IAEA-TECDOC-1423

Optimization of the radiological protection of patients undergoing radiography, fluoroscopy and computed tomography

Final report of a coordinated research project in Africa, Asia and eastern Europe

IAEA
International Atomic Energy Agency

December 2004

IAEA SAFETY RELATED PUBLICATIONS

IAEA SAFETY STANDARDS

Under the terms of Article III of its Statute, the IAEA is authorized to establish or adopt standards of safety for protection of health and minimization of danger to life and property, and to provide for the application of these standards.

The publications by means of which the IAEA establishes standards are issued in the **IAEA Safety Standards Series**. This series covers nuclear safety, radiation safety, transport safety and waste safety, and also general safety (i.e. all these areas of safety). The publication categories in the series are **Safety Fundamentals, Safety Requirements** and **Safety Guides**.

Safety standards are coded according to their coverage: nuclear safety (NS), radiation safety (RS), transport safety (TS), waste safety (WS) and general safety (GS).

Information on the IAEA's safety standards programme is available at the IAEA Internet site

http://www-ns.iaea.org/standards/

The site provides the texts in English of published and draft safety standards. The texts of safety standards issued in Arabic, Chinese, French, Russian and Spanish, the IAEA Safety Glossary and a status report for safety standards under development are also available. For further information, please contact the IAEA at P.O. Box 100, A-1400 Vienna, Austria.

All users of IAEA safety standards are invited to inform the IAEA of experience in their use (e.g. as a basis for national regulations, for safety reviews and for training courses) for the purpose of ensuring that they continue to meet users' needs. Information may be provided via the IAEA Internet site or by post, as above, or by e-mail to Official.Mail@iaea.org.

OTHER SAFETY RELATED PUBLICATIONS

The IAEA provides for the application of the standards and, under the terms of Articles III and VIII.C of its Statute, makes available and fosters the exchange of information relating to peaceful nuclear activities and serves as an intermediary among its Member States for this purpose.

Reports on safety and protection in nuclear activities are issued in other publications series, in particular the **Safety Reports Series**. Safety Reports provide practical examples and detailed methods that can be used in support of the safety standards. Other IAEA series of safety related publications are the **Provision for the Application of Safety Standards Series**, the **Radiological Assessment Reports Series** and the International Nuclear Safety Group's **INSAG Series**. The IAEA also issues reports on radiological accidents and other special publications.

Safety related publications are also issued in the **Technical Reports Series**, the **IAEA-TECDOC Series**, the **Training Course Series** and the **IAEA Services Series**, and as **Practical Radiation Safety Manuals** and **Practical Radiation Technical Manuals**. Security related publications are issued in the **IAEA Nuclear Security Series**.

IAEA-TECDOC-1423

Optimization of the radiological protection of patients undergoing radiography, fluoroscopy and computed tomography

Final report of a coordinated research project in Africa, Asia and eastern Europe

IAEA
International Atomic Energy Agency

December 2004

The originating Section of this publication in the IAEA was:

Radiation Safety Section
International Atomic Energy Agency
Wagramer Strasse 5
P.O. Box 100
A-1400 Vienna, Austria

OPTIMIZATION OF THE RADIOLOGICAL PROTECTION OF PATIENTS
UNDERGOING RADIOGRAPHY, FLUOROSCOPY
AND COMPUTED TOMOGRAPHY

IAEA, VIENNA, 2004
IAEA-TECDOC-1423
ISBN 92–0–113504–1
ISSN 1011–4289

Printed by the IAEA in Austria
December 2004

FOREWORD

Although radiography has been an established imaging modality for over a century, continuous developments have led to improvements in technique resulting in improved image quality at reduced patient dose. If one compares the technique used by Roentgen with the methods used today, one finds that a radiograph can now be obtained at a dose which is smaller by a factor of 100 or more. Nonetheless, some national surveys, particularly in the United Kingdom and in the United States of America in the 1980s and 1990s, have indicated large variations in patient doses for the same diagnostic examination, in some cases by a factor of 20 or more. This arises not only owing to the various types of equipment and accessories used by the different health care providers, but also because of operational factors.

The IAEA has a statutory responsibility to establish standards for the protection of people against exposure to ionising radiation and to provide for the worldwide application of those standards. A fundamental requirement of the International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources (BSS), issued by the IAEA in cooperation with the FAO, ILO, WHO, PAHO and NEA, is the optimization of radiological protection of patients undergoing medical exposure.

Towards its responsibility of implementation of standards and under the sub-programme of radiation safety, in 1995, the IAEA launched a coordinated research project (CRP) on radiological protection in diagnostic radiology in some countries in the Eastern European, African and Asian region. Initially, the CRP addressed radiography only and it covered wide aspects of optimisation of radiological protection. Subsequently, the scope of the CRP was extended to fluoroscopy and computed tomography (CT), but it covered primarily situation analysis of patient doses and equipment quality control. It did not cover patient dose reduction aspects in fluoroscopy and CT. The project continued up to 1999. The primary objective was to initiate a programme of optimization of protection in diagnostic radiology in each of the participating countries by introducing quality control (QC) practices, assessment of patient doses, evaluation of image quality, and identification and implementation of corrective actions. This TECDOC may be used as an approach to optimization of radiological protection for patients in diagnostic radiology.

The IAEA officers responsible for this publication were M. Oresegun and M.M. Rehani of the Division of Radiation, Transport and Waste Safety.

EDITORIAL NOTE

The use of particular designations of countries or territories does not imply any judgement by the publisher, the IAEA, as to the legal status of such countries or territories, of their authorities and institutions or of the delimitation of their boundaries.

The mention of names of specific companies or products (whether or not indicated as registered) does not imply any intention to infringe proprietary rights, nor should it be construed as an endorsement or recommendation on the part of the IAEA.

CONTENTS

1. INTRODUCTION

Two basic principles of radiological protection as recommended by the International Commission on Radiological Protection (ICRP) are justification of the practice and optimization of protection. These apply to the protection of the patient as well. These principles are incorporated in the International Basic Safety Standards against Ionizing Radiation and for the Safety of Radiation Sources (BSS) [1], which set currently internationally accepted requirements for radiation safety.

Justification is the first step in radiological protection. It is accepted that diagnostic exposure is justifiable only when there is a valid clinical indication, no matter how good the imaging performance may be. Every examination must result in a net benefit to the patient.

Once a diagnostic examination has been clinically justified, the subsequent imaging process must be optimized to obtain the required diagnostic information for a patient dose that is as low as reasonably achievable. Because the diagnostic medical procedures are usually for the direct benefit of the patient, somewhat less attention has been given to the optimization of protection in medical exposure than in other applications which use radiation sources.

In the area of optimization in diagnostic radiology there is considerable scope for reducing doses without loss of diagnostic information, but the extent to which the measures available are used varies widely. The optimization of protection in diagnostic radiology does not necessarily mean the reduction of doses to the patient — it is paramount that the image obtained contains the diagnostic information as intended.

In accordance with the recommendations of the ICRP [2, 3], it is often helpful in the management of operations to establish values of measured quantities above which some specified action or decision should be taken. These values are generally called reference or guidance levels [1].

In relation to this ICRP recommendation, the BSS define “guidance levels for medical exposure” as “a value of dose, dose rate or activity selected by professional bodies in consultation with the Regulatory Authority to indicate a level above which there should be a review by medical practitioners in order to determine whether or not the value is excessive, taking into account the particular circumstances and applying sound clinical judgment”.

The BSS also establish the following requirements on the use of guidance levels.

“II.24. Registrants and licensees should ensure that guidance levels for medical exposure be determined as specified in the Standards, revised as technology improves and used as guidance by medical practitioners, in order that:

(a) Corrective actions be taken as necessary if doses or activities fall substantially below the guidance levels and the exposures do not provide useful diagnostic information and do not yield the expected medical benefit to patients;

(b) Reviews be considered if doses or activities exceed the guidance levels as an input to ensuring optimized protection of patients and maintaining appropriate levels of good practice; and

(c) For diagnostic radiology, including computed tomography examinations, … the guidance levels be derived from the data from wide scale quality surveys which include entrance surface doses and cross-sectional dimensions of the beams delivered by individual facilities… to patients for the most frequent examinations in diagnostic radiology…

II.25. In the absence of wide scale surveys, performance of diagnostic radiography and fluoroscopy equipment…should be assessed on the basis of comparison with the guidance levels specified in Schedule III, Tables III-I to III-V. These levels should not be regarded as a guide for ensuring optimum performance in all cases, as they are appropriate only for typical adult patients and, therefore, in applying the values in practice, account should be taken of body size and age."

Guidance levels are also termed 'reference doses'. In this document the term guidance level has been used for consistency with the BSS.

It has also been demonstrated, through practice, that quality assurance programmes and quality control protocols form an essential part of the optimization process. Therefore, such programmes covering physical and technical parameters associated with the types of X ray examination being carried out need to be instigated in every medical X ray facility.

Finally, a 'culture' of regular patient dose measurements, film reject analysis, and image quality assessment need to become part of diagnostic radiology.

2. THE SCOPE AND OBJECTIVES OF THE COORDINATED RESEARCH PROJECT

The IAEA, through an earlier pilot coordinated research project (CRP) [4], had investigated the potential for patient dose reduction as part of the optimization of radiological protection. That study concluded that considerable reduction in patient dose could be achieved in conventional radiography by implementing simple and inexpensive actions such as added filtration, use of high kVp techniques, low mAs and use of appropriate screen-film combination. Based on these encouraging results, a second CRP, which extended over a period of three years, was started in 1995 on radiological protection in diagnostic radiology in some countries in the Eastern European, African and Asian region.

Initially, the CRP addressed radiography only, and it covered wide aspects of optimisation of radiological protection, including initial assessment of the situation of equipment, evaluation of image quality and patient dose followed by corrective actions through a quality control (QC) programme, and assessment of impact after QC actions. This is termed as Phase I in this publication. Subsequently, the scope of the CRP was extended to fluoroscopy and computed tomography (CT), but it covered primarily a situation analysis of patient doses and equipment quality control. It did not cover patient dose reduction aspects in fluoroscopy and computed tomography (CT). This is termed as Phase II in this publication and the project then continued up to 1999 for Phase II. A further objective was to promote awareness about practical implementation of quality control protocols, image quality evaluation and to create a pool of expertise in each participating country in the area of radiological protection of patients in diagnostic radiology.

Since no centre had digital radiography, the work pertained to only conventional radiography. Further, the term radiography has been used in this publication to imply conventional radiography.

While the CRP involved only a few hospitals in each country, the experience gained will be useful to other hospitals and centres in each participating country, and other countries as well. The collection of patient dose data is a first step towards establishing reference doses applicable in the respective countries.

This TECDOC is intended to serve as an example for the implementation of such a project in countries currently lacking an approach to optimization of radiological protection for patients in diagnostic radiology.

3. METHODOLOGY

Sixteen Member States, namely: Armenia, Croatia, the Czech Republic, Romania, Poland (eastern Europe); Morocco (Africa); Bangladesh, China, India, Indonesia, Islamic Republic of Iran, Malaysia, Pakistan, Philippines, Thailand and Vietnam (Asia) were initially involved in the CRP. However, six withdrew at various stages, primarily due to local difficulties. Of the original sixteen, eleven countries, namely: Armenia, the Czech Republic, Romania, Morocco, China, India, Indonesia, Malaysia, Pakistan, Thailand and Vietnam completed Phase I of the CRP. Nine countries, namely the Czech Republic, Romania, Morocco, China, India, Indonesia, Malaysia, Thailand and Vietnam completed Phase II of the CRP.

Close interaction and cooperation between radiology staff and medical physicists were essential for the success of this project. It was also the first time that most of the participating hospitals were involved in a research project of this kind. These practicalities necessitated participation of a limited number of diagnostic departments and a smaller focus of activities involving a few of the more common X ray examinations or those that had a potential for high doses to patients. Each participating country selected four hospitals, at least one of which was a major hospital.

In Phase I, the radiographic X ray examinations studied in the project were limited to a few selected common X ray examinations and the projections that commonly make up these examinations: chest posterior-anterior (PA) and lateral; lumbar spine anterior-posterior (AP) and lateral; pelvis AP; skull PA and lateral. Similarly, in Phase II, the fluoroscopy examinations covering barium meals and CT examinations of the chest were included.

3.1. IMAGE QUALITY EVALUATION

The assessment of patient doses always needs to be undertaken in parallel with image quality assessments. The exposure of patients needs to be the minimum necessary to achieve the required diagnostic objective taking into account norms of acceptable image quality for the clinical purpose, as established by appropriate professional bodies and relevant guidance levels for the examination considered. In this study, the European Community (EC) guidelines on quality criteria for radiographic images [5] were used for image evaluation.

The ‘European Guidelines on Quality Criteria for Diagnostic Radiographic Images’ were the result of a coordinated initiative by radiologists, radiographers, physicists, radiological protection experts, health authorities and professional, national and international organizations. The stated objectives of the guidelines were to achieve:

- adequate image quality, comparable throughout Europe;
- a reasonably low radiation dose per radiograph.

It is the aim of the Quality Criteria to characterize a level of acceptability for normal radiographs that would satisfy all clinical needs. They also provide the basis for accurate

radiological interpretation of the image. The European Guidelines are primarily directed at the technical and clinical staff involved in taking the radiographs and in reporting on them. They represent an achievable standard of good practice, which can be used as a basis for further development by the radiological community.

The applicability of the Quality Criteria for adult radiology has been verified in European-wide trials involving some hundred radiological departments and about 3000 radiographic images and dose measurements. The results have been discussed at workshops, by working parties and by dedicated study groups; advice and comments have been collected from professional associations, individual experts and healthcare authorities.

The European Guidelines do not claim to give strict instructions on day-to-day radiological practice, but attempt to introduce basic criteria that have been proved to lead to the necessary quality of the diagnostic information with reasonable dose values applied to the patient. This is a first step in the optimization of medical exposures, whereby a lower quality standard should ideally be associated to lower dose. Compliance with these Guidelines will help to protect the patient and staff against unnecessary radiation exposure, and will prevent any degradation of the equipment or faulty use of the imaging procedure from resulting in unsatisfactory images.

The European Guidelines address the three important inter-related aspects of the imaging process:

- the diagnostic quality of the radiographic image;
- the radiation dose to the patient;
- the choice of radiographic technique.

Quality Criteria were drawn up for representative radiographs from six routine examinations. Compliance with the criteria for these radiographs is a first but important step in ensuring satisfactory overall performance. To address each of the aspects above guidelines are given for each of the six examinations under the following topics:

- diagnostic requirements;
- criteria for radiation dose to the patient;
- examples of good radiographic technique.

3.1.1. Diagnostic requirements

These are image criteria for a particular type of radiograph deemed necessary to produce an image of standard quality. No attempt has been made to define acceptability for particular clinical indications. These are often a matter of personal preference for a radiologist and will be determined by local conditions and particular clinical situations.

3.1.1.1. Image criteria

The image criteria in most cases specify important anatomical structures that should be visible on a radiograph to aid accurate diagnosis. Some of these criteria depend fundamentally on correct positioning and cooperation of the patient, whereas others reflect technical performance of the imaging system.

3.1.1.2. Important image details

These provide quantitative information on the minimum sizes at which important anatomical details should become visible on the radiograph. Some of these anatomical details may be pathological and therefore may not be present.

3.1.2. Criteria for radiation dose to the patient

These are expressed in terms of a reference dose value for each type of radiograph which is based on the third quartile (75th percentile) value seen in earlier European patient dose surveys. Its purpose, if it is exceeded, is to initiate an investigation into the reasons for using relatively high dose techniques and to trigger appropriate corrective action. The reference dose value can be taken as a ceiling from which progress should be pursued to lower dose levels in line with the principle of optimization of protection.

Reference values are provided for the entrance surface dose to a standard-sized patient for each type of radiograph considered. The entrance surface dose for standard-sized patient is expressed as the absorbed dose to air (mGy) at the point of intersection of the X ray beam axis with the surface of a standard-sized adult patient (70 kg body-weight or 5 cm compressed breast thickness in case of mammography), backscatter radiation included.

3.1.3. Examples of good radiographic technique

Examples of good radiographic technique included in these Guidelines have involved the results of two European trials of the Quality Criteria. Compliance with the image and patient dose criteria was possible when the recommended techniques were used. To encourage widespread use, the image criteria have been expressed in a manner requiring personal visual assessment rather than objective physical measurements which need sophisticated equipment unavailable to most departments. However, the assessment of compliance with the criteria for radiation dose to the patient for a specific radiograph unavoidably involves some form of dose measurement. This requires representative sampling of the patient population.

This provides an example of one set of radiographic technique parameters that has been found to result in good imaging performance that is capable of meeting all the above quality criteria. Details are also given of a suitable combination of accessory devices, geometrical conditions and loading factors using current X ray imaging technology. If radiologists and radiographers find that diagnostic requirements or criteria for radiation dose to the patient are not met, then the example of good radiographic technique can be used as a guide to how their techniques might be improved.

3.1.4. Guidance on implementation of the guidelines

The Quality Criteria apply to adult patients of standard size (70 kg, or 5 cm compressed breast in the case of mammography) with the usual presenting symptoms for the type of examination being considered. They are to be used by radiologists, radiographers and medical physicists as a check on the routine performance of the entire imaging process.

It should be noted that the Quality Criteria cannot be applied to all cases. For certain clinical indications lower level of image quality may be acceptable, but this should ideally always be associated with a lower radiation dose to the patient. The Guidelines state that:

Under no circumstances should an image, which fulfils all clinical requirements but does not meet all image criteria, ever be rejected.

Below are examples of application of the Quality Criteria to two selected radiographic projections: Chest PA (posterior-anterior) and Chest LAT (lateral).

3.1.4.1. Chest-PA projection

Diagnostic requirements

(1) Image criteria

(a) Performed at full inspiration (as assessed by the position of the ribs above the diaphragm — either 6 anteriorly or 10 posteriorly) and with suspended respiration

(b) Symmetrical reproduction of the thorax as shown by central position of the spinous process between the medial ends of the clavicles

(c) Medial border of the scapulae to be outside the lung fields

(d) Reproduction of the whole rib cage above the diaphragm

(e) Visually sharp reproduction of the vascular pattern in the whole lung, particularly the peripheral vessels

(f) Visually sharp reproduction of:

- the trachea and proximal bronchi
- the borders of the heart and aorta
- the diaphragm and lateral costo-phrenic angles

(g) Visualization of the retrocardiac lung and the mediastinum

(h) Visualization of the spine through the heart shadow

(2) Important image details

(a) Small round details in the whole lung, including the retrocardiac areas:

- high contrast: 0.7 mm diameter
- low contrast: 2 mm diameter

(b) Linear and reticular details out to the lung periphery:

- high contrast: 0.3 mm in width
- low contrast: 2 mm in width.

Criteria for radiation dose to the patient

Entrance surface dose for a standard-sized patient: 0.3 mGy

Example of good radiographic technique

(1) Radiographic device: vertical stand with stationary or moving grid

(2) Nominal focal spot value: 1.3

(3) Total filtration: 3.0 mm Al equivalent

(4) Anti-scatter grid: r = 10; 40/cm

(5) Screen film system: nominal speed class 400

(6) FFD (Focus-Film distance): 180 (140-200) cm

(7) Radiographic voltage: 125 kV

(8) Automatic exposure control: chamber selected — right lateral

(9) Exposure time: < 20 ms

(10) Protective shielding: standard protection.

3.1.4.2. Chest-lateral projection

(if indicated after viewing PA film)

Diagnostic requirements

(1) Image criteria

(a) Performed at full inspiration and with suspended respiration

(b) Arms should be raised clear of the thorax

(c) Superimposition of the posterior lung borders

(d) Reproduction of the trachea

(e) Reproduction of the costo-phrenic angles

(f) Visually sharp reproduction of the posterior border of the heart, the aorta, mediastinum, diaphragm, sternum and thoracic spine.

(2) Important image details

(a) Small round details in the whole lung:

- high contrast: 0.7 mm diameter
- low contrast: 2 mm diameter

(b) Linear and reticular details out to the lung periphery:

- high contrast: 0.3 mm in width
- low contrast: 2 mm in width.

Criteria for radiation dose to the patient

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

Example of good radiographic technique

(1) Radiographic device: vertical stand with stationary or moving grid

(2) Nominal focal spot value: 1.3

(3) Total filtration: 3.0 mm Al equivalent

(4) Anti-scatter grid: r = 10; 40/cm

(5) Screen film system: nominal speed class 400

(6) FFD: 180 (140-200) cm

(7) Radiographic voltage: 125 kV

(8) Automatic exposure control: chamber selected — central

- Exposure time: < 40 ms
- Protective shielding: standard protection.

