++	++	++
Visualization of the pubic and ischial rami	+++	+++	++	++
Visualization of the sacroiliac joints	+++	+++	+++	+++
Reproduction of the necks of the femora which should not be distorted by foreshortening or rotation	+++	+++	+++	+++
Reproduction of spongiosa and corticalis, and visualization of the trochanters	++	++	++	+++

+ Poor ++ Satisfactory +++ Good

ETHIOPIA

Chief investigator and research team:

Chief investigator:	Wondwosen Mengesha
Research team:	Hailu Wolde
	Tsegaye Tolossa
	Dereje Anbessei

Institution(s):

Radiation Protection Unit
Institute of Pathobiology
Addis Ababa University

Names of the hospital(s):

Black Lion Hospital
Zewditu Hospital
General Army Hospital (activity interrupted due to equipment failure)

Radiology staff involved in the pilot programme:

None

The CRP pilot programme was started in three hospitals, namely the Black Lion hospital, the Zewditu hospital and the General Army hospital. It was fully completed in the first two hospitals, but could not be completed in the General Army hospital due to technical failure encountered with the X ray equipment.

Chest (PA) and pelvis (AP) examinations were considered for the study. The latter was found to be rare so that water phantom was used also for collecting data. A total of 20 patients were considered for each examination.

Technical problems were faced which made the study relatively difficult. In both hospitals considered, there was a severe shortage of chemicals for the darkroom. This had a direct impact on the dose reduction process. Commonly exhausted chemicals were used. In order to get the required image quality on developed films, radiographic settings were increased. Radiographic films were not sufficient in the hospitals. Therefore, economical usage of films had to be exercised which hindered the flexible usage in the study of image quality. Three-fourths of the equipment in use was more than twenty years of age. Speed class of film screen combinations could not be known.

Irrespective of the problems encountered, a considerable reduction in patient dose values were achieved for chest examination by employing higher kilo voltage technique and consistency in the settings. No measures were taken for the pelvis examination.

TABLE I. SUMMARY OF THE MEASUREMENTS OF PATIENTS ENTRANCE SURFACE DOSE (ETHIOPIA)

HOSPITAL	X RAY ROOM	EXAMINATION	DOSE PRIOR TO QC (mGy)	DOSE AFTER QC (mGy)	DOSE REDUC-TION IF ANY (%)	CORRECTIVE ACTIONS
1	1	Chest PA	0.94	0.70	25.5	Increase of kVp and lowering of mA · s
2	2	Chest PA	1.74	0.43	75.3	Increase of kVp and lowering of mA · s
1	3	Pelvis AP	5.11	9.74	--	None
2	4	Pelvis AP	5.41	11.40	--	None

TABLE II. QC PARAMETERS CONTROLLED (ETHIOPIA)

PARAMETERS	HOSPITAL 1 X RAY ROOM 1	HOSPITAL 2 X RAY ROOM 2	HOSPITAL 1 X RAY ROOM 3	HOSPITAL 2 X RAY ROOM 4
Film Processing Conditions	NA	NA	NA	NA
kV Accuracy (10%)* kV Reproducibility (4%)* kV Consistency (10%)*	A A A	NA NA NA	A A A	A A A
HVL, mm of Al (measured at 80 kV)	3.69	4.14	3.55	3.33
Timer Accuracy (10%)* Timer Reproducibility (5%)*	A A	NA NA	NA NA	NA NA
mA · s Linearity, Consistency	A	A	A	A
Output (mGy/mA · s) (5%)* Consistency	NA	A	A	A
Light/Radiation Beam Alignment (deviation at 1 m) (+2%)*	A	A	A	A
Grid Alignment	A	NA	NA	A

*Tolerance A = Acceptable NA = Not acceptable NM = Not measured

TABLE III. COMPLIANCE WITH THE CEC IMAGE CRITERIA. CHEST (PA) (ETHIOPIA)

IMAGE CRITERIA	HOSPITAL 1 X RAY ROOM 1	HOSPITAL 2 X RAY ROOM 2
Performed at deep inspiration and with suspended respiration	++	++
Symmetrical reproduction of the thorax	+++	+++
Medial border of the scapulae to be outside the lung fields	++	+++
Reproduction of the whole rib cage above the diaphragm	+	++
Reproduction of the vascular pattern in the whole lung, particularly the peripheral vessels	+	+
Visually sharp reproduction of the trachea and proximal bronchi, the borders of the heart and aorta and the diaphragm and costo-phrenic angles	++	+++
Visualization of the retrocardiac lung and the mediastinum	+	++

+ Poor ++ Satisfactory +++ Good

TABLE IV. COMPLIANCE WITH THE CEC IMAGE CRITERIA. PELVIS (AP) (ETHIOPIA)

IMAGE CRITERIA	HOSPITAL 1 X RAY ROOM 3*
Symmetrical reproduction of the pelvis	+++
Visualization of the sacrum and its intervertebral foramina	+
Visualization of the public and ischial rami	++
Visualization of the sacroiliac joints	+++
Reproduction of the necks of the femora which should not be distorted by foreshortening or rotation	+++
Reproduction of spongiosa and corticalis, and visualization of the trochanters	+

*Image quality evaluation at Hospital 2/X ray Room 4 was not made since a water phantom was used for data collection.