3.2. ASSESSMENT OF PATIENT DOSES

3.2.1. Choice of dose quantities

Weighted-organ dose quantity, such as effective doses represents a convenient indicator of overall exposure in diagnostic practice [6]. Effective dose broadly reflects the risks to health of stochastic effects, and can be used for comparison purposes[1].

The analysis of radiation risk from diagnostic medical exposure requires a detailed knowledge of organ doses, the age and sex of patient. Organ doses from diagnostic x ray procedures are difficult to assess, and in practice routine patient monitoring is usually based on direct measurable quantities, such as entrance surface dose (ESD). ESD is the absorbed dose to air measured in the primary X ray beam in the entrance plane of the patient with the patient present in the beam, and therefore includes backscatter. Organ doses can be estimated from ESD by using conversion factors appropriate to the conditions of the exposure. These coefficients can be determined experimentally on physical anthropomorphic phantoms or calculated using Monte Carlo techniques to simulate photon transport in mathematical phantoms.

Effective dose can then be obtained from organ doses by the sum of weighted organ doses and can be used for comparative purposes for individuals undergoing each type of procedure and, taking into account the number of procedures, for the estimation of the collective effective dose.

In this study, a pragmatic approach to dose was needed. The dose quantity chosen needed to 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 organ doses or effective dose.

For simple X ray projections, ESD is a reliable dose quantity, commonly used in diagnostic radiology to give an indication of the typical dose to the patient. In addition, the measurement of ESD permits easy comparison with published diagnostic guidance or

[1] However, effective dose should not be used directly for estimating the detriment from medical exposure by applying, for example, the nominal fatality probability coefficient given by the ICRP. Such assessment would be inappropriate and would serve no purpose in view of the uncertainties arising from potential differences (in terms of health status, age and sex) between particular populations from whom the ICRP has derived the risk coefficient.

reference levels. The use of thermoluminescent dosimeter (TLD) chips placed on the skin of the patient is a simple means of measuring ESD.

Estimating patient doses in fluoroscopy is made difficult by the nature of the examination. Any combination of factors such as kVp, mA, beam area, projection, body part irradiated can change at any time throughout the examination. Keeping track of such changes is unrealistic and a more holistic approach is needed. Dose area product is a measure of the energy imparted to the patient, and in turn is related to effective dose. Measurement of dose area product is easily achievable with a transmission ionization chamber attached to the X ray tube assembly.

Two of the common measurable quantities used for patient dosimetry in CT have been the computed tomography dose index (CTDI) and the multiple scan average dose (MSAD).

CTDI is defined as the integrated dose profile (in the z-direction) for a single slice, normalized to the nominal slice thickness. It can be measured either in air or in a phantom using either a pencil ion chamber or a row of TLDs. In essence the CTDI gives a measure of the "raw" output of a scanner. Common forms of CTDI include:

CTDI in air ($CTDI_{air}$), measured at the centre of rotation of the beam in the absence of a patient or phantom (without scatter and attenuation);

CTDI measured at the centre of a PMMA phantom (16 cm of diameter for head scans and 32 cm for body scans) as $CTDI_c$, and at the phantom periphery (1 cm depth) as $CTDI_p$;

$CTDI_w$, a weighted version of CTDI, defined as $CTDI_w = \frac{1}{3} CTDI_c + \frac{2}{3} CTDI_p$.

MSAD is effectively the sum of the dose profiles for a scan series. Measurement of the MSAD requires the use of a dosimetry phantom, such as a solid PMMA cylinder, and either a pencil chamber or a significant stack of TLD to obtain the integrated dose profile resulting from a multiple scan series. MSAD has the advantage over $CTDI_{air}$ of reflecting how the scanner is used in clinical reality, although it falls short of reflecting the whole examination. In its guidance levels for medical exposures the BSS used MSAD measured on axis in water equivalent phantoms (16 cm diameter for the head and 30 cm diameter for the lumbar spine and abdomen).

When MSAD is measured for multiple slices and the distance between slices is equal to the slice width (or pitch = 1) the MSAD is equal to the CTDI measured in the phantom at the same radial position as the MSAD.

The effective dose to a patient undergoing CT can be calculated from the normalized organ dose data obtained from the scanner-specific $CTDI_{air}$. A more recent simplified approach has been to use the quantity dose length product (DLP) as a surrogate for patient dose, especially in the context of diagnostic reference levels. DLP can be determined for a given examination from measured $CTDI_w$ value, together with the examinations technique

factors. Published data also allow the estimation of $CTDI_w$, and hence DLP, from measurements of $CTDI_{air}$.

The decision to use $CTDI_{air}$, on axis, as the basis for CT dosimetry in this study was threefold:

It is easily measured with a TLD or a pencil chamber and does not need a special phantom. Not all of the participants had access to phantoms.

$CTDI_{air}$ was used as the "input" into the standardized CT dose database that was used in this study - namely, the NRPB SR250 data sets, which allowed the calculation of effective dose.

Since the BSS was written, dosimetry for CT has evolved and the now preferred quantities for diagnostic reference levels are $CTDI_w$ and DLP. Data and software programmes exist that allow estimation of these quantities from $CTDI_{air}$.

For these reasons, in this study CTDI was measured and reported, and compared with published data.

In addition, for the selected general chest CT examination, the dose length product (DLP) was calculated.

However, for complete assessment of patient doses in CT, examination technique factors must be considered. kVp, mAs per slice, slice width, couch increment and number of slices all affect the patient dose. Analogous to dose area product for fluoroscopy, dose length product (DLP) can be used for CT. DLP is essentially the product of the incident radiation per slice ($CTDI_w$) and the extent of the patient irradiated. Published data enable DLP to be calculated from $CTDI_{10cm,air}$ by using conversion coefficients together with the examination technique actually used.

3.2.2. Dosimetry systems

The thermoluminescence dosimeters (TLD) chosen to perform dose measurements were lithium fluoride (mostly LiF-100, plus GR-200) which has sufficient sensitivity and flat energy response within the range of the X ray beam qualities used in diagnostic radiology. Technical prerequisites that each participating country complied with before starting any patient dose measurements were:

- the standard deviation of the TLD batch should be about 5%
- the minimum detectable dose should be less than 0.05 mGy
- the standard deviation of readings at 0.1 mGy should be less than 30%

3.2.3. Calibration and intercomparison

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 be calibrated in the same manner and be capable of performing within the recommended levels of precision and accuracy.

All countries participated in calibration and intercomparison procedures which allowed an estimation of:

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

The primary standards dosimetry laboratory at the National Radiation Laboratory (PSDL-NRL), Christchurch, New Zealand performed the calibration and intercomparison exercise for the Asian countries while the Secondary Standards Dosimetry Laboratory of the National Institute of Public Health (SSDL-NIPH), Prague, Czech Republic performed the exercise for the European participants.

Each participating country sent TLD chips to the respective calibration laboratory. The dosimeters were annealed by the participating countries before being sent. Two calibration/intercomparison exercises took place over the course of the project. The first was in 1996 to coincide with patient dose assessment in Phase I, and the second in 1998 to coincide with the assessment of patient doses in CT as part of Phase II.

For energy calibration, 3 sets of dosimeters per country (5 TLDs in each set) were irradiated at a nominal air kerma of 50 mGy at 3 representative diagnostic energies, and 1 set of dosimeters was irradiated by γ radiation — ^{137}Cs (662 keV) for the Czech Republic and ^{60}Co (1.25 MeV) for New Zealand. For the linearity of TLD response, 3 supplementary sets of dosimeters were irradiated at nominal air kerma values of 0.1, 5 and 50 mGy respectively at the same X ray energy value.

For intercomparison purposes of the TLD systems, 3 sets of dosimeters per country were also irradiated at known X ray energies for air kerma values that were not disclosed to the participants - only information of air kerma range was provided to the participants. After each participating country had estimated the intercomparison doses, they were advised what the actual doses were.

A set of chips was reserved for background and transport dose evaluation. Once the TLDs were irradiated, they were returned to the respective countries.

The exposures at the PSDL-NZ were made free-in-air using a Pantak constant potential X ray equipment, plus an exposure with ^{60}Co. Air kerma was measured for the X ray

using a medium energy primary standard chamber, and for the γ rays using a secondary chamber (Farmer NE 2571).

The exposures at SSDL-NIPH were made using a Seifert Isovolt 400 X ray device, and a ^{137}Cs source of 87 GBq (γ rays). Air kerma was estimated using two secondary chambers - Victoreen 415A and VAK 253, respectively.

Details of the irradiation conditions for calibration and for intercomparison of the TLD systems are given in Annex I.

A standard calibration procedure for dose area product meters (DAP meter) was given to the participants. Similarly a methodology for determining the $CTDI_{air}$ was given to the participants.

3.3. POTENTIAL FOR DOSE REDUCTION

Patient dose in radiography can be reduced by a number of factors without losing the necessary information for diagnosis. Some of these factors may be applied without having access to sophisticated equipment and may lead to substantial improvement in terms of dose reduction. It is worth noting that not all methods for reduction of the entrance surface dose influence organ doses and the effective dose in the same proportion.

Increasing the speed class of the film/screen combination will affect both the ESD and effective dose by the same factor. This is because the X ray beam quality and therefore the dose inside the patient have remained unchanged. On the other hand, changing the kVp and/or filtration, for example, will not affect both the ESD and effective dose by the same factor. In these cases the beam quality has been changed and therefore the penetration and scattering inside the patient i.e. the dose distribution, are modified.

Both procedural and equipment factors influence patient dose in fluoroscopic and CT procedures. For this reason, information on fluoroscopy time and the number of images, and number of slices, thickness and mAs per slice for CT were reported and with these data it is possible to begin an optimization process by comparing these data with internationally accepted guidelines. And similarly, patient entrance dose rates (in conjunction with image intensifier input dose rates) for fluoroscopy and CTDI values for CT can also be compared with published values to give an indication of whether the equipment performance was acceptable or not.

3.3.1. Filtration

Filtration is used to remove the low energy components of the X ray spectrum which do not contribute to image formation but are absorbed by superficial layers of the tissues. X ray tubes have both inherent and added filtration. Inherent filtration is filtration provided by permanent materials through which the radiation beam must pass before emerging from the radiation source. For X ray tubes it is the filtration inherent in the structural components of the X ray tube head: the glass of the X ray tube, the insulating oil, the seal of the X ray port.

Additional filtration is the quality equivalent filtration due to added filters and other removable materials in the radiation beam which are between the radiation source and the patient or a specified plane. Total filtration is sum of effective thickness of materials traversed by the primary X ray beam before it enters the patient which is the sum of aluminium equivalent thickness of inherent and additional filtration.

The minimum total filtration present in a standard general radiographic X ray tube for use up to 100 kVp is not less 2.5 mm of aluminium. Filtration in addition to this minimum can be used to reduce ESD. If too much additional filtration is used, image quality can be compromised by the reduction in contrast that arises from the harder quality of the incident X ray beam. Also too much filtration reduces the amount of radiation reaching the film. Compensation for this reduction may lead to longer exposure times which can cause image blurring and larger tube loading factors (mAs), which may result in tube overheating.

3.3.2. Tube potential

A reduction of the ESD for the same optical density of the film can be achieved by increasing the "penetration" of the X ray beam (increasing the tube potential). However, the extent to which ESD may be reduced does not result in the same reduction in effective dose.

The optimal choice of energy spectrum depends primarily on patient thickness, contrasting detail, characteristics of the anti-scatter grid used, image receptor and display method. While a "high kV technique" is desirable in some types of examinations, in general "high kV techniques" cannot be recommended in cases where high contrast performance is needed. The usual approach is to use the highest kVp that is compatible with the imaging performance required to ensure a diagnostic image.

3.3.3. Screen-film combination

The higher the sensitivity class the lower the dose, but image quality requirements ultimately limit the range of acceptable sensitivities. 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 sensitive film). The sensitivity class of the screen-film combination used should be selected according to the type of examination. The quality of the image and the radiation dose depend on the characteristics and condition of the film and intensifying screens used. Therefore it is important that the screens are carefully handled and kept clean using the manufacturer's recommended products.

3.3.4. mAs product

In cases where the optical density of the film is too high, lowering the current x time product of the X ray tube (mAs) may improve image quality. Reductions in mAs affect both ESD and effective dose by the same factor. In some cases there is scope to keep the same mAs by increasing the mA and reducing the time. This also may yield image quality improvements by reduction of motion blurring due to shorter exposure time.

3.3.5. Film processing

During processing, the latent image captured on the film during the exposure is transformed into a visible, stable radiographic image. The processor is often the most critical element in the imaging chain from the quality control point of view. Deficiencies in processing methods, especially manual processing, accounts for a large percentage of rejected films which have to be repeated with attendant dose to the patients.

With 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 need to be assured with the greatest care, in order to avoid rapid degradation of the image quality (loss of contrast, speed, and increase in base + 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.

3.4. DIAGNOSTIC GUIDANCE LEVELS (REFERENCE LEVELS)

The BSS require that guidance levels for medical exposure be determined and revised as technology improves and used as guidance by medical practitioners, in order that:

(a) corrective actions be taken as necessary if doses or activities fall substantially below the guidance levels and the exposures do not provide useful diagnostic information and do not yield the expected medical benefit to patients;

(b) reviews be considered if doses or activities exceed the guidance levels as an input to ensuring optimized protection of patients and maintaining appropriate levels of good practice; and

(c) for diagnostic radiology, including computed tomography examinations, the guidance levels be derived from the data from wide scale quality surveys which include entrance surface doses (ESD) and cross-sectional dimensions of the beams delivered by individual facilities for the most frequent examinations in diagnostic radiology.

The BSS further require that in the absence of wide scale surveys, performance of diagnostic radiography and fluoroscopy equipment should be assessed on the basis of comparison with the guidance levels specified in Schedule III, Tables III-I to III-V. (see Annex II) These levels should not be regarded as a guide for ensuring optimum performance in all cases, as they are appropriate only for typical adult patients and, therefore, in applying the values in practice, account should be taken of body size and age.

In a study such as this, once suitable patient dose quantities have been chosen, indicative dose measurements are usually made on so-called “average” patients, under normal clinical conditions, using current imaging technologies and techniques. Since such an average patient (for example, assumed to be 20 cm AP trunk thickness and 70 kg weight in Europe) is unlikely to be available, measurements typically are made on a statistically significant sample

of patients (minimum of 10) whose weights are near average (± 10 kg). The mean value of these dose measurements can be taken as an estimate of the dose to a standard-sized patient for comparison with guidance levels (reference dose values).

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 reference dose values are consistently exceeded with normal sized patients.

Actual values for guidance levels and reference doses are typically based on surveys of current practices. For example, Guidance levels for diagnostic radiology procedures given in the BSS [1] are reproduced in the values in Annex II. Reference values given in the EC document [5], were determined on the basis of the 3rd quartile of patient dose distributions obtained in European surveys in recent years. These values, for some projections investigated in this study, are presented in Table I below.

TABLE I: REFERENCE VALUES OF ESD GIVEN IN THE EC DOCUMENT EUR16260 EN [5] AND GUIDANCE LEVEL OF ESD GIVEN IN BSS.

Examination Type	Reference values for ESD for a standard-sized patient (70 kg) [mGy]	Guidance levels for ESD for a typical adult patient (70 kg) [mGy]
Chest PA	0.3	0.4
Chest LAT	1.5	1.5
Skull PA	5.0	5.0
Skull LAT	3.0	3.0
Lumbar spine AP/PA	10	10
Lumbar spine LA	30	30
Lumbo-sacral junction LAT	40	40
Pelvis AP	10	10

In the same way, reference doses for some CT and fluoroscopy examinations have been proposed [7]. For fluoroscopy examinations DAP values are used, and for CT examinations DLP values are used. Of relevance to this project are reference values for barium meals and general chest CT, which are 25 $Gycm^2$ [8] and 650 mGycm [7, 9] respectively. In addition for CT, the weighted $CTDI_w$ has been suggested as a reference quantity for single slice performance. For Chest CT, a value of 30 mGy for $CTDI_w$ has been proposed [7, 9].

3.5. WORK PLAN

3.5.1. Radiography (Phase I)

The overall approach of Phase I was to assess the current status of practice and equipment performance in a selected number of X ray rooms and for specific categories of X

ray projections. Both image quality and patient dose were assessed. This was followed by the introduction of quality control measurements and the ensuing corrective actions. Image quality and dose were then re-measured to quantify the effectiveness of the implemented actions. The X ray projections selected were the following: chest PA and lateral; lumbar spine AP and lateral; pelvis AP; skull PA and lateral. In each participating hospital, at least two X ray rooms where these projections were performed were selected.

The following assessments were made, in turn, over an 18-month period.

3.5.1.1. Examination frequencies and radiographic techniques

At the start of Phase I, data were collected for each of the selected X ray rooms for a period of two weeks. For each X ray projection performed in the room the following parameters were recorded:

- Patient name or file number
- Age, sex, weight of the patient
- kVp
- mA
- exposure time
- FFD
- film size
- AEC (automatic exposure control) settings.

These data, together with the information on the relative frequency of examinations performed in the selected X ray room, provided base line information for the future QC programme in that hospital.

3.5.1.2. Evaluation of image quality and patient dose before quality control

Image quality assessment

For the radiographic images, the EC guidelines on quality criteria for radiographic images [5] were used for image evaluation (See Section 3.1). Local radiologists assessed films made for each projection type before the QC tests using the EU image evaluation using forms designed for the purpose. The films evaluated were those for which dose measurements had been made.

Originally, it had been proposed that films would be evaluated by a central panel of radiologists and also by an independent international panel of radiologists. However, practicalities in the end dictated that films were evaluated locally only, and, in many cases, by only one local radiologist. The difficulties encountered had to do with the local rules governing healthcare schemes in the various countries. For example, in some countries,

patients pay for their films and would keep them after diagnosis. This made it impossible to have the films later for review and evaluation by a panel of radiologists. Legal implications of sending out patient films from each country for external evaluations were also another impediment. Therefore it was not possible to conduct any comparison of image quality between countries.

Film reject analysis

Film reject analysis (FRA) was performed at the beginning of Phase I and after the QC part of the project had been completed. The FRA was performed for a minimum period of 2 weeks in each of the X ray rooms involved in the study. The causes for rejection of films were analysed according to the following:

- too dark
- too light
- positioning/collimation errors
- patient movement
- other.

Films were rejected at both the radiographer (or technologist) level and radiologist level. Comments were sought on the respective reasons for rejection.

Patient dose assessment

In accordance with the methodology of the EC document on quality criteria in diagnostic radiography [5], entrance surface dose values for each X ray projection performed in a given X ray room were measured for a sample of 10 adult normal sized patients. Sets of 3 TLDs were placed on the patient's skin in the centre of the X ray beam. For the European participating countries the accepted average weight of 70 kg ± 10 was appropriate. However, for the Asian participating countries, it was considered that the average weight of about 60 kg was more relevant. For the purpose of comparing measured doses with reference doses, and the application of EC developed image criteria, a compromise of 65 kg ± 10 was used for the Asian countries.

For the measurement of ESD, the following parameters were collected for each of the 10 patients in the sample for each projection:

- patient name or identifier
- age, sex, weight of the patient
- kVp, mA, exposure time
- FFD, FSD, film size, film screen sensitivity
- use of grid
- use of AEC
- X ray machine model, wave form, filtration.

A first set of dose measurements was carried out at the very beginning of the phase without any intervention aimed at improving the performance of the imaging systems.

3.5.1.3. Quality control

The following quality control tests were performed on the radiographic X ray equipment:

- accuracy and reproducibility of kVp
- accuracy and reproducibility of timer
- linearity of output with mA and time
- reproducibility of X ray output
- HVL determination
- light/radiation beam alignment
- brightness and homogeneity of viewing boxes, whenever possible
- X ray film processor (temperature, sensitometry).

For each of these tests, reporting forms were designed and used by all to allow for collection of all relevant data and comparison of data.

The introduction of the quality control tests marked the half-way of Phase I. Appropriate corrective actions were then made on the basis of the quality control tests on the equipment.

From a technical point of view, radiographic techniques (range of kVp, film-screen sensitivity etc.) were compared with those suggested by the EC image criteria document [5], in order to improve the local radiological practice. Further changes were then made, where indicated, as a result of the review of the protocols used for the projections under study. These corrective actions and changes were constrained by the existing practical and economic considerations within each participating country.

3.5.1.4. Evaluation of image quality and patient dose after quality control

Image quality assessment

A second set of image evaluation following the EC guidelines on quality criteria for radiographic images was performed by local radiologists for each projection type after the QC tests and corrective actions identified and implemented. The films evaluated were also those for which dose measurements had been made. All films were evaluated locally due to the reasons given in Section 3.5.1.2.

Film reject analysis

Film reject analysis (FRA) was repeated at the end of Phase I and after the QC part of the project had been completed and remedial action taken. The FRA was performed for a

minimum period of 2 weeks in each of the X ray rooms involved in the study. The causes for rejection of films were analysed according to the following criteria:

- too dark
- too light
- positioning/collimation errors
- patient movement
- other.

Films were rejected at both the radiographer (or technologist) level and radiologist level.

Patient dose assessment

A second series of dose measurements took place after having implemented remedial actions resulting from quality control tests and review of examination protocols. This was also done in accordance with the methodology of the EC guidelines on quality criteria in diagnostic radiography [5] used in the first exercise.

3.5.2. Fluoroscopy (Phase II)

The first purpose of Phase II was to assess the current status of radiological practice and equipment performance in fluoroscopy. This was achieved by considering the barium meal examination as representative of fluoroscopic procedures. In the selection of fluoroscopic systems both new and older systems were included to ensure that a wide range of likely imaging performance and patient dose would be assessed. Both image quality and patient dose were assessed. This was followed by the introduction of quality control measurements and the ensuing corrective actions. Image quality and dose were then re-measured to quantify the effectiveness of the implemented actions. Each participating hospital performed quality control measurements, estimated patient doses and assessed image quality.

3.5.2.1. Selection of fluoroscopy systems

At least 15 systems were to be part of the study, with at least 2 hospitals to be involved. Of these 15, there were to be a minimum of:

- mobile C-arm systems
- remote controlled table
- angiography system
- system without an image intensifier (if available).

3.5.2.2. Evaluation of image quality and patient doses

Image quality evaluation

Since internationally accepted evaluation criteria for fluoroscopy images currently do not yet exist, image assessment was performed by local radiologists. It was limited to the analysis of low contrast, high contrast and grey scale data obtained from the QC tests and recommended tolerance levels. The methodology for image quality assessment involved determination of high contrast resolution (in lp/mm) at the centre and at the periphery of the II, low contrast detectability and geometrical distortion.

Patient dose assessment

A dose area product meter (DAP meter) was used to assess patient doses for the barium meal (upper GI) examinations. This was performed for a minimum of 5 patients per centre.

The following parameters were collected for each patient:

- weight and age
- number of images
- total fluoroscopy time.

As in Phase I, a lower average weight was used for the Asian countries. Experience from Phase I suggested that the original idea of taking 65 kg average was still too high, and a lower range of 60 ± 10 kg was used for the Asian countries. For the Eastern European countries, the average weight remained as 70 ± 10 kg.

3.5.2.3. Quality control tests

The following quality control tests were made over a 15-month period:

- kVp accuracy
- linearity of X ray output with mA
- dose rates at the entrance of the image intensifier
- entrance surface dose rates to the patient equivalent phantom
- brightness and contrast of the TV monitor
- low contrast resolution
- high contrast resolution.

3.5.3. Computed tomography (Phase II)

The second purpose of Phase II was to assess the current status of radiological practice and equipment performance in CT. This was achieved by considering the general CT chest examination as representative of the CT procedures. In the selection of CT scanners, both new and older systems were included to ensure that a broader range of likely imaging performance

and patient dose would be assessed. Both image quality and patient dose were assessed. This was followed by the introduction of quality control measurements and the ensuing corrective actions. Image quality and dose were then re-measured to quantify the effectiveness of the implemented actions.

Each participating hospital performed quality control measurements, estimated patient doses and assessed image quality.

3.5.3.1. Selection of computed tomography systems

At least 3 systems were required to be part of the study, with one a newly installed unit, a second to be less than 5 years old, and the third to be not more than 10 years old.

3.5.3.2. Evaluation of image quality and patient doses

Image quality assessment

Image evaluation was performed using a provisional set of image criteria prepared by a group of experts of the EC [7]. Assessment of the CT images was performed by local radiologists by viewing images directly on the monitors at the consoles.

Patient dose assessment

For patient dose assessments in CT examinations, the computed tomography dose index ($CTDI_{10cm,air}$) was used. In addition, for the selected general chest CT examination, the dose length product (DLP) was calculated.

For each general chest CT examination, the following technical data were recorded:

- kV and mAs per slice
- number of slices and slice thickness
- couch increment.

In line with the fluoroscopy examinations, the average weight for the Asian patients was 60 ± 10 kg and 70 ± 10 kg for the Eastern Europeans.

3.5.3.3. Quality control tests

Due to the different features of the available CT phantoms, as a minimum the following limited QC tests were performed:

- calibration of CT numbers
- uniformity of CT numbers
- high contrast resolution
- noise
- low contrast detectability
- slice thickness.

4. RESULTS AND DISCUSSION

In this section, the findings of the collective experience of the participating countries are presented and discussed. Detailed results of some participants' reports on TLD calibration and intercomparison can be found in Annex I.

4.1. CALIBRATION AND INTERCOMPARISON OF DOSIMETRY SYSTEMS

The calibration and intercomparison exercise for the TLD systems used for patient dosimetry was coordinated by the Praha Laboratory, Czech Republic, for the European countries and by the National Radiation Laboratory, New Zealand, for the Asian countries. The details of the characteristics of equipment used, quality of X ray beams used for the irradiations and results for each country are reported in Annex I.

Table II summarizes the minimum detectable doses for most of the participants' TLD systems for both the first and second intercomparison, demonstrating an improved performance for those countries whose initial minimum detectable dose was higher than generally considered acceptable, and consistency of performance for the other countries. At the outset of the programme, the performance specification for the minimum detectable dose was given as less than 0.05 mGy. Three countries that reported TLD results failed to meet this specification in the first intercomparison, but in the second intercomparison and except one, all others came within the acceptable range.

TABLE II. PERFORMANCE OF TL DOSIMETRY SYSTEMS — MINIMUM DETECTABLE DOSE IN THE 1ST AND 2ND CALIBRATION AND INTERCOMPARISON EXERCISES

Country	Minimum detectable dose (mGy)	
	1st calibration	2nd calibration
China	0.007	0.011
Czech Republic	0.041	0.045
India	0.350	0.021
Indonesia	0.076	0.008
Malaysia	0.056	0.066
Thailand	0.014	0.005
Vietnam	0.034	0.024

Table III presents reported values at low doses (for true air kerma of 2.26 mGy) and percent deviation from true dose. These data are also displayed in Figure 1.

TABLE III. PERFORMANCE OF TLD SYSTEMS: PERCENTAGE DEVIATION FROM TRUE AIR KERMA (2.26 mGy) AND THE DOSE REPORTED BY PARTICIPATING COUNTRIES. THE STANDARD DEVIATIONS ARE GIVEN FOR THE 5 DOSIMETER READINGS USED FOR EACH REPORTED VALUE

Country	Reported values		Deviation from true value (%)
	Air Kerma (mGy)	SD (%)	
China	2.27	4.2	0.5
India	2.54	18.2	12.0
Indonesia	2.32	6.3	2.6
Malaysia	2.00	7.7	12.0
Thailand	2.30	4.8	5.7
Vietnam	2.26	4.8	0.0
Czech Republic*	2.14	4.90	7.0

* for the Czech Republic, the true air kerma value was 2.0 mGy.

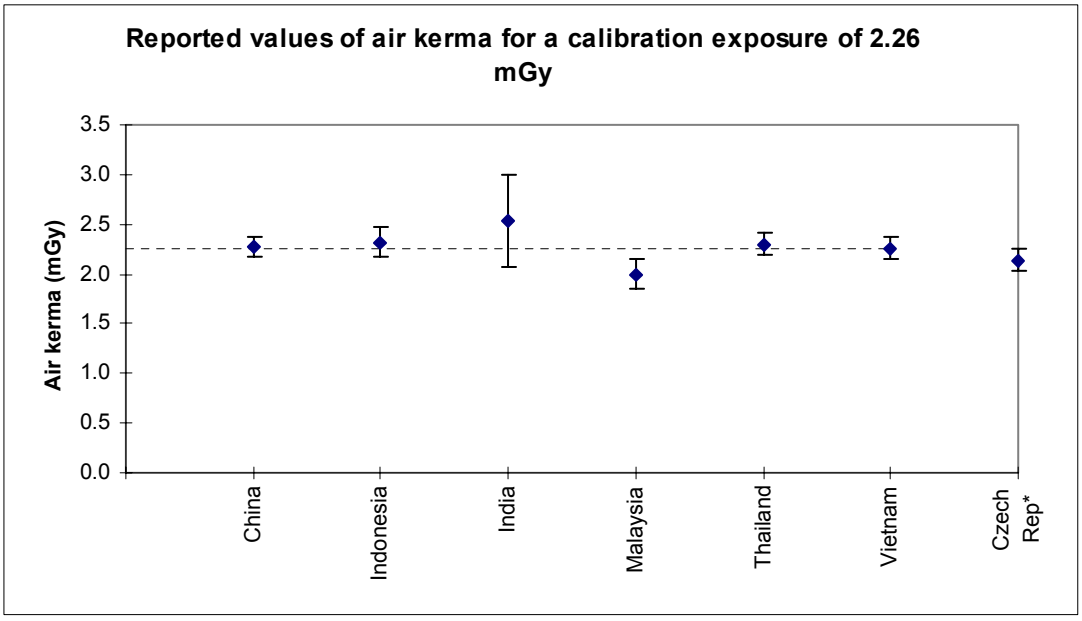

*FIG. 1. Performance of TLD systems: percentage deviation from true air kerma (2.26 mGy) given by the dotted line and the mean dose reported by participating countries. The uncertainties are one standard deviation as given in Table III. * Note: for the Czech Republic, the true air kerma was 2.0 mGy.*

The calibration and intercomparison exercises, performed at diagnostic beam qualities and at lower levels of dose, gave some additional assurance that the patient doses reported were credible and hence able to be recognized as representative of practice in the institution in the respective country.

4.2. PHASE I: RADIOGRAPHY — RESULTS AND DISCUSSION

General information

The number of beds and the number of examinations per year for the hospitals participating in the project varied widely, with the number of beds ranging from less than 100 to in excess of 2000 and the number of examinations per year ranging from around 5000 to over 100 000. Many of the centres are performing radiological examinations at a rate approximately 10 times lower than hospitals in Level I countries (as defined in UNSCEAR [10]) for a similar number of beds. Figure 2 presents the distribution of the number of X ray examinations per year for hospitals in the study.

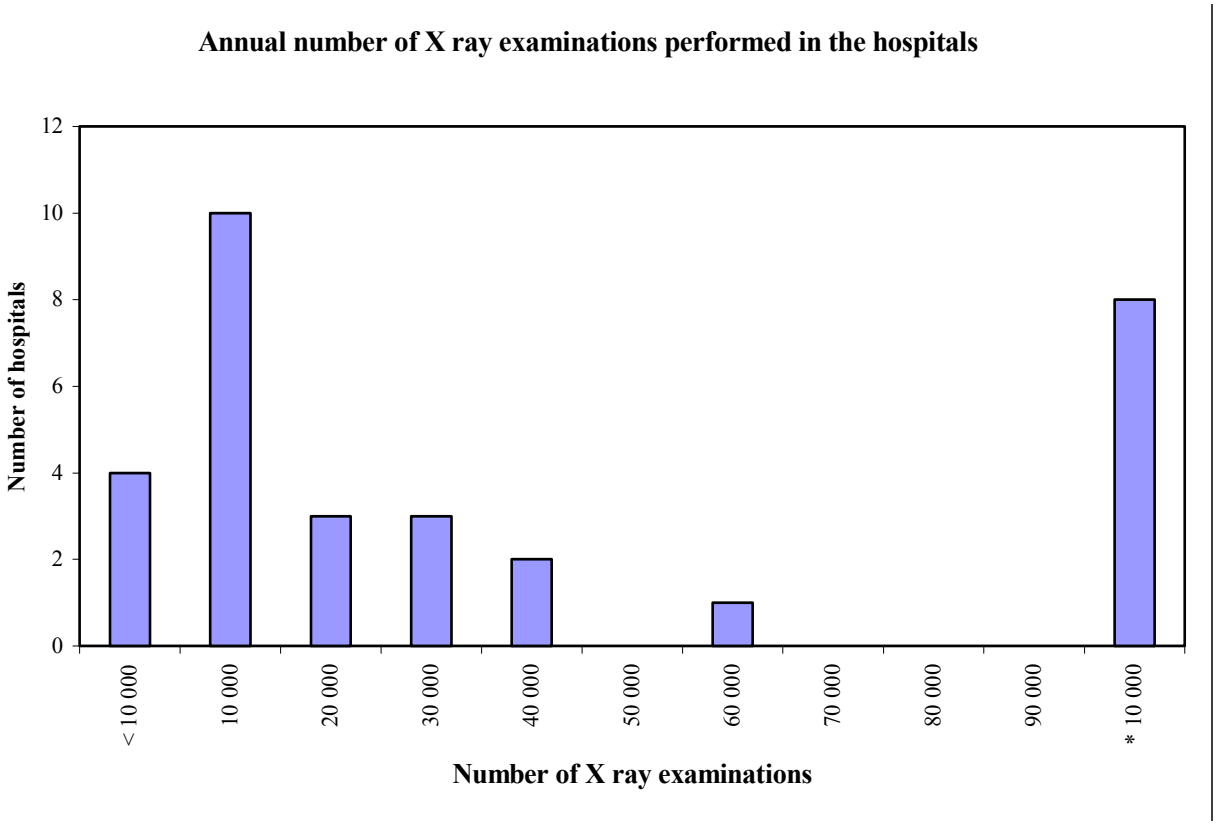

FIG. 2. Annual number of X ray examinations performed in the hospitals of the study.

4.2.1. Radiographic equipment details

X ray machines that were part of the study ranged from near new high frequency generators to single-phase units that had been in use for over 30 years. Figure 3 below shows the distribution of wave forms amongst the machines in the project. Clearly the most common wave forms were two pulse units and 12-pulse units. Further details on X ray equipment and film processors are given for each country in Annex III.

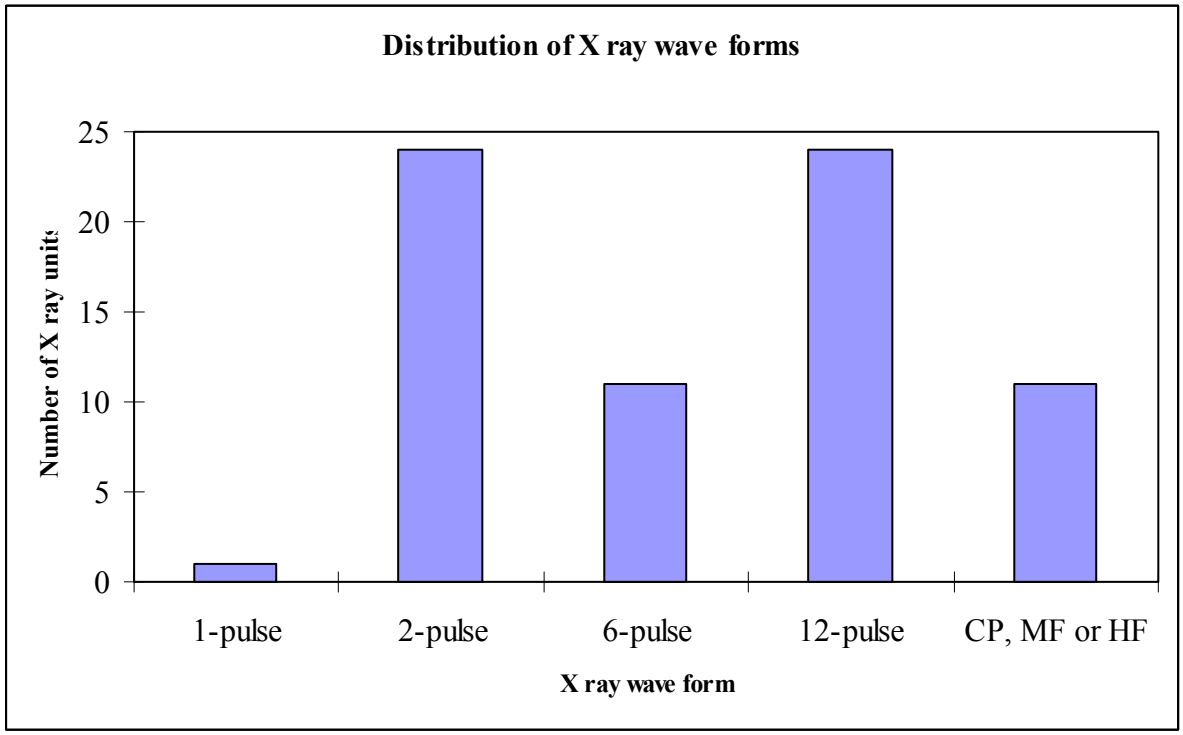

FIG. 3. Distribution of wave forms for X ray units in the study. (Note: CP means constant potential, and MF and HF, medium and high frequency respectively.)

4.2.2. Film reject rate analysis

Participants provided data on film reject rates for different types of examinations and the cause of rejection on a room-by-room basis, both before and after the QC programme and these data are given in Table IV. The collection time for each set of data was nominally two weeks, resulting in relatively low film numbers for some projections. Film rejection rates ranged from higher than 40% to less than 2%. Part of this wide spread of rates can be attributed to poor statistics from low film numbers on the one hand, and a lower threshold of acceptance of films due to lack of local resources, including the ready availability of film. With small exceptions, overall there was a decrease in the film reject rates after the introduction of the QC programme and its ensuing corrective actions.

TABLE IV. COUNTRYWISE FILM REJECT RATES (AS A PERCENTAGE OF TOTAL NUMBER OF FILMS) FOR EACH PROJECTION BEFORE QC AND AFTER QC

	Chest		Skull		Lumbar spine		Pelvis		All four examinations	
	Pre QC	Post QC	Pre QC	Post QC	Pre QC	Post QC	Pre QC	Post QC	Pre QC	Post QC
China	3.8	1.2	17.6	8.0	3.5	1.6	11.9	5.7	4.2	1.6
Czech Rep.	2.3	2.3	2.6	1.5	5.5	2.4	5.9	< 2	3.0	2.1
India	5.2	2.8	8.3	6.3	9.0	3.2	11.0	8.1	6.3	3.4
Indonesia	6.3	2.8	8.7	9.6	9.8	7.5	11.9	11.5	7.1	3.7
Malaysia	-	5.7	-	8.7	-	8.4	-	9.8	-	6.5
Morocco	23.5	8.3	16.7	< 8	41.5	25	16.7	16.7	26.4	12.5
Pakistan	6.3	8.0	12.3	12.7	8.6	9.5	7.5	11.1	6.9	8.8
Romania	11.1	9.8	11.9	17.3	20.5	16.8	8.7	10.9	13.8	13.0
Thailand	6.0	1.8	15.9	6.3	11.4	10.1	4.8	< 3	7.6	3.6
Vietnam	3.1	3.6	2.8	4.8	3.8	4.6	10.3	10.2	3.5	4.6

Causes of rejection are presented in Table V. For each country, these causes are averaged over examinations, hospitals, and both pre- and post- QC.

TABLE V. CAUSES OF REJECTION OF FILMS FOR EACH COUNTRY AVERAGED OVER PROJECTIONS AND ROOMS, AND BEFORE AND AFTER QC

Country	Rejection rate causes (%)				
	Too dark	Too light	Positioning	Movement	Others
China	32	42	16	10	0
Czech Rep.	21	22	27	7	23
India	37	27	13	12	11
Indonesia	24	46	20	5	5
Malaysia*	29	29	25	7	10
Pakistan	30	26	17	16	11
Romania	0	23	17	0	50
Thailand	32	28	11	4	25
Vietnam	9	6	0	0	85

*Reported results for too dark and too light were combined, and have been assigned equally in this table.

Combining the data in Table V, the pie chart in Figure 4 illustrates average causes of film rejection across the countries in the project.