+ Poor ++ Satisfactory +++ Good

GHANA

Chief investigator and research team:

C. Schandorf, Chief investigator
G. Emi-Reynolds, Scientist
R. Abdel Awudu (Technician)

Institution(s):

National Nuclear Research Institute
Ghana Atomic Energy Commission

Names of the hospital(s):

Achimota Hospital
Police Hospital
Ridge Hospital
Cocoa Clinic
Nyaho Clinic

Radiology staff involved in the pilot programme:

C.N. Kotei, Radiologist
T. Jecty, Senior Technical Officer
E. Antwi, Technical Officer
B.K. Amponsah, Senior Radiographer
D. A. Hammond, Radiographer
S. Larbi-Lartey, Principal Technical Officer
K. Owusu, Senior Technical Officer

TABLE I. SUMMARY OF THE MEASUREMENTS OF PATIENTS ENTRANCE SURFACE DOSE (GHANA)

HOSPITAL	X RAY ROOM	EXAMINATION	DOSE PRIOR TO QC (mGy)	DOSE AFTER QC (mGy)	DOSE REDUC-TION IF ANY (%)	CORRECTIVE ACTIONS
1	1	Chest PA	0.40	--	--	None
2	1	Chest PA	0.32	--	--	None
2	2	Chest PA	0.41	--	--	None
3	1	Chest PA	0.53	--	--	None
5	1	Chest PA	1.75	0.86	50.8	Increase of speed class of film-screen sensitivity
6	1	Chest PA	1.48	0.87	41.2	Increase of focus-to-film distance
6	1	Chest PA	1.48	0.85	42.6	Increase of filtration
6	1	Chest PA	1.48	0.36	75.6	Increase of speed class of film-screen combination
1	1	Lumbar Spine AP	10.6	--	--	None
2	2	Pelvis AP	13.1	--	--	None
5	1	Lumbar Spine AP	15.1	--	--	None

TABLE II. QC PARAMETERS CONTROLLED (GHANA)

PARAMETERS	HOSPITAL 1 X RAY ROOM 1	HOSPITAL 2 X RAY ROOM 1	HOSPITAL 2 X RAY ROOM 2	HOSPITAL 3 X RAY ROOM 1	HOSPITAL 5 X RAY ROOM 1	HOSPITAL 6 X RAY ROOM 1
Film Processing Conditions	A	A	A	A	A	A
kV Accuracy (10%)*	A	A	NM	A	A	A
kV Reproducibility (4%)*	A	A	NM	A	NA	A
kV Consistency (10%)*	A	A	NM	A	A	A
HVL, mm of Al (measured at 80 kV)	4.8	5.3	NM	4.3	4.7	3.6
Timer Accuracy (10%)*	A	A	NM	A	A	A
Timer Reproducibility (5%)*	A	A	NM	A	A	A
mA · s Linearity, Consistency	A	A	NM	A	A	A
Output (mGy/mA · s) (5%)*	2.0	4.1	NM	2.7	0.8	4.0
Consistency	NA	A	NM	A	A	A
Light/Radiation Beam Alignment (deviation at 1 m) (+2%)*	A	A	NM	A	A	NA

*Tolerance A = Acceptable NA = Not acceptable NM = Not measured

TABLE III. COMPLIANCE WITH THE CEC IMAGE CRITERIA. CHEST (PA) (GHANA)

IMAGE CRITERIA	HOSPITAL 1 X RAY ROOM 1	HOSPITAL 2 X RAY ROOM 1	HOSPITAL 2 X RAY ROOM 2	HOSPITAL 3 X RAY ROOM 1	HOSPITAL 5 X RAY ROOM 1	HOSPITAL 6 X RAY ROOM 1
Performed at deep inspiration and with suspended respiration	+++	+++	+++	++	+++	+++
Symmetrical reproduction of the thorax	+++	+++	+++	+++	+++	++
Medial border of the scapulae to be outside the lung fields	++	+++	+++	++	+++	+++
Reproduction of the whole rib cage above the diaphragm	+++	+++	+++	+++	+++	+++
Reproduction of the vascular pattern in the whole lung, particularly the peripheral vessels	+	+++	+++	++	+++	+++
Visually sharp reproduction of the trachea and proximal bronchi, the borders of the heart and aorta and the diaphragm and costo-phrenic angles	+	+++	+++	++	+++	+++
Visualization of the retrocardiac lung and the mediastinum	++	++	++	++	+++	++

+ Poor ++ Satisfactory +++ Good

TABLE IV. COMPLIANCE WITH THE CEC IMAGE CRITERIA. PELVIS (AP) (GHANA)

IMAGE CRITERIA	HOSPITAL 1 X RAY ROOM 1	HOSPITAL 2 X RAY ROOM 1	HOSPITAL 2 X RAY ROOM 2	HOSPITAL 3 X RAY ROOM 1	HOSPITAL 5 X RAY ROOM 1	HOSPITAL 6 X RAY ROOM 1
Symmetrical reproduction of the pelvis	+++	+++	+++	+++	++	+++
Visualization of the sacrum and its intervertebral foramina	+++	+++	+++	+++	++	+++
Visualization of the pubic and ischial rami	+++	+++	+++	+++	++	+++
Visualization of the sacroiliac joints	+++	+++	+++	+++	+++	+++
Reproduction of the necks of the femora which should not be distorted by foreshortening or rotation	+++	++	++	++	+	+++
Reproduction of spongiosa and corticalis, and visualization of the trochanters	+++	++	++	++	+++	+++