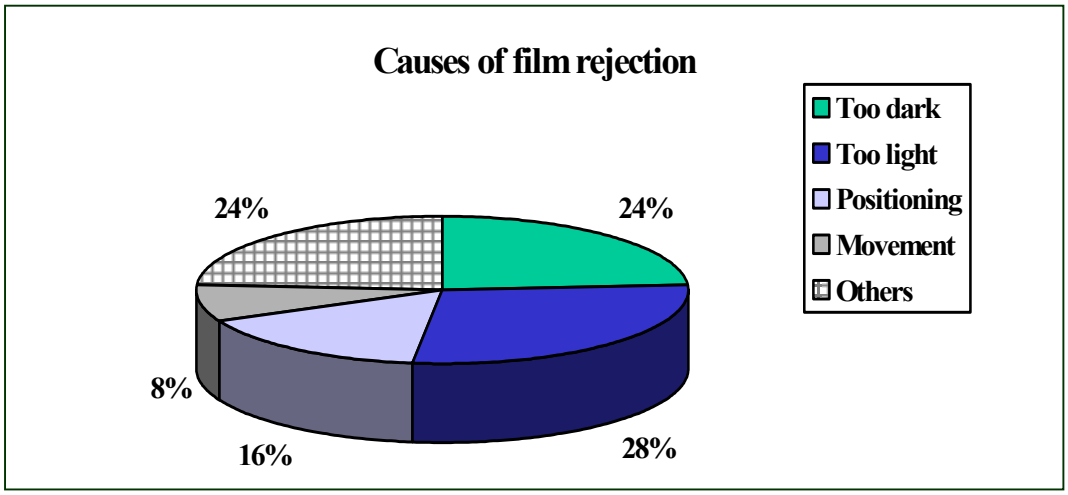

FIG. 4. Causes of film rejection averaged for all countries and for all projections combined.

The data in Figure 4 show that over half of films rejected were either too dark or too light. Films can be too light or too dark because of incorrect film processing or incorrect exposure settings. It should be noted that a film being too light is not necessarily the result of an under exposure of radiation.

4.2.3. Quality control

The overall results of the basic quality control measurements, that have been described in Section 3, and were performed as part of the programme, showed that there was a large variation in the level of equipment performance in different countries. One the one extreme, one country's results showed that all the parameters measured were within the tolerances recommended by international protocols, while on the other side, some countries reported big discrepancies for some rooms. Common problems were in kV accuracy, linearity of output with mAs, reproducibility, and in a few cases insufficient filtration.

Radiation output was measured at 80 kVp and at 75 cm from the focus and expressed as dose to air (mGy/mAs) free-in-air. Reported values ranged from less than 0.02 to more than 0.14 mGy/mAs, indicative of the range of wave forms, filtration, kVp accuracy and mAs calibration. Figure 5 presents these output data in a histogram. Where output values are very low, X ray examination methodology may need to be revised to avoid long exposure times that could lead to image quality degradation.

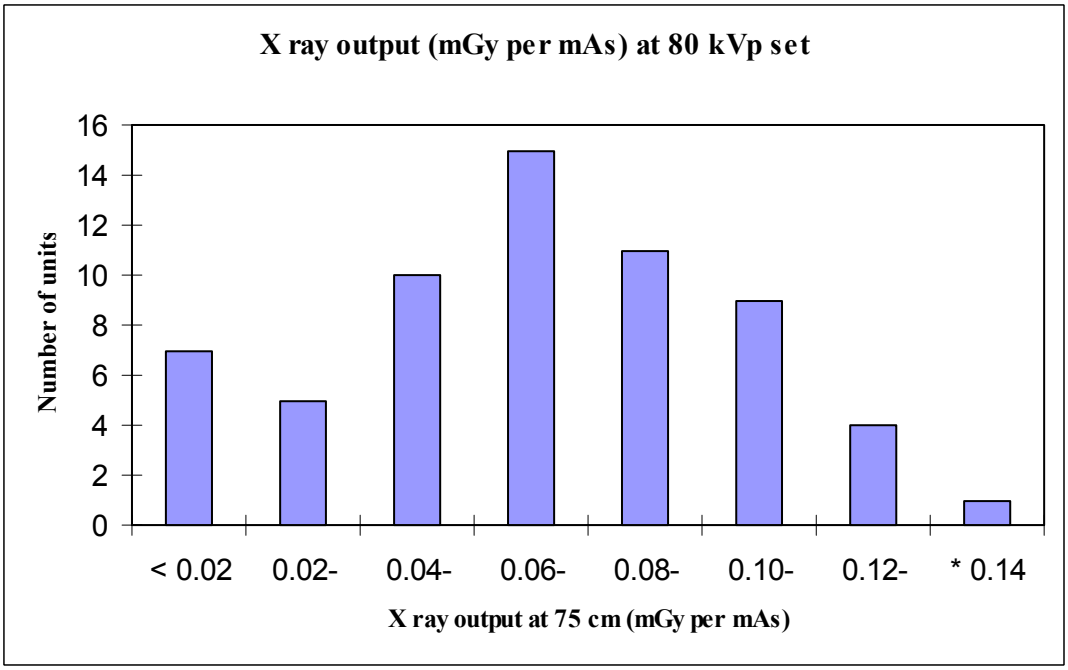

FIG. 5. Distribution of X ray outputs (mGy per mAs) at set value of 80 kVp, measured at 75 cm focal distance.

The half value layer was determined for each X ray unit at 80 kVp. The results, presented in Figure 6, show that some units were clearly under filtered. A minimum total filtration of 2.5 mm Al equivalent is the international recommendation and this corresponds to a half value layer typically in the range 2.3 to 3.1 mm Al, depending on factors such as the wave form and target angle. An HVL below 2.3 mm Al would almost certainly be indicative of an X ray tube with insufficient filtration. Increasing the primary beam filtration is a very simple method for lowering patient doses.

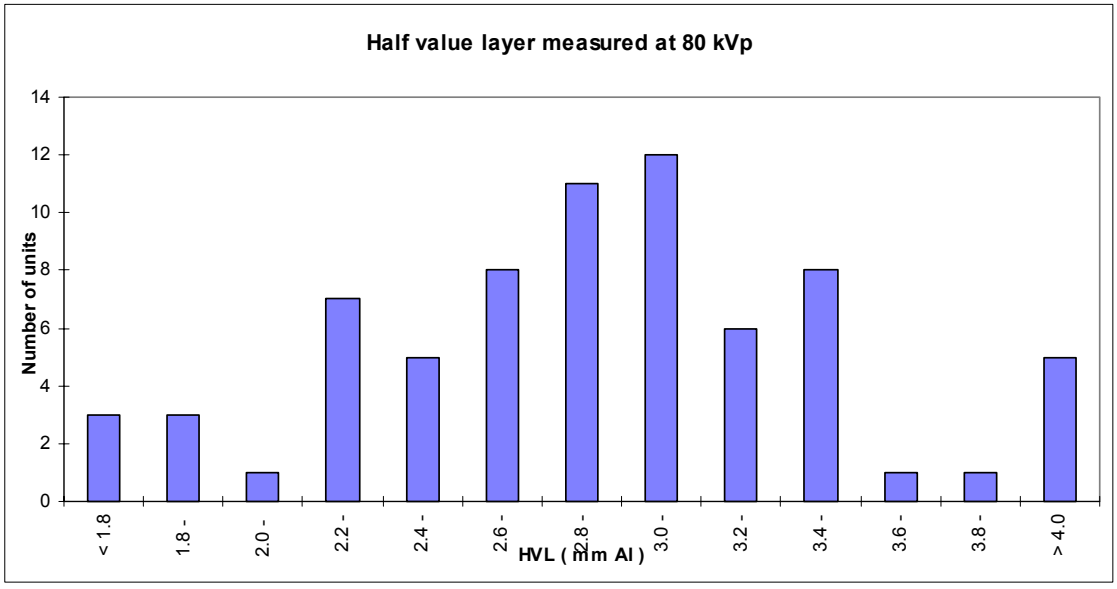

FIG. 6. Distribution of half value layer (mm of Al equivalent) measured at 80 kVp.

The quality control measurements on viewing boxes, where performed, showed that there was a considerable range of variation of brightness for the viewing boxes used in the project. These data are presented in a histogram below in Figure 7. In general the mean value of brightness for individual viewing boxes was very low, with few viewing boxes having a brightness in the range 2000 to 4000 cd/m^2 as recommended by the EC guideline [5] for films in the density range 0.5 to 2.2. Luminance values as low as 400 cd/m^2 were reported. A considerable degree of brightness in homogeneity was also reported, exceeding the 15% of variation typically considered as acceptable. Clearly there is great scope for improvement here. Fluorescent tube outputs decrease with time, and replacement of low output tubes must be a recognized part of the programme for X ray departments. Considering the situation of scarcity of funds, the benefits of a well-lighted view box in terms of reducing the chances of missing a diagnosis outweigh the small additional expenditure involved.

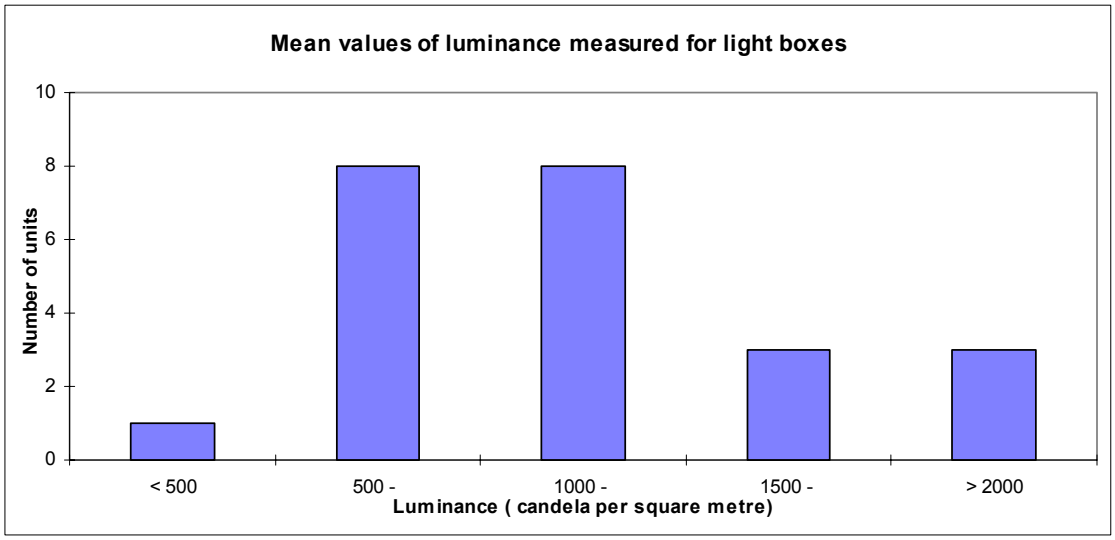

FIG. 7. Distribution of mean values of luminance (cd/m^2) measured for light boxes used in the study.

Quality control measurements were performed on the X ray film processors (temperature, base+fog, speed and contrast index) but few numerical data were reported. Reported developer temperatures ranged from 31.8°C to as high as 39.0°C, with most of them in the range of 32°C to 35°C. Excessively high developer temperatures can lead to elevated fog values, but in some countries with high ambient temperatures maintaining the temperature in the desired range may be difficult. Of the base fog values reported, one was sufficiently high (0.27 OD) to indicate the need for corrective action.

4.2.4. Patient doses before and after quality control tests

Patient doses were measured before the implementation of QC programme to assess the status. Following the introduction of QC and including corrective actions, patient doses were again assessed to gauge the impact on doses. The corrective actions invoked were aimed at increasing the consistency and reproducibility of the imaging chain and to optimize the relationship between patient dose and image quality. For the former, corrective actions implemented by some countries included generator repair and calibration, and improved film

processing and darkroom practice. And for the latter, the main methods implemented were the use of higher kVp, faster film/screen systems, increased filtration, tighter collimation, increased focus to film distance, and improved film processing – all methods that should lead to lower patient doses. To illustrate the use of corrective actions further, Table VI presents a summary of those actions used in the X ray rooms by various countries for the chest PA projection. Some X ray rooms underwent more than one corrective action.

TABLE VI. SUMMARY OF CORRECTIVE ACTIONS USED IN THE HOSPITALS FOR THE CHEST PA PROJECTION

Corrective action	Number of rooms where the corrective action was used
Increased kVp	15
Increased filtration	8
Faster film/screen systems	10
Tighter collimation	2
Increased focus-to-film distance	1
Improved film processing	5
Repaired/calibrated generator	6
Improved darkroom practice	2

Results for patient dose are reported in Table VII below in terms of entrance surface dose (ESD) for chest, skull, lumbar spine and pelvis X ray examinations, both before and after quality control and the corrective actions.

TABLE VII. PATIENT DOSES (ENTRANCE SURFACE DOSE, mGy) FOR EACH PROJECTION BEFORE AND AFTER QUALITY CONTROL, AVERAGED OVER ALL ROOMS WITHIN PARTICIPATING CENTRES IN EACH COUNTRY. THE DOSE REDUCTION IS THE AVERAGE OF THE DOSE REDUCTIONS ACHIEVED IN EACH ROOM (NOTE: N.R. MEANS NOT REPORTED)

	Chest PA			Chest Lat		
Country	ESD before QC (mGy)	ESD after QC (mGy)	Average dose reduction %	ESD before QC (mGy)	ESD after QC (mGy)	Average dose reduction %
Armenia*	2.1	0.31	78	n.r.	n.r.	n.r.
China	0.35	0.24	31	n.r.	n.r.	n.r.
Czech Rep.	0.24	0.14	40	0.55	0.44	20
India	0.37	0.25	31	1.5	1.1	30
Indonesia	0.62	0.32	50	n.r.	n.r.	n.r.
Malaysia	0.35	0.22	34	1.3	0.7	41
Morocco	0.55	0.23	50	0.8	0.8	0
Pakistan	0.56	0.41	21	2.3	1.7	28
Romania	2.2	1.0	48	4.1	3.1	19
Thailand	0.25	0.16	27	0.9	0.5	35
Vietnam	1.1	0.28	70	4.4	1.3	64

	Skull PA			Skull Lat		
Country	ESD before QC (mGy)	ESD after QC (mGy)	Average dose reduction %	ESD before QC (mGy)	ESD after QC (mGy)	Average dose reduction %
Armenia*	26.2	5.0	81	n.r.	n.r.	n.r.
China	4.1	4.8	-19	3.3	3.9	-35
Czech Rep.	4.1	2.7	35	3.1	2.7	19
India	3.8	3.0	22	5.2	3.8	28
Indonesia	3.5	2.7	25	3.6	2.6	32
Malaysia	6.7	3.3	29	5.1	2.3	35
Morocco	12.3	9.9	22	4.3	3.5	16
Pakistan	5.7	4.6	19	4.5	4.0	18
Romania	7.3	6.1	8	5.0	4.1	-18
Thailand	1.4	0.7	42	1.1	0.5	43
Vietnam	7.8	4.8	39	6.2	3.4	43

	Lumbar Spine AP			Lumbar Spine Lat		
Country	ESD before QC (mGy)	ESD after QC (mGy)	Average dose reduction %	ESD before QC (mGy)	ESD after QC (mGy)	Average dose reduction %
Armenia*	24.9	8.9	64	n.r.	n.r.	n.r.
China	8.6	6.4	23	15.8	12.0	23
Czech Rep.	10.3	6.8	35	19.0	9.9	47
India	13.3	9.9	25	24.1	17.8	26
Indonesia	5.8	2.3	56	9.3	4.6	50
Malaysia	15.9	8.0	20	31.1	12.0	38
Morocco	15.0	10.7	28	34.0	16.3	52
Pakistan	15.9	12.3	20	29.1	26.0	11
Romania	14.7	13.5	-14	23.6	22.4	-4
Thailand	2.8	1.2	50	8.2	4.1	45
Vietnam	6.3	4.5	30	13.8	7.3	45

	Pelvis AP		
Country	ESD before QC (mGy)	ESD after QC (mGy)	Average dose reduction %
Armenia*	26.2	7.3	72
China	6.6	3.5	40
Czech Rep.	8.0	5.2	24
India	9.9	6.4	34
Indonesia	3.7	1.4	62
Malaysia	11.9	4.7	38
Morocco	12.0	8.8	28
Pakistan	7.8	6.5	16
Romania	15.2	12.7	-24
Thailand	1.5	0.9	25
Vietnam	4.7	5.8	-31

* It should be noted that because Armenia lacked a thermoluminescent dosimetry system, their patient dosimetry was performed using an ionization chamber to measure ESD on a patient equivalent phantom (water) using the appropriate radiographic technique factors for an average patient.

The following figures (Figures 8 to 14) illustrate the respective distributions of ESD per hospital before and after QC for the projections: chest PA, chest lat, skull PA, skull lat, lumbar spine AP, lumbar spine lat and pelvis AP. The histogram in each pair of figures shows the distributions of the average ESD per hospital both before and after QC while the bar chart shows the range and average value of ESD (before and after QC) for the projection for each hospital in ascending order of the average ESD as measured before QC. It is evident from these figures that the spread of doses in most hospitals was reduced as a consequence of the introduction of QC and corrective actions, as well as a general lowering of the average hospital dose.

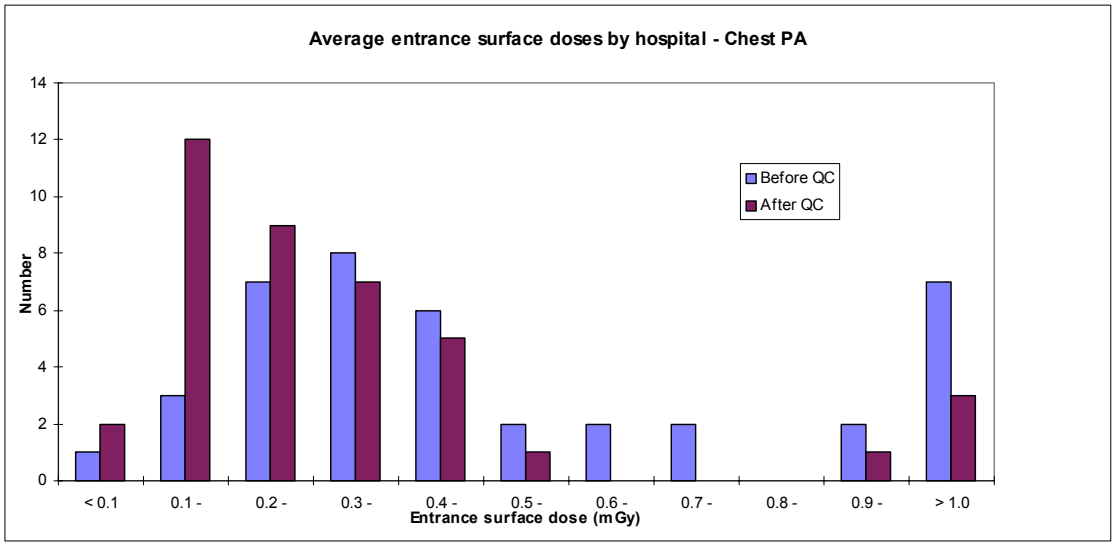

FIG. 8. Variations of the entrance surface dose by hospital — chest PA before and after QC.