+ Poor ++ Satisfactory +++ Good

TABLE V. COMPLIANCE WITH THE CEC IMAGE CRITERIA. LUMBAR SPINE (AP) (GHANA)

IMAGE CRITERIA	HOSPITAL 1 X RAY ROOM 1	HOSPITAL 2 X RAY ROOM 1	HOSPITAL 2 X RAY ROOM 2	HOSPITAL 3 X RAY ROOM 1	HOSPITAL 5 X RAY ROOM 1	HOSPITAL 6 X RAY ROOM 1
Linear reproduction of the upper and lower-plate surfaces in the centred beam area and visualization of the intervertebral spaces	+++	+++	+++	+++	+++	+++
Visually sharp reproduction of the pedicles	+++	++	+++	+++	+++	+++
Visualization of the intervertebral joints	+++	++	++	+++	+++	+++
Reproduction of the spinous and transverse processes	+++	++	++	+++	++	+++
Visually sharp reproduction of the cortex and trabecular structures	++	+	+	++	++	+++
Reproduction of the adjacent soft tissues, particularly the psoas shadows	++	+	+	++	+	+++

+ Poor ++ Satisfactory +++ Good

ISLAMIC REPUBLIC OF IRAN

Chief investigator and research team:

Chief investigator:	M. Sohrabi
Research team:	S. Borhan Azad
	B. Aghahadi

Institution(s):

National Radiation Protection Department, Atomic Energy Organization of the Islamic Republic of Iran

Names of the hospital(s):

Loghman Hakim (LH) Hospital
Vahab Aghaee Radiology (VAR) Clinic

Radiology staff involved in the pilot programme:

H. Vahab Aghai
M. Shahnazy
H. Badakhshan

TABLE I. SUMMARY OF THE MEASUREMENTS OF PATIENT ENTRANCE SURFACE DOSE (IRAN, ISLAM. REP.)

HOSPITAL	X RAY ROOM	EXAMINATION	DOSE PRIOR TO QC (mGy)	DOSE AFTER QC (mGy)	DOSE REDUC-TION IF ANY (%)	CORRECTIVE ACTIONS
1	1	Chest PA	0.19	0.04	79	Increase of kV, decrease of mA · s, increase of FFD
1	2	Chest PA	0.26	0.09	65	Increase of kV, decrease of mA · s, increase of FFD
1	3	Chest PA	0.19	0.05	74	Increase of kV, decrease of mA · s, increase of FFD
1	1	Abdomen AP	3.62	2.07	43	Increase of kV, decrease of mA · s, increase of FFD
1	2	Abdomen AP	2.83	2.08	27	Increase of kV, decrease of mA · s, increase of FFD
1	3	Abdomen AP	4.25	1.47	65	Increase of kV, decrease of mA · s, increase of FFD
2	4	Breast Medio-Lateral, Right	5.85	4.36	27	Film changed from Agfa curix MR4 to Agfa Mammoray MR3
2	4	Breast Medio-Lateral, Left	6.07	4.35	28	Film changed from Agfa curix MR4 to Agfa Mammoray MR3
2	4	Breast Cranio-Caudal, Right	4.81	4.27	12	Film changed from Agfa curix MR4 to Agfa Mammoray MR3
2	4	Breast Cranio-Caudal, Left	5.01	4.17	17	Film changed from Agfa curix MR4 to Agfa Mammoray MR3

TABLE II. QC PARAMETERS CONTROLLED (IRAN, ISLAM. REP.)

PARAMETERS	HOSPITAL 1 X RAY ROOM 1	HOSPITAL 2 X RAY ROOM 2	HOSPITAL 1 X RAY ROOM 3	HOSPITAL 2 X RAY ROOM 4
Film Processing Conditions	A	A	A	A
kV Accuracy (10%)* kV Reproducibility (4%)* kV Consistency (10%)*	A A A	A A A	A A A	NM NM NM
HVL, mm of Al (measured at 80 kV)	3.6	5.5	2.9	0.4
Timer Accuracy (10%)* Timer Reproducibility (5%)*	A A	A A	A A	NM NM
mA · s Linearity, Consistency	A	A	NA	NM
Output (mGy/mA · s) (5%)* Consistency	(0.014)** A	(0.01)** A	(0.02)** A	(0.01)*** A
Light/Radiation Beam Alignment (deviation at 1 m) (+2%)*	A	A	A	A

*Tolerance ** Measured at 80 kV *** Measured at 35 kV A = Acceptable NA = Not acceptable NM = Not measured

TABLE III. COMPLIANCE WITH THE CEC IMAGE CRITERIA. MAMMOGRAPHY (IRAN, ISLAM. REP.)

IMAGE CRITERIA	MAMMOGRAPHY BEFORE QC (HOSPITAL 2, X RAY ROOM 4)				MAMMOGRAPHY AFTER QC (HOSPITAL 2, X RAY ROOM 4)			
	Medio-Lateral (Left)	Medio-Lateral (Right)	Cranio-Caudal (Left)	Cranio-Caudal (Right)	Medio-Lateral (Left)	Medio-Lateral (Right)	Cranio-Caudal (Left)	Cranio-Caudal (Right)
Visually sharp reproduction of the whole glandular breast	++	++	++	++	+++	+++	+++	+++
Visually sharp reproduction of the cutis and subcutis	++	++	++	++	+++	+++	+++	+++
Nipple should be parallel to the film	++	++	++	++	+++	+++	+++	+++

\+ Poor ++ Satisfactory +++ Good

TABLE IV. COMPLIANCE WITH THE CEC IMAGE CRITERIA. CHEST (AP) (IRAN, ISLAM. REP.)