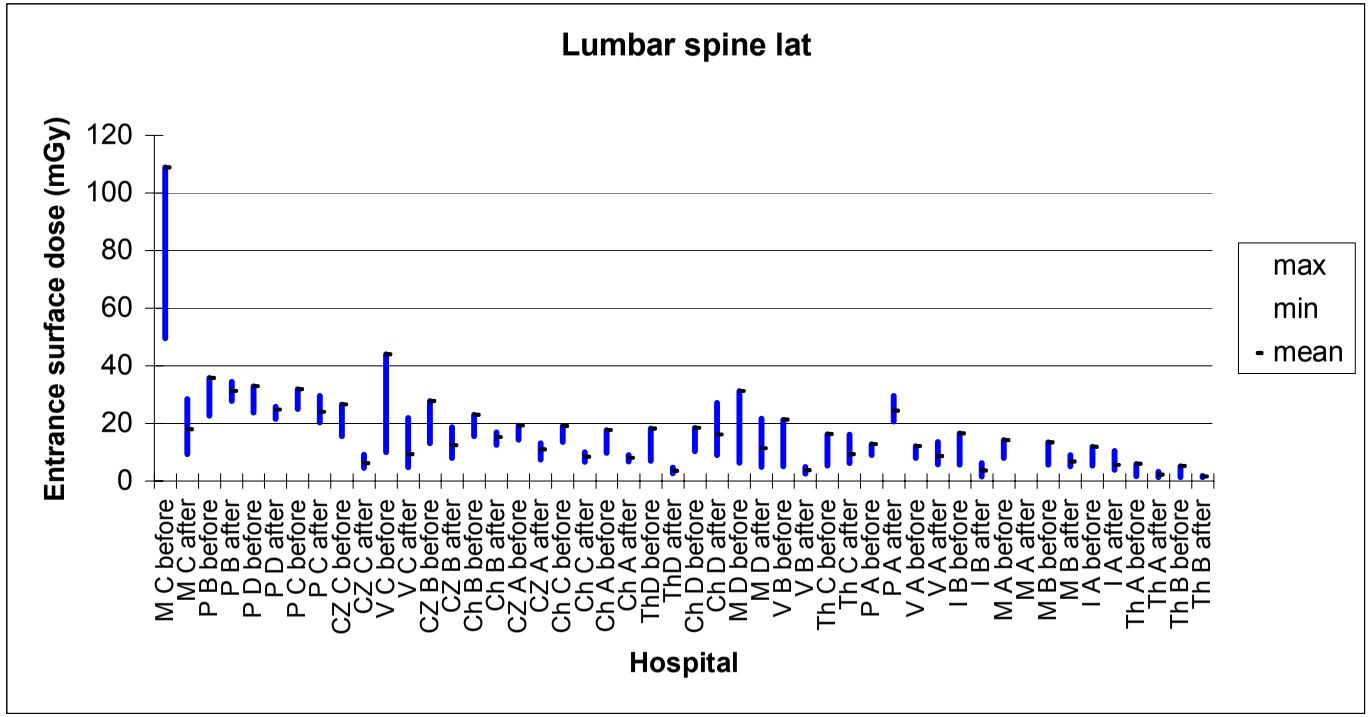

FIG. 8. (cont.) Variations of the entrance surface dose by hospital — chest PA before and after QC.

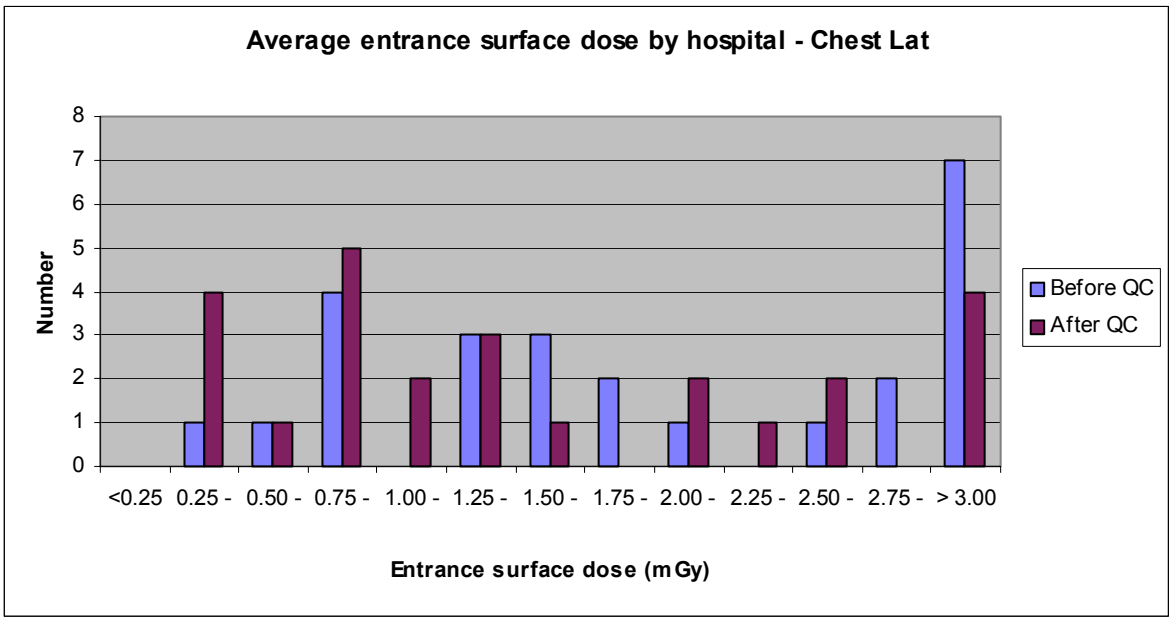

FIG. 9. Variations of the entrance surface dose by hospital — chest lat before and after QC.

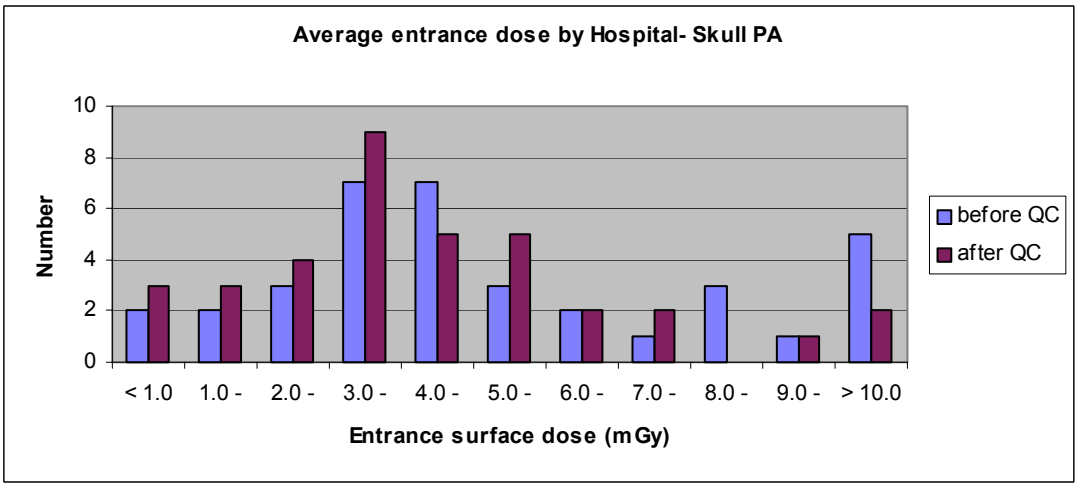

FIG. 9. (cont.) Variations of the entrance surface dose by hospital — chest lat before and after QC.

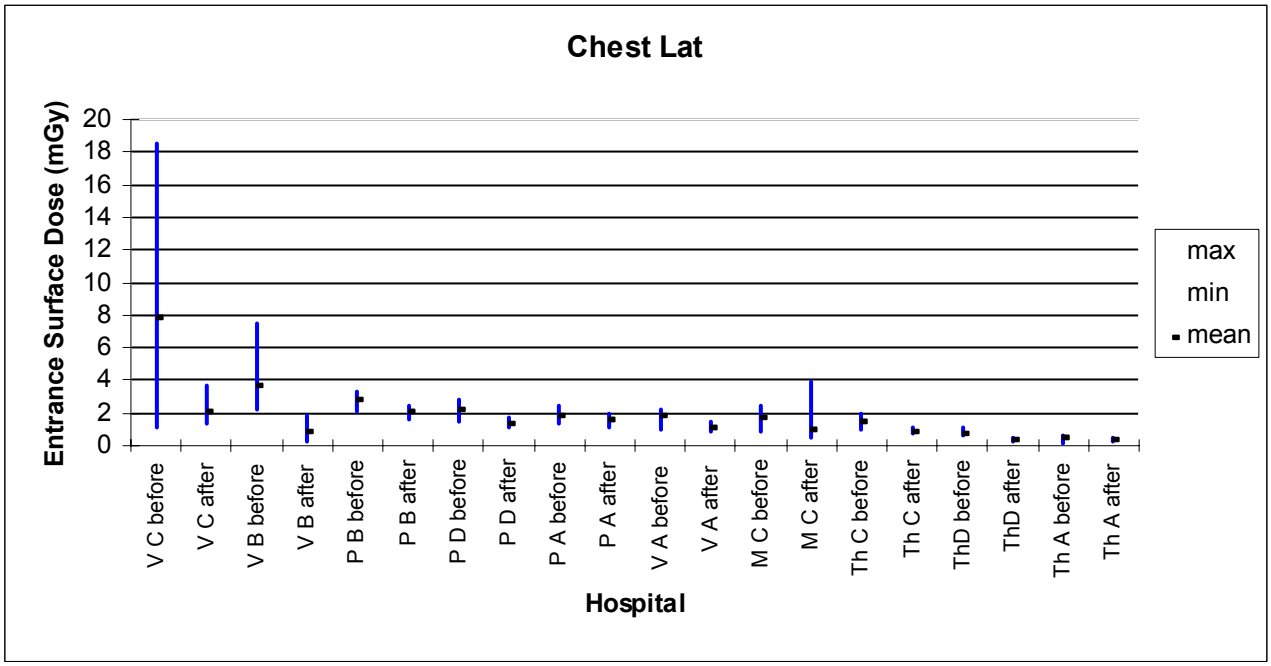

FIG. 10. Variations of the entrance surface dose by hospital — skull PA before and after QC.

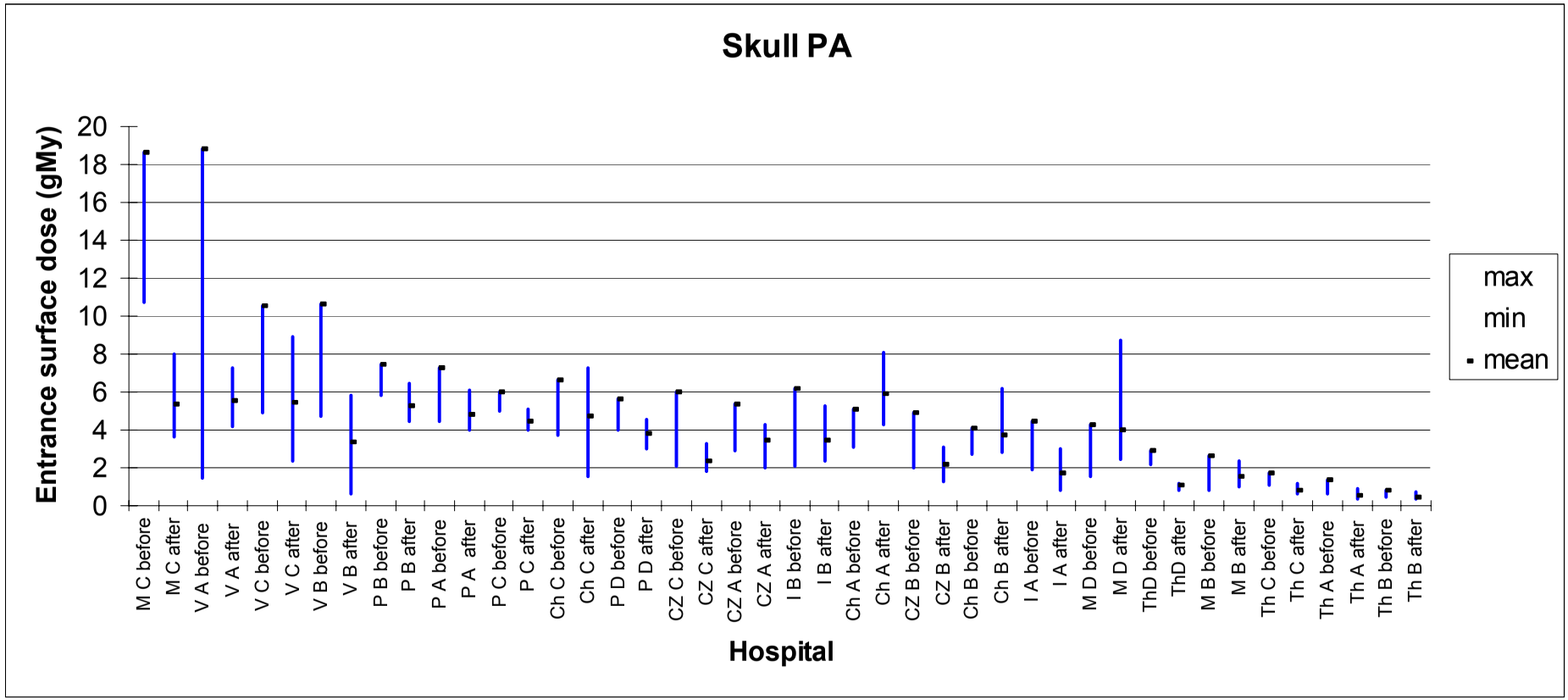

FIG. 10. (cont.) Variations of the entrance surface dose by hospital — skull PA before and after QC.

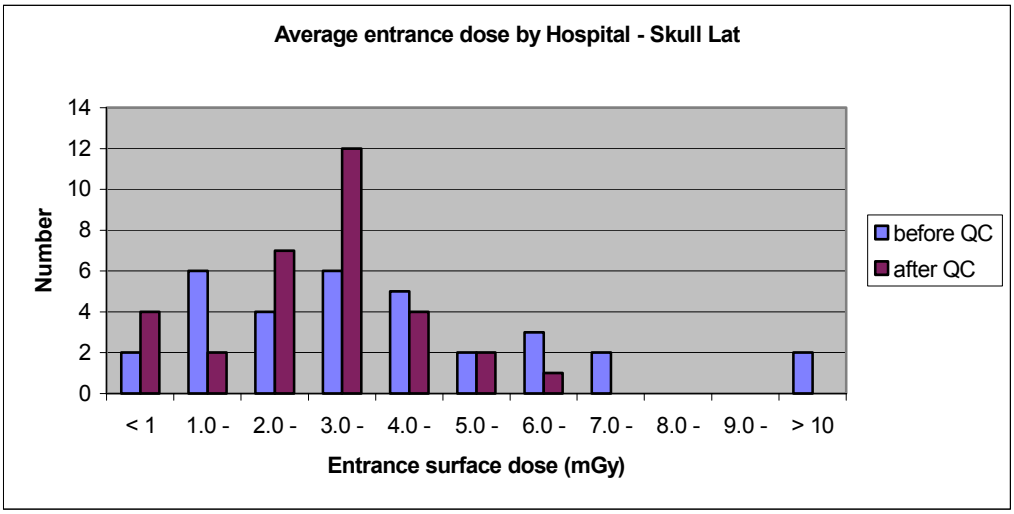

FIG. 11. Variations of the entrance surface dose by hospital — skull lat before and after QC.

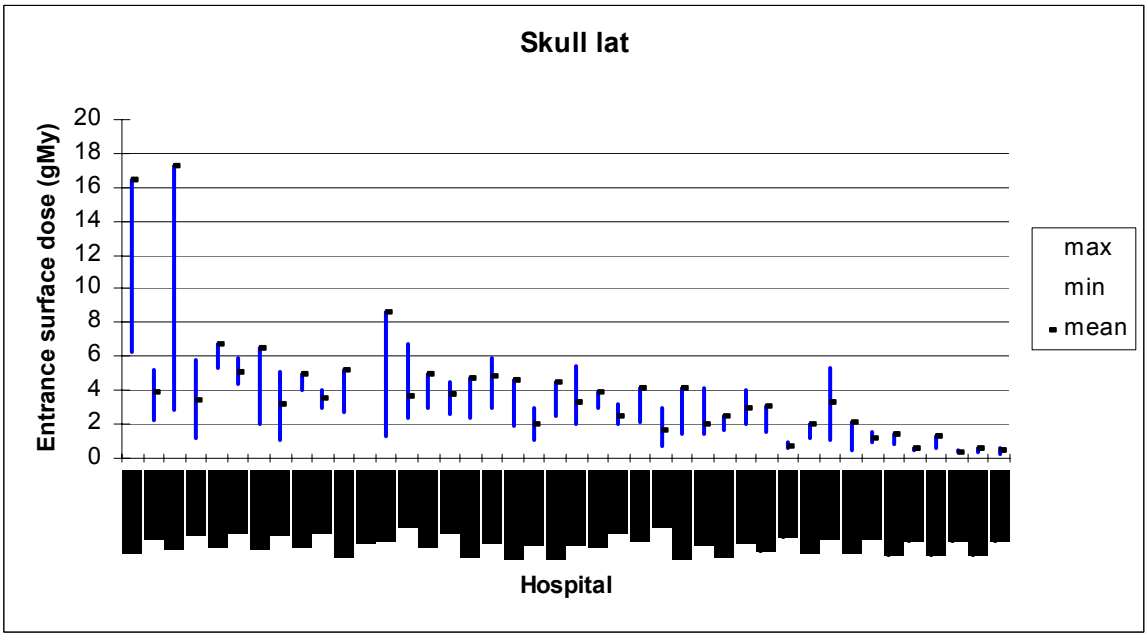

FIG. 11. (cont.) Variations of the entrance surface dose by hospital — skull lat before and after QC.

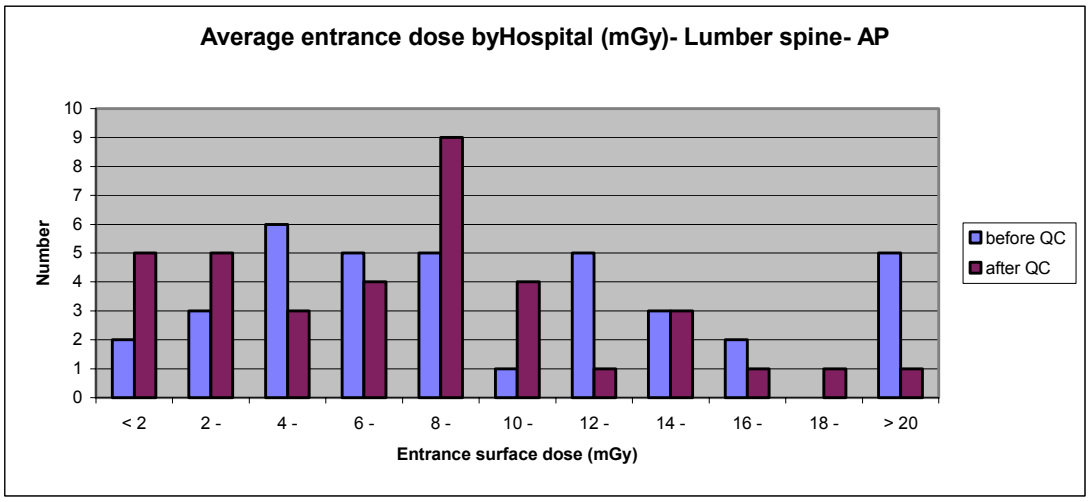

FIG. 12. Variations of the entrance surface dose by hospital — lumbar spine AP before and after QC.

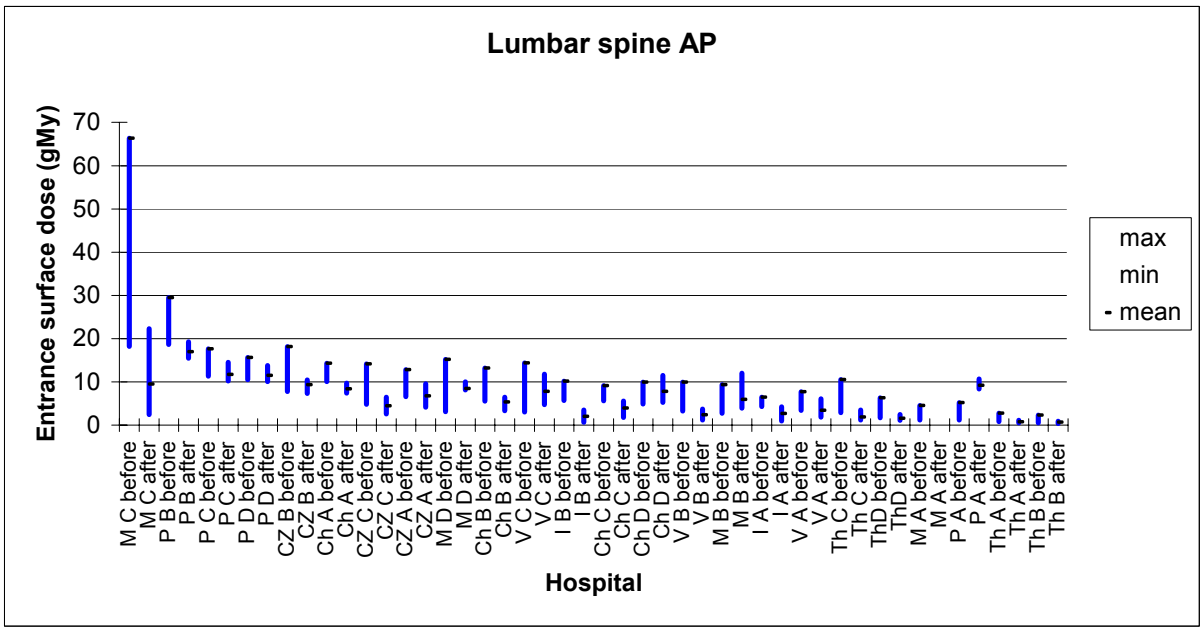

FIG. 12 (cont.). Variations of the entrance surface dose by hospital — lumbar spine AP before and after QC.

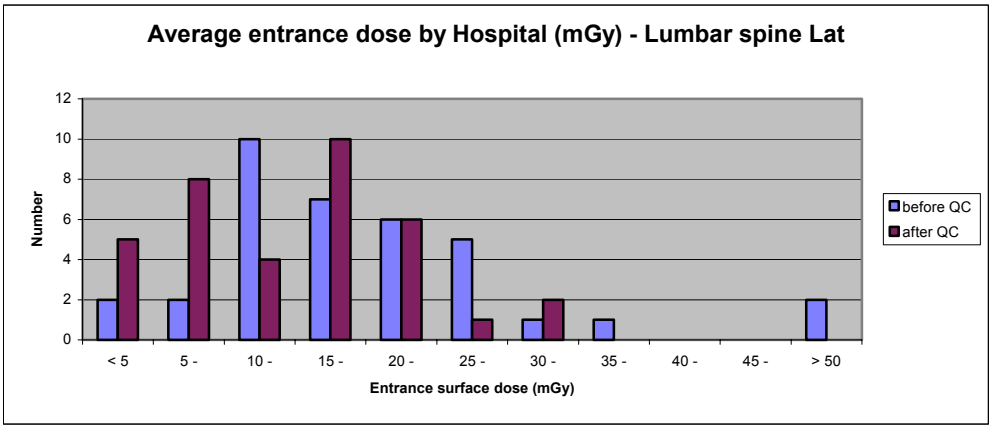

FIG. 13. Variations of the entrance surface dose by hospital — lumbar spine lat before and after QC.

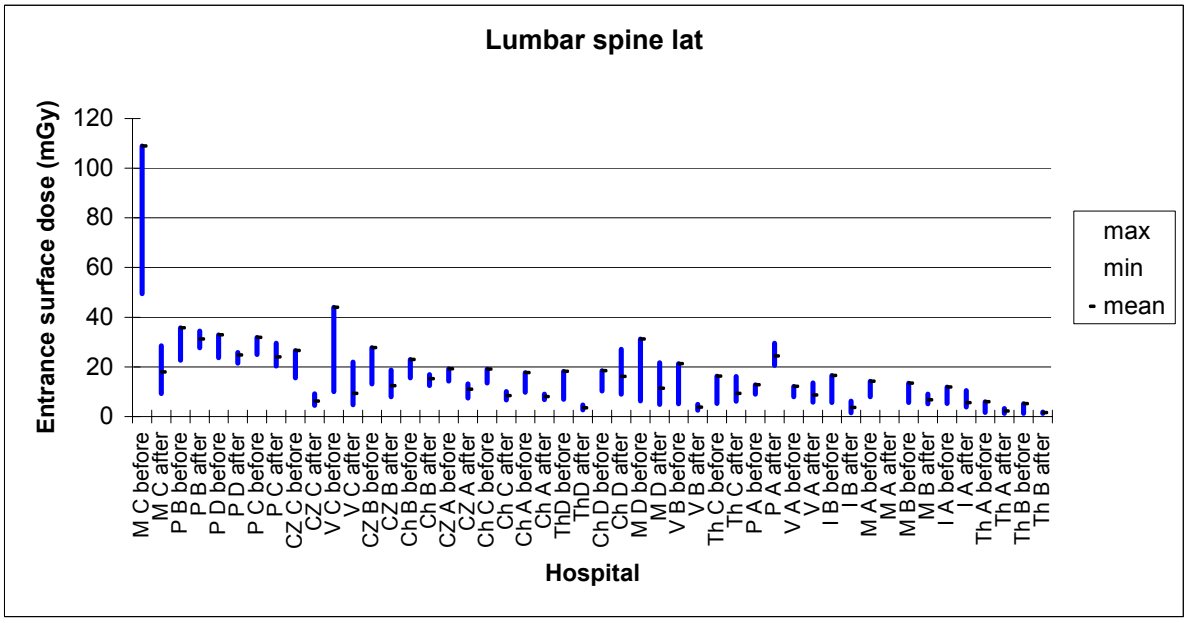

FIG. 13 (cont.). Variations of the entrance surface dose by hospital — lumbar spine lat before and after QC.

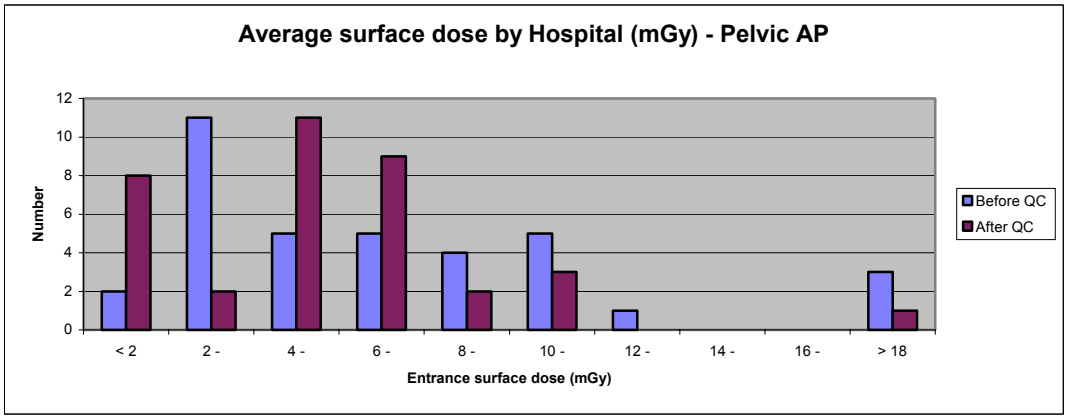

FIG. 14. Variations of the entrance surface dose by hospital — pelvis AP before and after QC.

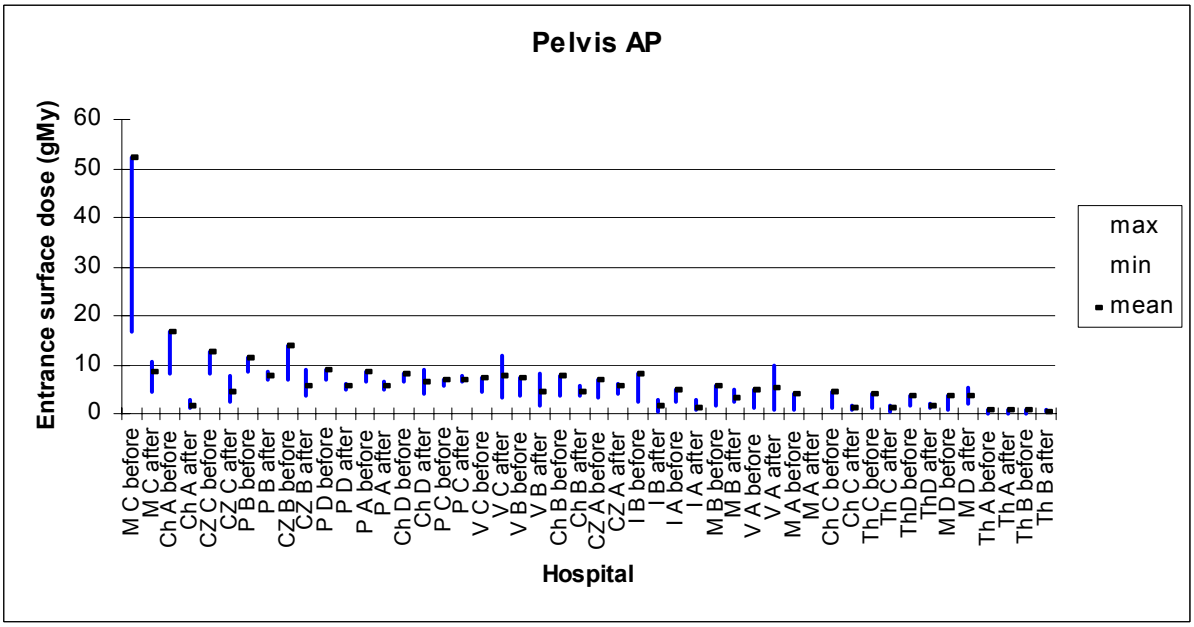

FIG. 14. (cont.) Variations of the entrance surface dose by hospital — pelvis AP before and after QC.

Table VIII presents a summary of average doses over all rooms and countries for each examination, both before and after the implementation of QC and corrective actions. The uncertainties in the average doses are large, due in part to the amalgamation of the data from the European centres, with an average patient weight of 70 kg, and the Asian data, with an average patient weight nearer 60 kg. Significant dose reductions were achieved, and the average doses for examinations after QC are almost all under the respective diagnostic reference dose values recommended by the EC [5] and the BSS [1]. The exceptions were the chest projections, where the higher doses relative to the reference doses are probably due to low kVp chest techniques being widely used in the participating countries.

TABLE VIII. AVERAGE PATIENT DOSES PER PROJECTION AVERAGED ACROSS ALL PARTICIPATING COUNTRIES, BOTH BEFORE AND AFTER QC.

Examination type	Diagnostic reference level (mGy)	Entrance surface dose (mGy)		Dose reduction (%)
		Prior QC	After QC	
Chest PA	0.3	1.3 ± 2.3	0.39 ± 0.38	69
Chest LAT	1.5	2.4 ± 1.9	1.7 ± 1.2	31
Skull AP/PA	5.0	5.8 ± 4.7	4.3 ± 2.6	25
Skull LAT	3.0	4.2 ± 2.6	3.1 ± 1.5	26
Lumbar spine AP	10	10.1 ± 7.7	8.1 ± 5.0	20
Lumbar spine LAT	30	21.2 ± 13	14.6 ± 8	31
Pelvis	10	8.2 ± 11	6.4 ± 7.8	22

In contrast, Figure 15 reports the percentage of X ray rooms in which the mean ESD is greater than the diagnostic reference values, before QC and after QC. Again the data show that simple dose saving measures can greatly influence the patient dose, and clearly there was a marked improvement in the number of rooms meeting the reference doses. However, a significant percentage of rooms still used doses, after implementation of QC and corrective actions that exceeded the relevant reference doses. It should be noted that it was expected that the Asian countries should be able to more easily meet the reference doses because of their lower average patient weight.

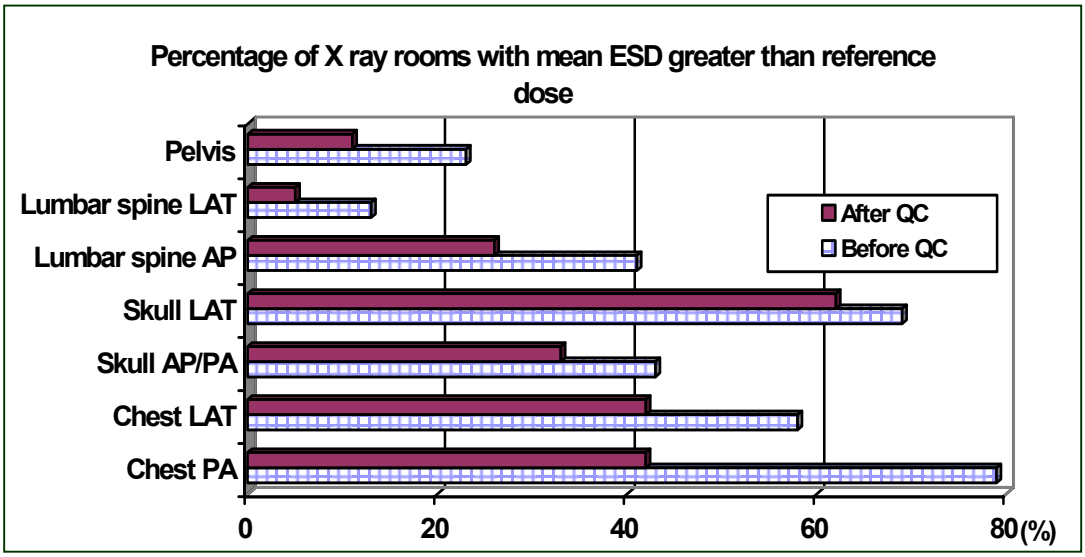

FIG. 15. Percentage of X ray rooms where the average entrance surface dose exceeded the corresponding EC reference dose value.

That the weight of the Asian average man differs considerably from the European average man suggests that more applicable data are needed for the Asian context. This study itself has provided some initial base line data on average patient doses in several Asian countries. Table IX presents the ESD data for the Asian countries alone where the average

patient weight across all projections was 61.5 kg. While a lower body mass is probably a good predictor for lower patient doses for trunk examinations (especially lower trunk), it is less likely to be the same for skull examinations. This is borne out by the results in Table IX.

TABLE IX. AVERAGE ESD VALUES AFTER THE INTRODUCTION OF QC, FOR ASIAN COUNTRIES (AVERAGE WEIGHT WAS 61.5 KG.)

Examination type	Average entrance surface dose (mGy)	Diagnostic reference level for 70 kg patient (mGy)
Chest PA	0.26	0.3
Chest LAT	1.1	1.5
Skull AP/PA	3.4	5.0
Skull LAT	2.8	3.0
Lumbar spine AP	6.3	10
Lumbar spine LAT	12.4	30
Pelvis	4.2	10

4.2.5. Image quality evaluation

Almost all participants provided image quality evaluations based on on-site evaluation of images by radiologists using the quality criteria of the EC document [5]. The EC image quality criteria have been developed over a number of years, with refinements being made as experience has been gained from various clinical trials. The radiologists using the image criteria in this project had no previous experience with the use of the image criteria. For this reason it was not unexpected that the implementation of the criteria in the Asian and East-European context would be subject to the individual approaches and interpretations of the local radiologists. This makes analysis of the results between centres and countries difficult but the following results were evident.

Some countries provided data regarding image quality before and after QC. In general, there were no clear differences between the two image quality evaluations, but with some countries' results hinting at a small improvement in image quality. At worst, the results would seem to confirm that corrective actions arising from the QC programme were able to produce lower patient doses without compromising image quality.

As mentioned above, on-site evaluations from different centres are not easily compared. In addition to the problem of different interpretations by the local radiologists of the quality criteria method, there were local attitudes towards the image quality produced in the department. Economic considerations such as cost of film and availability of film impinge on what is locally acceptable in terms of image quality.

Table X gives percentages of image criteria met for four countries before and after QC for the chest PA projection. In each case ten films were reviewed by local radiologists. The average percentage of image criteria met by films before QC was 77.5 while after QC the

average value was 82.8. This shows a small, but not statistically significant, improvement. However both values are less than the value of 85.8 for this projection for field radiologists given in an EC trial [11].

TABLE X. PERCENTAGES OF EC IMAGE CRITERIA FOR THE CHEST PA PROJECTION MET BY HOSPITALS IN FOUR COUNTRIES BEFORE AND AFTER QC

Country/ Hospital	Chest PA		
	Percentage of image criteria met by films before QC	Percentage of image criteria met by films after QC	Change in percentage
Czech Republic/A	86	88	2
Czech Republic/B	67	71	4
Czech Republic/C	67	71	4
Indonesia/A	70	99	29
Indonesia/B	99	88	-11
Malaysia/A	90	85	-5
Malaysia/B	93	86	-7
Malaysia/C	60	73	13
Thailand/A	63	71	8
Thailand/B	88	97	9
Thailand/C	75	96	21
Thailand/D	72	69	-3

Some countries provided raw data on the radiologists' image evaluations. As an illustration, data from Thailand are presented in Figure 16 showing the percentage of films, both before QC and after QC, which fulfilled the various numbers of criteria for the chest PA projection and the lumbar spine AP projection. In these particular examples it is evident that there is an improvement in the percentage of films meeting a high proportion of criteria. It is interesting to observe that for these data, all criteria or one less than all criteria were fulfilled by 70%, and 90% of films after QC and corrective actions for the chest PA and lumbar spine AP projections respectively. These values are comparable to results reported for field radiologists in a European trial [11] of 66% and 85% respectively.

A final comment on the use of the image quality criteria is pertinent. An underlying assumption is that all the image quality criteria have the same importance or weight. But this has been demonstrated to be not the case [12]. Some of the criteria are "key-criteria" and if they are not fulfilled the images are usually rejected. Clearly these key criteria have more importance than other complementary criteria. No account of the relative importance of the various criteria was considered in this study.

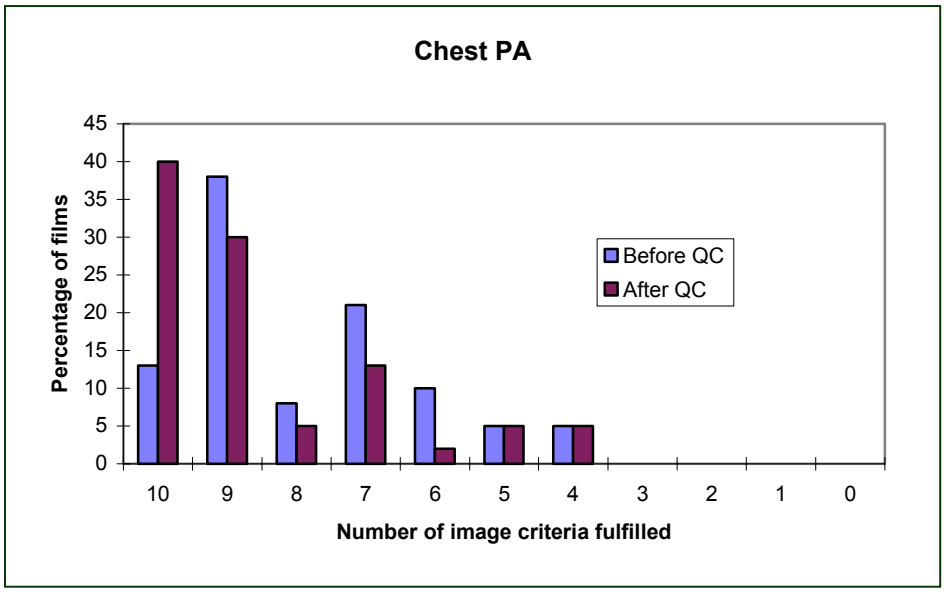

FIG. 16. Percentage of the films for each of the chest PA and lumbar spine AP examinations from Thailand that fulfilled image quality criteria. Four hospitals were involved, with 40 films before QC and 40 films after QC and corrective action.

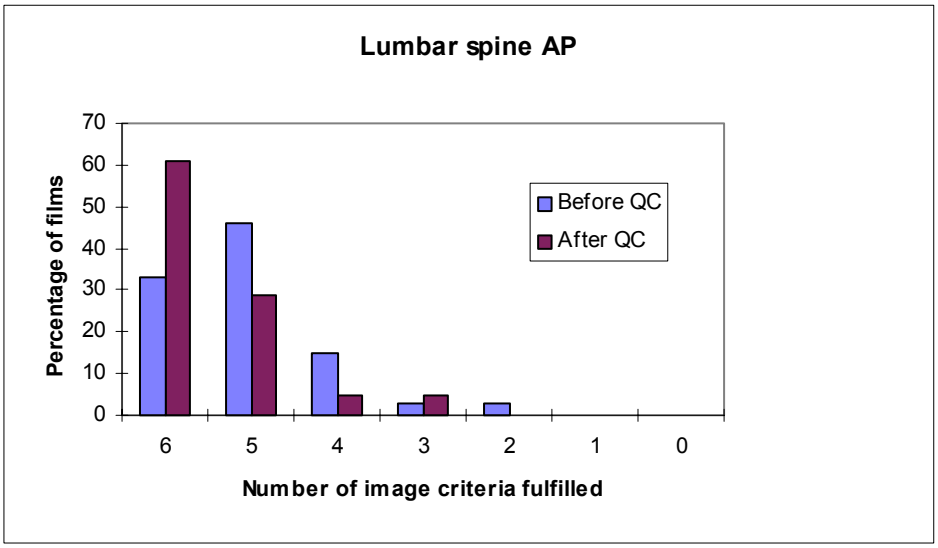

FIG. 16. (cont.) Percentage of the films for each of the chest PA and lumbar spine AP examinations from Thailand that fulfilled image quality criteria. Four hospitals were involved, with 40 films before QC and 40 films after QC and corrective action.