IMAGE CRITERIA	CHEST (BEFORE QC)			CHEST (AFTER QC)		
	Hospital 1 Room 1	Hospital 1 Room 2	Hospital 1 Room 3	Hospital 1 Room 1	Hospital 1 Room 2	Hospital 1 Room 3
Performed at deep inspiration and with suspended respiration	++	++	++	++	++	++
Symmetrical reproduction of the thorax	+++	+++	+++	+++	+++	+++
Medial border of the scapulae to be outside the lung fields	+++	+++	++	+++	+++	++
Reproduction of the whole rib cage above the diaphragm	+++	+++	++	+++	+++	+++
Reproduction of the vascular pattern in the whole lung, particularly the peripheral vessels	++	+++	++	++	+++	+++
Visually sharp reproduction of the trachea and proximal bronchi, the borders of the heart and aorta	+++	+++	+++	+++	+++	+++
Visually sharp reproduction of the diaphragm and costo-phrenic angles	++	+++	++	+++	+++	+++
Visualization of the retrocardiac lung and the mediastinum	+++	+++	+++	+++	+++	+++

+ Poor ++ Satisfactory +++ Good

TABLE V. COMPLIANCE WITH THE CEC IMAGE CRITERIA. ABDOMEN (AP) (IRAN, ISLAM. REP.)

IMAGE CRITERIA*	ABDOMEN (BEFORE QC)			ABDOMEN (AFTER QC)		
	Hospital 1 Room 1	Hospital 1 Room 2	Hospital 1 Room 3	Hospital 1 Room 1	Hospital 1 Room 2	Hospital 1 Room 3
Symmetrical reproduction of the abdomen	+++	++	++	+++	++	++
Visualization of the gaz pattern	+++	+++	++	+++	+++	++
Visualization of the public and ischial rami	+++	++	++	+++	++	++
Visualization of the sacroiliac joints	+++	+++	++	+++	+++	++
Visualization of the lateral border of psoas muscles	+++	+++	++	+++	+++	++
Visualization of the kidney	+++	+++	++	+++	+++	++
Visualization of the iliac and sacrum	+++	+++	++	+++	+++	++
Visualization of the vertebra	+++	+++	++	+++	+++	++
Visualization of peritoneal fat lines	+++	+++	++	+++	+++	++
Visualization of inferior ribs	+++	+++	++	+++	+++	++

* For the evaluation of the image quality of X ray abdomen examination, the image criteria were defined by the field radiologist.

+ Poor ++ Satisfactory +++ Good

ROMANIA

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TABLE I. SUMMARY OF THE MEASUREMENTS OF PATIENTS ENTRANCE SURFACE DOSE (ROMANIA)

HOSPITAL	X RAY ROOM	EXAMINATION	DOSE PRIOR TO QC (mGy)	DOSE AFTER QC (mGy)	DOSE REDUC-TION IF ANY (%)	CORRECTIVE ACTIONS
1	1	Chest PA	0.95	0.76	20	Increase of kV and reduction of both mA · s and field size
2	2	Chest PA	0.77	0.69	10	Increase of kV and reduction of both mA · s and field size
1	3	Chest PA	0.66	--	--	Paediatric Dept.
1	4	Urinary Tract AP	17.98	9.29	48	
1	4	Urinary Tract AP	12.87	10.48	19	
1	4	Urinary Trace Oblic	17.70	8.37	53	
1	7	Lumbar Spine AP	33.46	24.56	27	
1	7	Lumbar Spine LAT	41.75	35.66	15	

TABLE II. QC PARAMETERS CONTROLLED (ROMANIA)

PARAMETERS	HOSPITAL 1 X RAY ROOM 3	HOSPITAL 1 X RAY ROOM 3	HOSPITAL 1 X RAY ROOM 4	HOSPITAL 1 X RAY ROOM 7
Film Processing Conditions	A	NA	A	NA
kV Accuracy (10%)* kV Reproducibility (4%)* kV Consistency (10%)*	A A A	NA A A	A A A	A A A
HVL, mm of Al (measured at 80 kV)	3.6	2.8	3.8	3.6
Timer Accuracy (10%)* Timer Reproducibility (5%)*	A A	A A	A A	A A
mA · s Linearity, Consistency	A	A	A	A
Output (mGy/mA · s) (5%)* Consistency	00.96 A	0.102 A	0.120 A	0.105 A
Light/Radiation Beam Alignment (deviation at 1 m) (+2%)*	NA	NA	NA	NA
Ratio field size/film size	NA	NA	NA	NA

*Tolerance A = Acceptable NA = Not acceptable NM = Not measured

TABLE III. COMPLIANCE WITH THE CEC IMAGE CRITERIA. CHEST (PA) (ROMANIA)

IMAGE CRITERIA	HOSPITAL 1 X RAY ROOM 1	HOSPITAL 2 X RAY ROOM 2
Performed at deep inspiration and with suspended respiration	+++	+++
Symmetrical reproduction of the thorax	++	+
Medial border of the scapulae to be outside the lung fields	+++	+++
Reproduction of the whole rib cage above the diaphragm	+++	+++
Reproduction of the vascular pattern in the whole lung, particularly the peripheral vessels	++	+
(a) Visually sharp reproduction of the trachea and proximal bronchi, the borders of the heart and aorta	++	++
(b) and the diaphragm and costo-phrenic angles	++	+
Visualization of the retrocardiac lung and the mediastinum	++	+

+ Poor ++ Satisfactory +++ Good

Annex I

RESULTS AVERAGED FOR EACH ROOM/EXAMINATION AND CLASSIFIED BY FIRST/SECOND SET OF MEASUREMENTS, COUNTRY AND HOSPITAL

ABDOMEN AP/PA, FIRST ROUND OF MEASUREMENTS. RESULTS BY COUNTRY, HOSPITAL AND X RAY ROOM

Countries	Hospital	X ray Room	Speed class of film screen combination	Patient thickness (cm)[a]		Focus to Film Distance (cm)	Applied Potential (kVp)[a]		Half Value Layer (mm Al)	Tube Current (mA · s)[a]		Entrance Patient Dose (mGy)[b]	
Argentina	1	4	400	22	±2	100	68	±3	2.0	61	±10	5.09	±1.61
Brazil	1	3	200	21	±1	110	75	±4	3.5	76	±7	5.72	±0.82
Brazil	2	C	200	23	±1	100	63	±5	1.8	91	±16	8.70	±1.96
Brazil	3	2	200	20	±2	100	82	±14	1.0	37	±14	15.25	±7.50
Iran, Islam. Rep.	1	1	100	25	±22	107	71	±4	3.6	48	±6	3.56	±0.91
Iran, Islam. Rep.	1	2	100	21	±4	113	70	±11	5.5	48	±18	3.00	±1.58
Iran, Islam. Rep.	1	3	100	23	±5	118	77	±7	2.9	105	±27	4.28	±1.36
Romania	1	4	--	26	±5	100	78	±11	3.8	140	±38	17.98	±7.62

[a] Mean value ± one standard deviation. [b] CEC dose reference value: 10 mGy.

CHEST AP/PA, FIRST ROUND OF MEASUREMENTS

Countries	Hospital	X ray Room	Speed class of film screen combination	Patient thickness (cm)[a]		Focus to Film Distance (cm)	Applied Potential (kVp)[a]		Half Value Layer (mm Al)	Tube Current (mA·s)[a]		Entrance Patient Dose (mGy)[b]	
Argentina	1	1	400	24	±2	200	66	±2	1.6	21	±5	0.45	±0.13
Argentina	1	2	400	22	±1	200	69	±2	3.0	33	±4	0.24	±0.04
Argentina	2	3	400	21	±2	180	67	±2	2.7	20	±2	0.43	±0.07
Brazil	1	C	200	29	±5	165	95	±4	2.5	10	±2	0.67	±0.23
Brazil	2	D	200	21	±2	150	125	±0	3.7	0	±0	0.29	±0.04
Brazil	4	0	200	23	±2	169	125	±0	3.5	0	±1	0.17	±0.05
Czech Republic	1	1	200	23	±2	185	73	±3	2.4	88	±33	0.99	±0.43
Czech Republic	2	2	100	24	±2	150	60	±4	3.1	31	±5	0.45	±0.11
Czech Republic	3	2	400	22	±4	200	59	±4	3.0	12	±0	0.11	±0.03
Czech Republic	4	1	700	24	±3	150	63	±3	3.3	18	±3	0.08	±0.05
Ethiopia	1	1	--	18	±2	145	70	±4	--	24	±21	0.94	±0.34
Ethiopia	2	2	--	17	±2	148	61	±6	--	73	±13	1.84	±0.65
Ghana	1	1	100	18	±0	152	82	±2	4.8	18	±1	0.41	±0.10
Ghana	2	1	100	19	±2	183	76	±7	5.3	28	±3	0.32	±0.05
Ghana	2	2	100	19	±4	176	63	±4	5.0	14	±3	0.41	±0.14
Ghana	3	1	100	21	±3	156	83	±16	5.0	43	±9	0.53	±0.15
Ghana	5	1	100	19	±3	174	71	±5	4.7	30	±6	1.72	±0.98
Ghana	6	1	100	17	±3	171	78	±6	3.6	48	±4	1.36	±0.57
Iran, Islam. Rep.	1	1	100	22	±5	140	55	±4	3.6	12	±3	0.19	±0.13
Iran, Islam. Rep.	1	2	100	21	±2	145	62	±4	5.5	12	±4	0.26	±0.07
Iran, Islam. Rep.	1	3	100	20	±5	145	66	±6	2.9	19	±7	0.19	±0.10
Romania	1	1	--	24	±3	172	89	±7	3.6	28	±6	.95	±0.13
Romania	2	2	--	22	±3	172	81	±5	--	29	±4	0.77	±0.08
Romania	2	3	--	19	±3	190	81	±3	2.8	32	±8	0.66	±0.20

[a] Mean value ± one standard deviation. [b] CEC dose reference value: 0.3 mGy.

IVU, FIRST ROUND OF MEASUREMENTS

Countries	Hospital	X ray Room	Speed class of film screen combination	Patient thickness (cm)[a]		Focus to Film Distance (cm)	Applied Potential (kVp)[a]		Half Value Layer (mm Al)	Tube Current (mA·s)[a]		Entrance Patient Dose (mGy)[b]	
Romania	1	4	--	22	±3	100	73	±4	3.8	120	±27	12.87	±4.9

[a] Mean value ± one standard deviation. [b] CEC dose reference value: 10 mGy.