4.3. FLUOROSCOPY (PHASE II)

4.3.1. Fluoroscopy systems

Fewer countries participated in Phase II than in Phase I. Countries providing data for Phase II were China, Czech Republic, India, Indonesia, Malaysia, Morocco, Romania, Thailand and Vietnam. Specific details on the fluoroscopic units in the project are given in

Annex III for the respective countries. These details include the make and model of the fluoroscopy system and the age of the image intensifier.

Some of the fluoroscopic units were new or recently installed, but many had already seen many years of clinical service. As outlined in the methodology, the units were selected to be representative of different configurations — including remote control table, angiographic units and mobile C-arm systems.

Specific aspects of the performance of the fluoroscopy systems are presented and discussed in the following sections.

4.3.2. Patient doses

4.3.2.1. Fluoroscopic dose rates

From the point of view of potential patient dose the most useful data are the dose rates at the entrance plane of the image intensifier (II), and the patient entrance surface dose rates. The latter results were normalized to 50 cm from the focus. Due to the large number of factors that can affect these dose rate parameters, it was decided to perform the measurements using a 23 cm field of view (or the nearest to this size) and the normal mode of fluoroscopy. Measurements of patient entrance surface dose rates were performed with the grid in place, but for measurements of the input dose rates to the II the grid was removed, if possible. If the grid could not be removed for the measurement, allowance for grid attenuation was made. A patient equivalent phantom of either 2 mm Cu or 40 mm Al was used for both measurements.

It was noted that in some of the data reported by the participants, there were possible inconsistencies between the II input dose rates and the patient dose rates. The relationship between these two parameters is not simple, with many factors affecting their relationship : filtration, kV, mA, geometry, use of grid and collimation. Figures 17 and 18 below present the distributions of measured image intensifier input dose rates and patient dose rates for those data that could be verified.

The results show a wide range in both the II input dose rates and patient entrance dose rates. The former ranged from 0.3 to 3.4 μGy/s, while the latter range from 5 to in excess of 50 mGy/min at the entrance surface of the patient.

For a 23 cm field size, image intensifier input dose rates should be less than 1 μGy/s for a well set-up system, with new systems able to operate at input dose rates lower than 0.2 μGy/s [13]. Thirty percent of the units in this study were using input dose rates in excess of 1 μGy/s. It would normally be expected that II input dose rates would be lowest for new or near new systems, with the dose rate increasing as the conversion factor of the II dropped off with age. Although not presented, the age of the II did not correlate with input dose rates, with some new units having II input dose rates that were clearly excessive. Acceptance tests on new units should have identified such faults.

Patient entrance surface dose rates would normally be less than 50 mGy/min for a 23 cm II field size under normal mode fluoroscopy for an average patient. That some units had dose rates in excess of this is indicative of inadequate quality assurance programmes. Routine periodic measurements should prevent systems with excessive dose rates being used clinically, by detecting abnormal performance and initiating corrective actions. It should be noted that the BSS [1] give a guidance level of 25 mGy per minute entrance surface dose rate for an adult undergoing normal mode fluoroscopy.

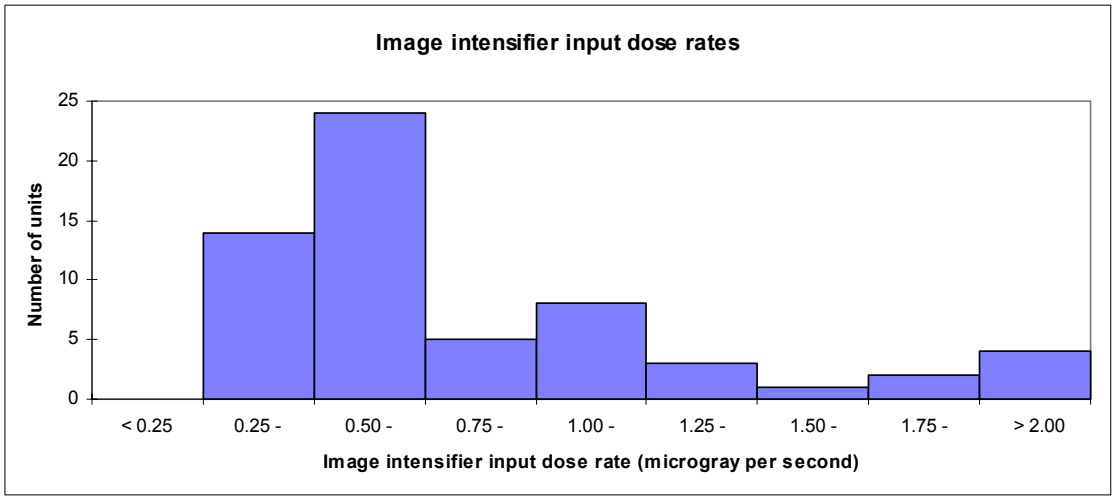

FIG. 17. Dose rates into the image intensifier under normal mode fluoroscopy using a 23 cm field of view with an average patient.

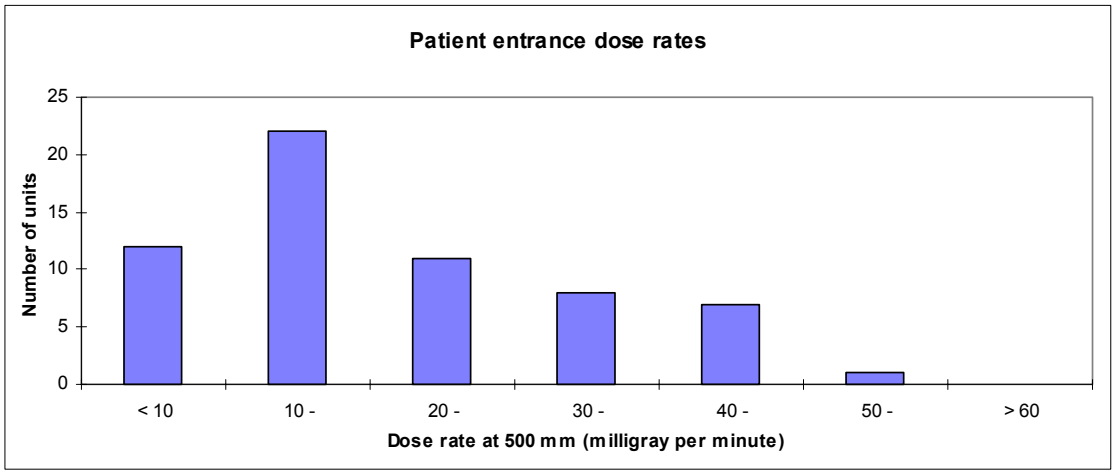

FIG. 18. Patient entrance surface dose rates, normalized to 500 mm focus-to-skin distance, under normal mode fluoroscopy using a 23 cm field of view with an average patient.

4.3.2.2. Fluoroscopic image quality from analysis of quality control tests

The methodology for image quality assessment involved determination of high contrast resolution (in lp/mm) at the centre and at the periphery of the II, low contrast detectability and geometrical distortion. Unfortunately a lack of consistency in approach by the participating countries (e.g. different phantoms were used under different conditions) meant that only the high contrast resolution results could be compared across the participants. Figure 19 presents the distribution of high contrast performance at the centre of the image intensifier field for the 23 cm field under normal mode of operation. The mean limiting resolution was 1.2 line pairs per mm — possibly a little lower than typical value for the field size [13].

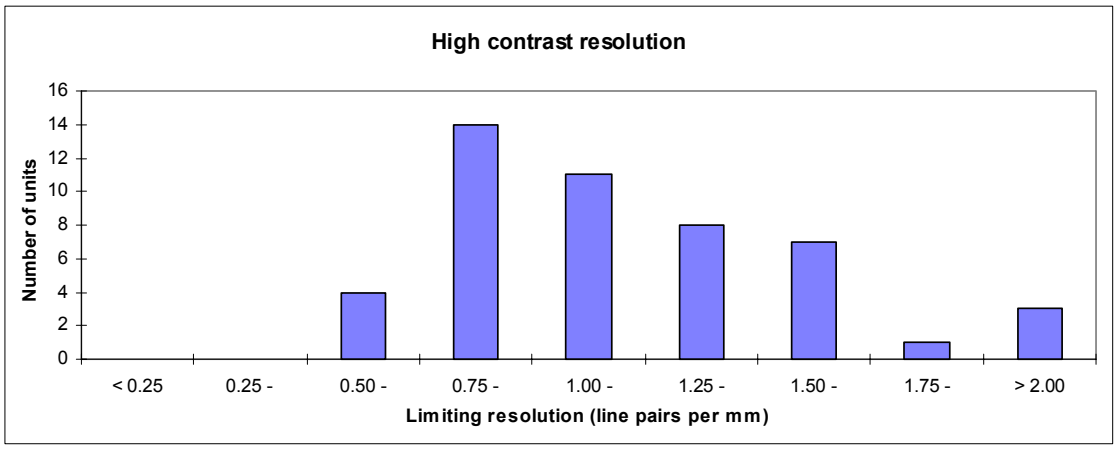

FIG. 19. High contrast resolution performance at the centre of the image intensifier for the 23 cm field of view under normal mode fluoroscopy.

4.3.3. Patient doses for barium meal examination

Patient doses were estimated for samples of at least 5 patients (of an average weight of 70±10 kg for the European countries and 60±10 kg for the Asian countries) per centre undergoing a barium meal examination. Data concerning age and weight, number of images, fluoroscopy time and dose area product (DAP) were collected. Most of the countries that participated in Phase II were non-European (7 out of 9), and this is reflected in the average patient weight of 58.9 kg over all countries, and an average of 54 kg for the Asian countries alone.

The mean number of images taken during the barium meal examination, per room, ranged from 3 to 40, with an average over all rooms of 8 images and a median of 5 images. Figure 20 presents a histogram of these room averages.

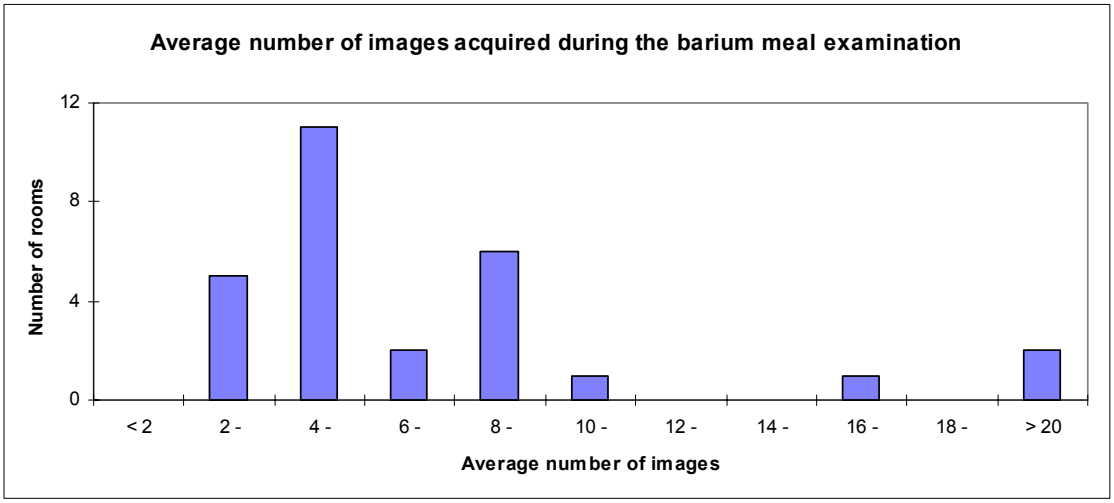

FIG. 20. Distribution of the average number of images acquired during the barium meal examination per room in the project.

Screening times also varied considerably, with the mean fluoroscopy time per room ranging from less than 1 minute to 11.9 minutes. The average screening time across all rooms was 3.5 minutes with a median value of 2.9 minutes. Figure 21 gives the distribution of average screening times.

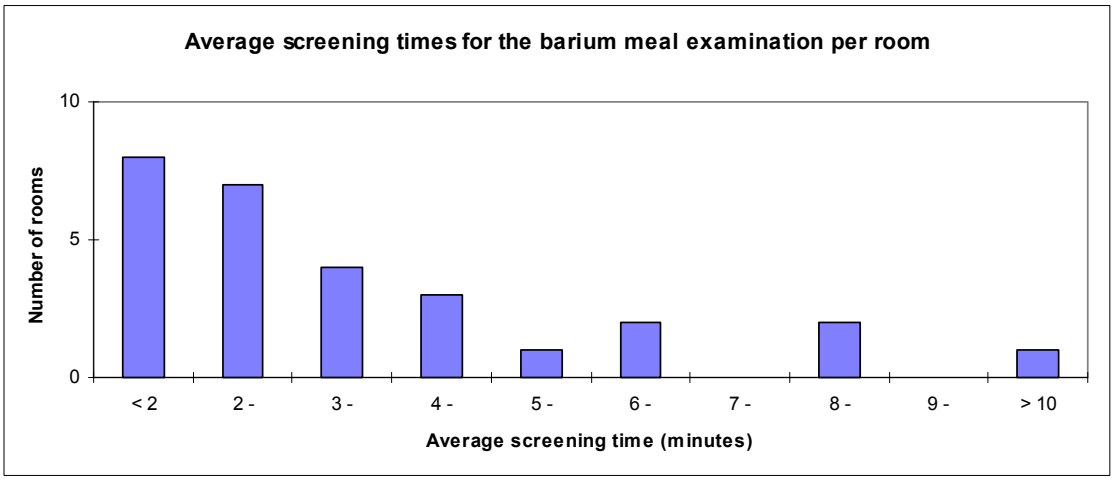

FIG. 21. Distribution of the average fluoroscopy time during the barium meal examination per room in the project.

Dose area product values ranged between 3.5 and 84.5 Gycm^2. The mean value of the DAP values over all rooms was 23.2 Gycm^2 with a median value of 18.8 Gycm^2. A histogram of the distribution of average DAP values for the various rooms is given in Figure 22.

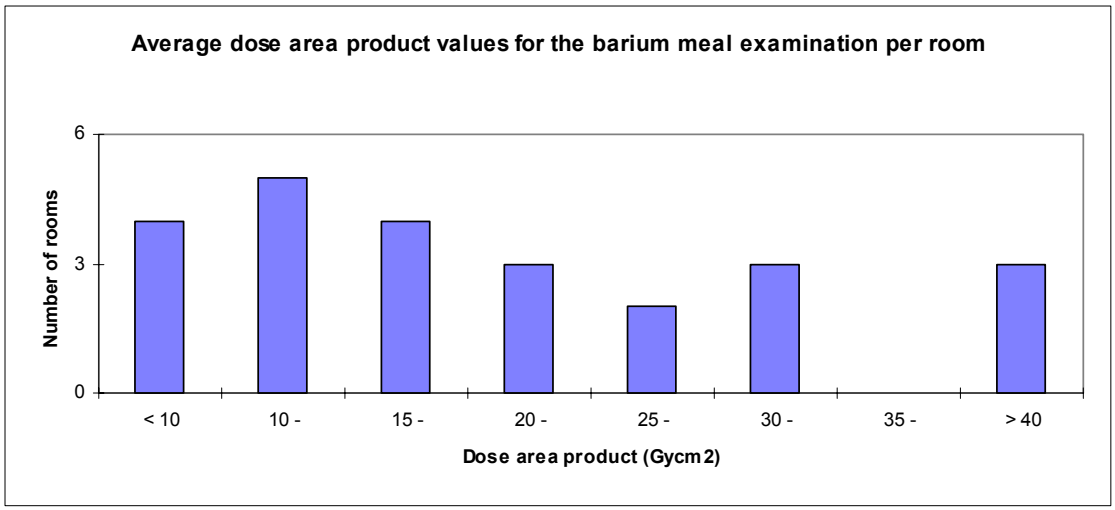

FIG. 22. Distribution of the average dose area product values for the barium meal m examination per room in the project.

The wide ranges found for the mean number of images and fluoroscopy time are indicative of major differences in clinical protocols between centres and countries. These differences in turn contribute to the wide range of DAP values found. There was no clear correlation between DAP value and the age of the fluoroscopic system, with some older fluoroscopy units giving lower patient doses than some of the more modern equipment.

When comparing the above distribution of average DAP values with the NRPB diagnostic reference value of 25 $Gycm^2$ for the barium meal examination [8, 14], it is noticed that in this study, 8 rooms out of 24 are over this reference value – more than the expected number of 6 rooms (i.e. 25% of the total number of rooms). In addition, the mean weights of the Asian patient samples are significantly less than the 70 kg for which the reference value is stated, which should have made it easier to be below the NRPB reference dose value. Clearly the significant differences in the clinical protocols used leave considerable scope for patient dose reductions.

Optimization of fluoroscopic examinations such as the barium meal would be achieved by ensuring in the first instance that the imaging and dose performance of the fluoroscopic system met acceptable standards and then, second, that the examination protocol achieved the diagnostic aims for the minimum use of radiation.

4.4. COMPUTED TOMOGRAPHY (PHASE II)

4.4.1. CT systems

As described in the methodology, scanners were selected to be representative of the age of scanners in use in each country. Hence, scanners ranged from new to older than 10 years. The distribution of the number of CT examinations performed on the CT scanners in the project is presented in Figure 23. This is fewer examinations than is typically associated

with CT scanners in Level 1 countries [10]. The mean throughput per CT scanner was just over 4000 examinations per year. The detailed data for the CT scanners that were part of this programme are given in Annex III for the respective participating countries. These data include information on CT scanner make and model, age, and the number of examinations performed per year.

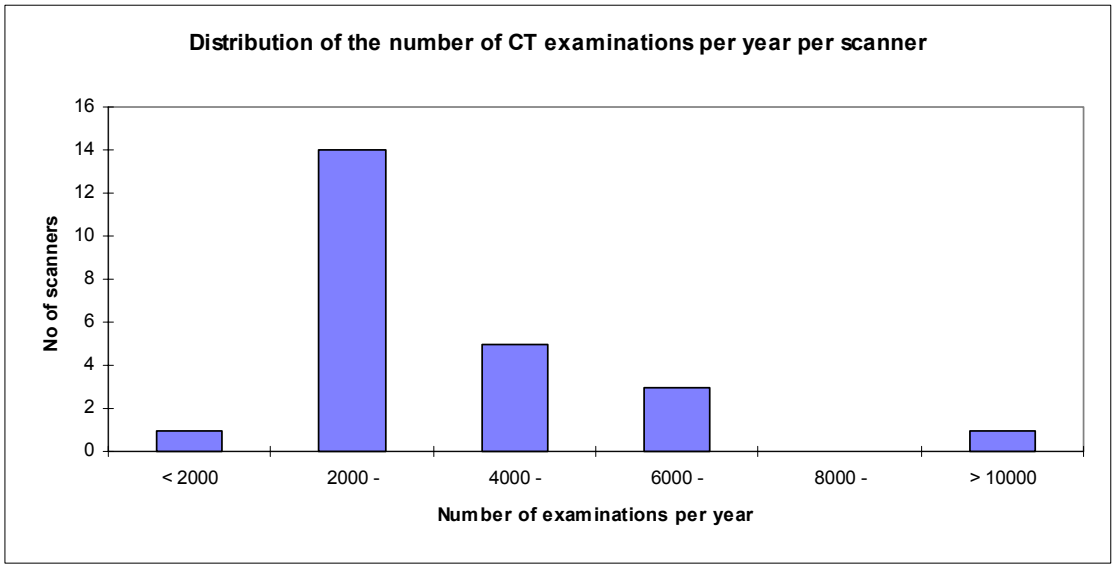

FIG. 23. Histogram of the distribution of the annual number of examinations performed per CT scanner in the project.

4.4.2. Quality control of CT equipment

Presenting a summary of all the quality control measurements made on the CT scanners is difficult because there was not a consistent approach, among the participating countries as to how the measurements were performed. For example, tube loadings varied as did the matrix size used, and these factors, among others, influence the measured values of some parameters. For each country, Annex III contains results for high contrast resolution, CT number calibration, low contrast detectability, noise and ${}_{n}CTDI_{air}$. Some results are given below.