LUMBAR SPINE AP/PA, FIRST ROUND OF MEASUREMENTS

Countries	Hospital	X ray Room	Speed class of film screen combination	Patient thickness (cm)[a]		Focus to Film Distance (cm)	Applied Potential (kVp)[a]		Half Value Layer (mm Al)	Tube Current (mA·s)[a]		Entrance Patient Dose (mGy)[b]	
Brazil	1	B	200	22	±2	110	75	±4	2.5	106	±11	14.83	±5.34
Brazil	2	6	200	23	±2	100	81	±1	3.5	250	±0	14.54	±2.79
Czech Republic	2	1	100	22	±2	100	75	±3	3.1	AEC	--	12.04	±5.47
Czech Republic	3	1	100	25	±4	100	69	±6	2.3	136	±25	9.49	±4.07
Czech Republic	4	1	700	24	±2	100	70	±5	3.3	215	±30	8.39	±4.29
Ghana	5	1	100	21	±4	109	77	±5	4.7	132	±47	15.20	±6.35
Romania	1	7	--	27	±5	112	65	±2	3.6	200	±0	36.22	±10.46

[a] Mean value ± one standard deviation. [b] CEC dose reference value: 10 mGy.

MAMMOGRAPHY, FIRST ROUND OF MEASUREMENTS

Countries	Hospital	X ray Room	Speed class of film screen combination	Patient thickness (cm)[a]		Focus to Film Distance (cm)	Applied Potential (kVp)[a]		Half Value Layer (mm Al)	Tube Current (mA · s)[a]		Entrance Patient Dose (mGy)[b]	
Argentina	3	5	400	4	±1	65	29	±1	0 3	98	±14	11 22	±2 13
Argentina	3	6	400	5	±1	65	29	±1	0 3	93	±14	10 95	±2 21
Iran, Islam Rep	2	4	--	3	±1	60	34	±2	0 4	93	±16	5 45	±1 94

[a] Mean value ± one standard deviation [b] CEC dose reference value 10 mGy

PELVIS AP, FIRST ROUND OF MEASUREMENTS

Countries	Hospital	X ray Room	Speed class of film screen combination	Patient thickness (cm)[a]		Focus to Film Distance (cm)	Applied Potential (kVp)[a]		Half Value Layer (mm Al)	Tube Current (mA s)[a]		Entrance Patient Dose (mGy)[b]	
Czech Republic	2	1	100	22	±3	100	68	±2	3 1	--	±0	5 59	±1 80
Czech Republic	3	1	100	21	±3	100	65	±5	2 3	117	±28	6 71	±2 68
Czech Republic	3	2	100	21	±1	100	70	±0	3 0	100	±0	5 98	±0 56
Czech Republic	4	1	700	25	±3	100	73	±5	3 3	227	±25	6 99	±4 61

[a] Mean value ± one standard deviation [b] CEC dose reference value 10 mGy

PELVIS AP, FIRST ROUND OF MEASUREMENTS

Countries	Hospital	X ray Room	Speed class of film screen combination	Patient thickness (cm)[a]		Focus to Film Distance (cm)[a]	Applied Potential (kVp)[a]		Half Value Layer (mm Al)	Tube Current (mA · s)[a]		Entrance Patient Dose (mGy)[b]	
Ethiopia	1	3	0	17	±2	108	65	±4	--	44	±24	5.11	±4.81
Ethiopia	2	4	0	19	±6	100	72	±4	--	218	±134	5.41	±2.03
Ghana	1	1	100	20	±4	85	88	±3	4.8	73	±6	6.89	±1.49
Ghana	2	1	100	21	±3	95	83	±0	5.3	160	±0	7.40	±0.20
Ghana	2	2	100	20	±3	105	79	±5	5.0	89	±9	13.08	±3.68

[a] Mean value ± one standard deviation. [b] CEC dose reference value: 10 mGy.

SKULL, FIRST ROUND OF MEASUREMENTS

Countries	Hospital	X ray Room	Speed class of film screen combination	Patient thickness (cm)[a]		Focus to Film Distance (cm)	Applied Potential kVp[a]		Half Value Layer (mm Al)	Tube Current mA · s[a]		Entrance Patient Dose (mGy)[b]	
Brazil	1	6	100	19	±0	100	68	±4	2.5	84	±8	3.74	±0.88
Brazil	1	B	100	19	±0	100	65	±4	2.5	77	±6	5.24	±0.59
Brazil	2	2	100	19	±0	98	72	±9	1.0	72	±18	7.79	±2.38
Brazil	2	6	100	19	±0	100	72	±8	3.5	91	±10	3.69	±1.21
Brazil	2	9	100	19	±1	100	63	±3	1.4	119	±11	6.01	±0.48

[a] Mean value ± one standard deviation. [b] CEC dose reference value: 5 mGy.

ABDOMEN AP/PA, SECOND ROUND OF MEASUREMENTS

Countries	Hospital	X ray Room	Speed class of film screen combination	Patient thickness (cm)[a]		Focus to Film Distance (cm)	Applied Potential (kVp)[a]		Half Value Layer (mm Al)	Tube Current (mA · s)[a]		Entrance Patient Dose (mGy)[b]	
Argentina	1	4	400	21	±2	100	68	±4	2.7	60	±11	3.31	±1.19
Brazil	1	3	200	20	±1	110	64	±1	3.5	96	±8	4.51	±0.37
Brazil	2	C	200	23	±4	100	61	±1	3.5	80	±0	3.46	±0.05
Brazil	3	2	--	22	±2	100	76	±4	3.5	85	±0	2.46	±0.27
Iran, Islam. Rep.	1	1	100	20	±2	125	80	±16	3.6	32	±4	2.07	±0.41
Iran, Islam. Rep.	1	2	100	19	±3	125	84	±4	5.5	36	±4	2.08	±0.27
Iran, Islam. Rep.	1	3	100	19	±4	120	86	±2	2.9	30	±0	1.47	±0.29
Romania	1	4	--	24	±5	100	87	±7	3.8	63	±22	9.29	±3.27

[a] Mean value ± one standard deviation. [b] CEC dose reference value: 10 mGy.

CHEST PA, SECOND ROUND OF MEASUREMENTS

Countries	Hospital	X ray Room	Speed class of film screen combination	Patient thickness (cm)[a]		Focus to Film Distance (cm)	Applied Potential (kVp)[a]		Half Value Layer (mm Al)	Tube Current (mA · s)[a]		Entrance Patient Dose (mGy)[b]	
Argentina	1	1	400	24	±2	200	68	±3	2.2	20	±1	0.34	±0.03
Argentina	2	3	400	21	±3	180	133	±0	4.0	--	±0	0.31	±0.03
Brazil	1	C	200	28	±4	165	92	±6	2.5	10	±0	0.64	±0.26
Brazil	2	D	200	23	±3	150	125	±0	3.7	--	±0	0.28	±0.03
Czech Republic	2	2	400	22	±1	150	58	±0	--	18	±0	0.13	±0.02
Ethiopia	1	1	--	18	±2	150	97	±5	--	7	±1	0.70	±0.18
Ethiopia	2	2	--	17	±2	150	98	±6	--	3	±1	0.38	±0.09
Ghana	5	1	100	22	±3	188	75	±1	4.7	38	±4	0.95	±1.96
Ghana	6	1	100	22	±2	187	72	±4	4.4	37	±7	0.71	±0.22
Iran, Islam. Rep.	1	1	100	21	±4	180	99	±2	3.6	1	±0	0.03	±0.01
Iran, Islam. Rep.	1	2	100	20	±3	180	98	±3	5.5	4	±0	0.09	±0.02
Iran, Islam. Rep.	1	3	100	23	±2	180	95	±5	2.9	3	±0	0.05	±0.01
Romania	1	1	--	24	±3	172	103	±3	3.6	16	±3	0.73	±0.15
Romania	2	2	--	23	±3	172	99	±7	0.0	17	±2	0.71	±0.09

[a] Mean value ±1 standard deviation. [b] CEC dose reference value: .3 mGy.

IVUR, SECOND ROUND OF MEASUREMENTS

Countries	Hospital	X ray Room	Speed class of film screen combination	Patient thickness (cm)[a]		Focus to Film Distance (cm)	Applied Potential (kVp)[a]		Half Value Layer (mm Al)	Tube Current (mA·s)[a]		Entrance Patient Dose (mGy)[b]	
Romania	1	4	--	23	±3	100	85	±3	3.8	63	±22	10.48	±4.41

[a] Mean value ± one standard deviation. [b] CEC dose reference value: 10 mGy.

LUMBAR SPINE AP/PA, SECOND ROUND OF MEASUREMENTS

Countries	Hospital	X ray Room	Speed class of film screen combination	Patient thickness (cm)[a]		Focus to Film Distance (cm)	Applied Potential (kVp)[a]		Half Value Layer (mm Al)	Tube Current (mA·s)[a]		Entrance Patient Dose (mGy)[b]	
Brazil	1	B	200	24	±1	110	77	±2	2.9	90	±10	4.36	±1.21
Brazil	2	6	200	22	±1	100	73	±4	3.5	138	±3	9.28	±3.57
Czech Republic	2	1	100	21	±1	100	70	±0	3.1	--	±1	4.76	±0.51
Romania	1	7	--	26	±4	112	71	±3	3.6	160	±0	24.56	±2.24

[a] Mean value ± one standard deviation. [b] CEC dose reference value: 10 mGy.

LUMBAR SPINE LAT, SECOND ROUND OF MEASUREMENTS

Countries	Hospital	X ray Room	Speed class of film screen combination	Patient thickness (cm)[a]		Focus to Film Distance (cm)	Applied Potential (kVp)[a]		Half Value Layer (mm Al)	Tube Current (mA·s)[a]		Entrance Patient Dose (mGy)[b]	
Romania	1	7	--	31	±3	112	77	±2	3.6	176	±17	36.31	±6.70

[a] Mean value ± one standard deviation. [b] CEC dose reference value: 10 mGy.

MAMMOGRAPHY, SECOND ROUND OF MEASUREMENTS

Countries	Hospital	X ray Room	Speed class of film screen combination	Patient thickness (cm)[a]		Focus to Film Distance (cm)	Applied Potential (kVp)[a]		Half Value Layer (mm Al)	Tube Current (mA·s)[a]		Entrance Patient Dose (mGy)[b]	
Argentina	3	5	400	5	±1	65	25	±2	0.3	98	±11	7.68	±2.20
Iran, Islam. Rep.	2	4	--	3	±1	60	34		0.4	92		4.27	

[a] Mean value ± one standard deviation. [b] CEC dose reference value: 10 mGy.

PELVIS AP, SECOND ROUND OF MEASUREMENTS

Countries	Hospital	X ray Room	Speed class of film screen combination	Patient thickness (cm)[a]		Focus to Film Distance (cm)	Applied Potential (kVp)[a]		Half Value Layer (mm Al)	Tube Current (mA·s)[a]		Entrance Patient Dose (mGy)[b]	
Czech Republic	2	1	400	21	±1	100	68	±0	3.1	AEC	--	3.28	±0.15
Czech Republic	3	1	400	21	±2	100	60	±2	2.3	100	±0	3.12	±0.13
Czech Republic	3	2	400	21	±1	100	62	±2	3.0	100	±0	3.10	±0.22

[a] Mean value ± one standard deviation. [b] CEC dose reference value: 10 mGy. AEC = Automatic Exposure Control.

PELVIS AP, SECOND ROUND OF MEASUREMENTS

Countries	Hospital	X ray Room	Speed class of film screen combination	Patient thickness (cm)[a]		Focus to Film Distance (cm)	Applied Potential (kVp)[a]		Half Value Layer (mm Al)	Tube Current (mA·s)[a]		Entrance Patient Dose (mGy)[b]	
Ethiopia	1	3	--	16	±2	101	64	±5	±0	54	±17	9.74	±5.82

[a] Mean value ± one standard deviation. [b] CEC dose reference value: 10 mGy.

CRP RESULTS BY COUNTRY, BY HOSPITAL AND BY X RAY ROOM. (SKULL) - SECOND ROUND OF MEASUREMENTS

Countries	Hospital	X ray Room	Speed class of film screen combination	Patient thickness (cm)[a]		Focus to Film Distance (cm)	Applied Potential (kVp)[a]		Half Value Layer (mm Al)	Tube Current (mA · s)[a]		Entrance Patient Dose (mGy)[b]	
Brazil	1	6	100	19	±0	100	66	±2	2.5	100	±0	3.08	±0.38
Brazil	1	B	100	19	±0	100	67	±4	2.9	80	±0	4.49	±0.29
Brazil	2	6	100	19	±0	100	68	±2	2.5	83	±7	3.11	±0.65
Brazil	2	9	100	19	±0	100	71	±5	3.5	94	±9	4.74	±0.33

[a] Mean value ± one standard deviation. [b] CEC dose reference value: 5 mGy.

Annex II

EXAMPLES OF IMAGE QUALITY CRITERIA AND OF GOOD RADIOGRAPHIC TECHNIQUE, TAKEN FROM THE SECOND EDITION OF THE CEC WORKING DOCUMENT ON QUALITY CRITERIA FOR DIAGNOSTIC RADIOGRAPHIC IMAGES

LATERAL PROJECTION

1. DIAGNOSTIC REQUIREMENTS

Image criteria

1.1 Performed at deep inspiration and with suspended respiration

1.2 Arms should be raised clear of the thorax

1.3 Visually sharp reproduction of the posterior border of the heart, aorta, mediastinum, trachea, diaphragm, sternum and thoracic spine

2. CRITERIA FOR GOOD IMAGING PERFORMANCE

2.1 Important image details

Small round details in the whole lung, including the retrocardiac area:

high contrast : 0.7 mm diameter

low contrast : 2 mm diameter

Linear and reticular details out to the lung periphery:

high contrast : 0.3 mm in width,

low contrast : 2 mm in width

2.2 Entrance surface dose for a standard-sized patient : 1.5 mGy

3. EXAMPLE OF GOOD RADIOGRAPHIC TECHNIQUE

3.1	Radiographic device	:	vertical stand with stationary or moving grid
3.2	Focal spot size	:	$\leq$ 1.3 mm
3.3	Total filtration	:	$\geq$ 3.0 mm Al equivalent
3.4	Anti-scatter grid	:	r = 12; 40/cm
3.5	Film-screen combination	:	speed class 200 - 400
3.6	FFD	:	180 (140 - 200) cm
3.7	Radiographic voltage	:	100 - 150 kV
3.8	Automatic exposure control	:	chamber selected - central
3.9	Exposure time	:	< 40 ms

AP/PA PROJECTIONS

1. DIAGNOSTIC REQUIREMENTS

Image criteria

1.1 Linear reproduction of the upper and lower-plate surfaces in the centred beam area and visualisation of the intervertebral spaces

1.2 Visually sharp reproduction of the pedicles

1.3 Visualisation of the intervertebral joints

1.4 Reproduction of the spinous and transverse processes

1.5 Visually sharp reproduction of the cortex and trabecular structures

1.6 Reproduction of the adjacent soft tissues, particularly the psoas shadows

2. CRITERIA FOR GOOD IMAGING PERFORMANCE

2.1 Important image details : 0.3 - 0.5 mm

2.2 Entrance surface dose for a standard-sized patient : 10 mGy

3. EXAMPLE OF GOOD RADIOGRAPHIC TECHNIQUE

3.1	Radiographic device	:	grid table or vertical stand with stationary or moving grid
3.2	Focal spot size	:	$\leq$ 1.3 mm
3.3	Total filtration	:	$\geq$ 3.0 mm Al equivalent
3.4	Anti-scatter grid	:	r = 12(8); 40/cm
3.5	Film-screen combination	:	speed class 400
3.6	FFD	:	115 (100 - 150) cm
3.7	Radiographic voltage	:	70 - 90 kV
3.8	Automatic exposure control	:	chamber selected - central
3.9	Exposure time	:	< 400 ms

REMARKS Radiation protection, where appropriate, gonad shields should be employed for male patients, and for female patients if possible.

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