4.4.2.1. Noise

Figure 24 presents reported values of noise for a 10 mm slice width, using a head phantom. Noise was calculated as the percentage of the effective linear attenuation coefficient of water, corrected for the scanner contrast scale using acrylic and water. Most results were obtained for 300 mAs per slice, but where noise was determined at a different mAs the values have been scaled by the ratio of $(Q/300)^{1/2}$, where Q is the mAs used per slice.

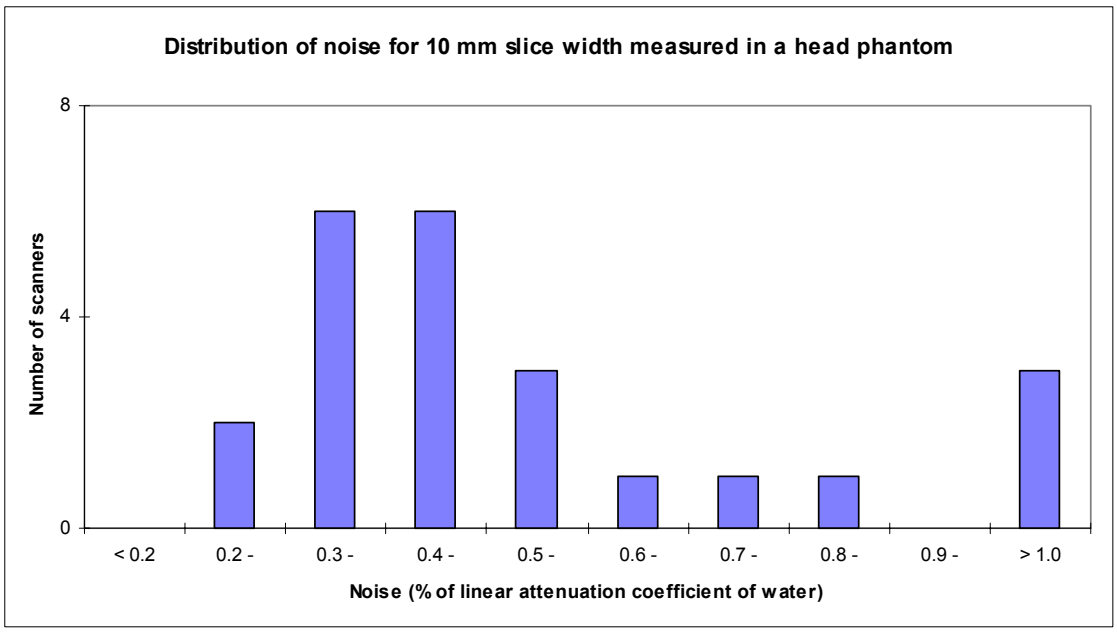

FIG. 24. Distribution of reported values of noise measured in a head phantom for a 10 mm slice width. Results are reported as a percentage of the linear attenuation coefficient of water and were normalized to 300 mAs per slice.

4.4.2.2. CT numbers calibration

The CT number for water is normally in the range 0.0 ± 4, and the CT number for air should be as near to –1000 as possible, preferably in the range –1000 ± 10. Most scanners met the criterion for water (21 out of 23) but only 7 out of 18 met the criterion for air, suggesting that machine calibrations were not performed as often as they should. The distributions of reported CT numbers for water and air determined for a 10 mm slice width, are given in Figures 25 and 26 respectively.

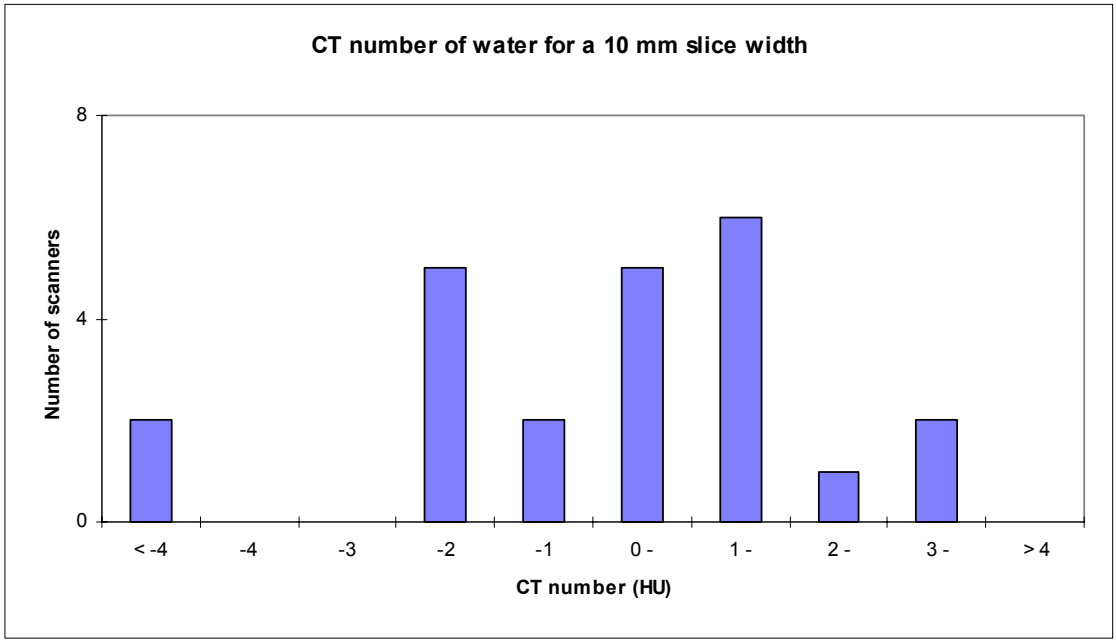

FIG. 25. Distribution of reported values of CT numbers for water.

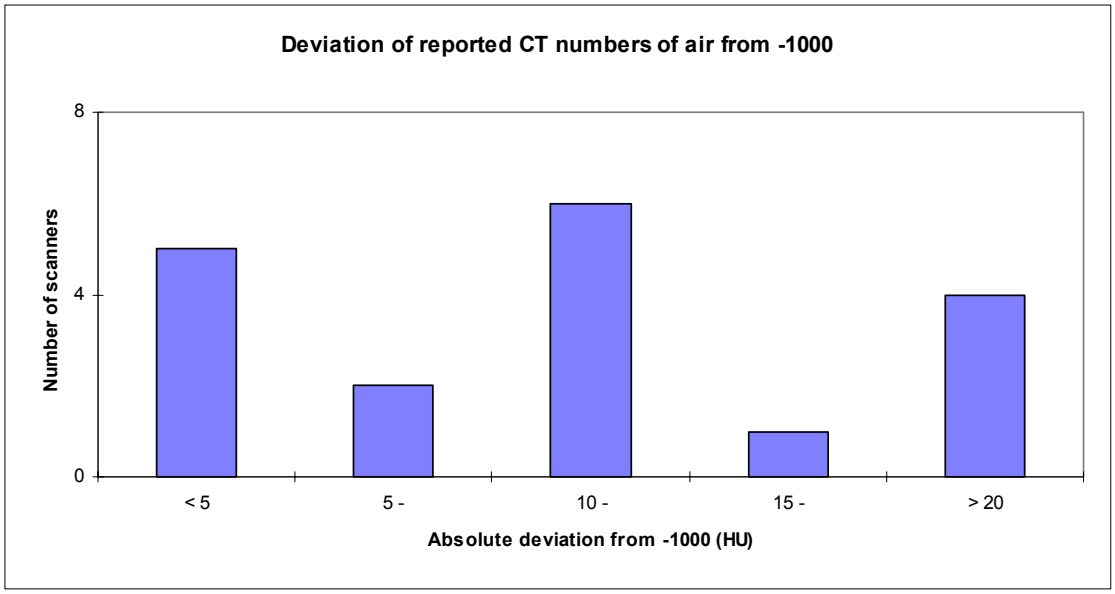

FIG. 26. Distribution of the deviation of the reported values of CT number of air from –1000 HU.

4.4.3. Patient doses

4.4.3.1. Dosimetry

Values of $CTDI_{10cm,air}$ measured for the 10 mm slice width are reported in Table XI. In addition, some values of ${}_nCTDI_w$ for the 10 mm slice width are also reported in Table XI. Many factors affect the likely values of $CTDI_{10cm,air}$ for any particular machine, including the geometry of the scanner, the kVp, the amount and type of filtration, and the type of detector system used. However the typical range of $CTDI_{10cm,air}$ is between 0.08 and 0.35 mGy/mAs, depending on the type of scanner, and the values reported in the table fall within this range. For comparison some mean values reported in the literature [14,15] are given.

TABLE XI. REPORTED VALUES OF CTDI FOR 10 MM SLICE WIDTH FOR THE CT SCANNERS IN THE STUDY

CT model	Country	kV	${}_nCTDI_{10cm,air}$ (mGy/mAs) for 10 mm slice thickness	${}_nCTDI_w$ (mGy/mAs) for 10 mm slice thickness	Typical ${}_nCTDI_{,10cm,air}$ values [14,15]
Elscint Helicat II	Czech Rep.	120	0.17	0.135 head	0.19
Elscint Helicat II	Czech Rep.	120	0.191	0.142 head	0.19
		140	0.257		
Elscint Select	Czech Rep.	120	0.22	0.176 head	
Elscint Twin	Czech Rep.	120	0.17	0.253 head	0.19

CT model	Country	kV	$_{n}CTDI_{10cm,air}$ (mGy/mAs) for 10 mm slice thickness	$_{n}CTDI_{w}$ (mGy/mAs) for 10 mm slice thickness	Typical $_{n}CTDI_{,10cm,air}$ values [14,15]
Elscint Twin II	Czech Rep.	120	0.18	0.142 head	0.19
GE 9800	Malaysia	140	0.124		
GE 9800 Q	Thailand	120	0.219 head 0.243 body		0.25
GE CT Pace	China	120	0.334	0.090 body	0.34
GE Prospeed S Fast	Vietnam	120	0.215	0.065 body	0.34
GE Sytec 4000	Thailand	120	0.291 head 0.345 body		0.41
GE Sytec 4000i	Vietnam	120	0.276	0.083 body	0.41
Philips Tomoscan CX/Q	Thailand	120	0.19 head 0.25 body		0.21
Picker 1200SX	China	125	0.215	0.095 body	0.32 (130 kV)
Siemens Somatom	Morocco	120	0.18		
Siemens Somatom AR	Morocco	125	0.19		
Siemens Somatom AR	Morocco	130	0.12		
Siemens Somatom AR-T	Vietnam	110	0.146	0.056 body	0.25
Siemens Somatom AR-T	China	130	0.302	0.115 body	0.36
Siemens Somatom HiQ	Romania	133	0.158		0.18
Siemens Somatom Plus	Romania	120	0.114		0.12
Siemens Somatom Plus 2	Malaysia	120	0.44		
Siemens Somatom Plus 4	India	120	0.117		0.18
Siemens Somatom Plus 4	Malaysia	120	0.216		0.18
Siemens Somatom Plus D	Romania	120	0.095		0.12

4.4.3.2. Patient doses for general CT chest examination

For the evaluation of doses arising from the use of CT in the participating countries, samples of 5 average patients per installation for a general chest CT examination were considered. Table XII summarizes the following parameters averaged over the 5 patients: kV, mAs per slice, patient weight, number of slices, slice thickness, $CTDI_w$ and the DLP. For examinations performed in spiral mode the pitch and total table movement were used to derive "equivalent" numbers of axial slices.

TABLE XII. AVERAGE PATIENT DOSES AND TECHNIQUES FOR THE GENERAL CHEST CT EXAMINATION PERFORMED AT PARTICIPATING HOSPITALS

Country/Hospital	Average patient weight (kg)	Average kVp	Average mAs	Average No of slices	Average slice thickness (mm)	$CTDI_w$ (mGy)	DLP (mGycm)
China /1	57	120	300	22	10	27.1	596
China /2	60	130	455	20	10	43.0	860
China /3	55	125	150	22	10	17.2	378
Czech Rep /1	73	120	130	11.4	7	6.8	54
Czech Rep /2	69	120	112	12	10	5.6	78
Czech Rep /3	61	130	150	35	10	10.1	392
Czech Rep /4	68	120	150	22	10	7.5	165
India /1	53	140	150	40	5	23.8	476
Malaysia /1	56	125	230	41	10	21.2	864
Malaysia /2	48	130	155	33	9	14.2	467
Malaysia /3	54	120	200	25	10	7.2	183
Morocco /1	60	125	275	18	10	19.1	351
Morocco /2	65	125	264	20	10	11.0	220
Morocco /3	60	120	270	20	9	18.5	370
Romania /1	68	137	220	21	3	9.9	62
Romania /2	65	133	240	50	5	17.5	438
Romania /3	60	120	315	30	10	17.0	510
Thailand /1	61	120	315	51	10	22.5	1178
Thailand /2	60	120	255	45	10	23.8	1083
Thailand /3	62	120	300	47	10	20.0	940
Vietnam /1	50	110	150	18	10	8.3	147
Vietnam /2	49	125	83	32	9	7.0	195
Vietnam /3	53	120	220	32	10	14.2	449

The EC [7] specify criteria for patient dose for CT examinations and give examples of good imaging technique. The dose that the patient receives in a CT examination is determined by two aspects of the particular scanner - the radiation output characteristics of the scanner and the clinical protocol of how the scanner is used in performing the examination. The first

aspect can be gauged using the $CTDI_w$ - a weighted measure of the amount of radiation the scanner "uses" per slice. This parameter in turn depends on the kVp, base filtration, shaping filters, FAD, slice width and the mAs per slice. The second aspect is essentially determined by the volume scanned. The combination of these two aspects determines the patient dose, which can be specified by effective dose or more simply by DLP.

The specification for $CTDI_w$ for the general chest CT is that it should be less than 30 mGy [7]. The distribution of average $CTDI_w$ values for the installations in this study is given in Figure 27. The mean of the average $CTDI_w$ values was 16.2, with minimum and maximum values of 5.6 and 43 mGy. These values are very similar to those reported from the UK [9] of 20.3, 4.0 and 46.4 mGy respectively. One out of 22 scanners in this project exceeded the 30 mGy criterion for $CTDI_w$.

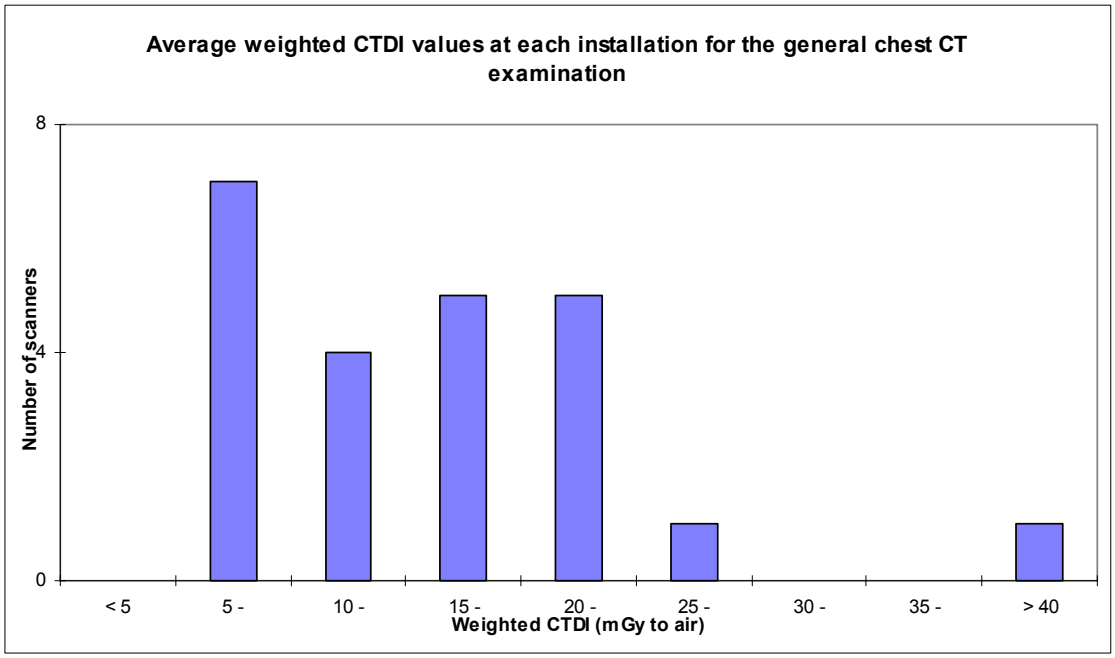

FIG. 27. Distribution of average weighted CTDI values reported for each CT scanner in the project, expressed in terms of absorbed dose to air.

Dose length product is an overall measure of patient dose and the distribution of reported average values is given in Figure 28. The proposed diagnostic reference level for DLP is given as 650 mGy cm [7]. The mean of the reported average DLP values was 455, with minimum and maximum values of 54 and 1178 mGy cm. These values are very similar to those reported from the UK [9] of 501, 72 and 1304 mGy cm respectively. There is a clear gap between those facilities whose doses met the EC criterion and the six facilities that did not.

The EC [7] in "examples of good imaging technique" state that the nominal slice width should be in the range 7 to 10 mm, with an inter-slice distance of zero (contiguous slices) or a pitch equal to 1 in the case of spiral scanners. Nearly all reported techniques used slice widths in the range 7 to 10 mm, but a few facilities used a smaller slice width as standard or in a second series of slices. Contiguous slices or a pitch of one were used again by nearly

all, but the extent of the scan in some cases clearly did not extend from the base of the lungs to the apices. It was unclear whether the application of a reduced region of interest was the standard approach to the general chest CT examination or whether the small sample of patients happened to have a disproportionate number of such cases. Only six out of the 23 facilities performed two series of scans (pre- and post-contrast) as their standard protocol.

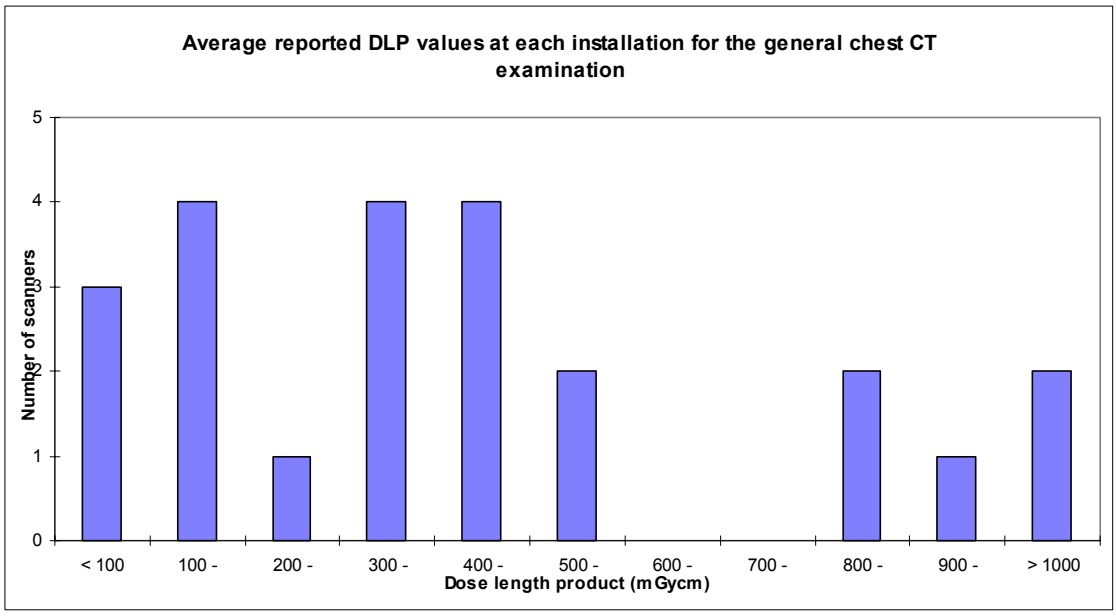

FIG. 28. Distribution of average dose length product values reported for each CT scanner in the project, expressed in terms of mGycm.

In general, the technical parameters used in the different centres and countries demonstrate that the performance of CT examinations in many centres was not optimized resulting in the observed wide variation in patient doses.

4.4.4. Image quality for general CT chest examinations

The assessment of image quality for the general chest CT examination was performed by local radiologists using the quality criteria proposed in an earlier version of the working document of the European Commission. For each criterion, a score of 1 is assigned if that criterion is fulfilled, and 0 if not. With the criteria used the maximum value was 18 points (or 17 if the examination was performed without contrast media). Table XIII presents the average results obtained by those countries that made image quality evaluations. The evaluations were made on a minimum of 5 average patients per scanner.

The mean image quality score for the 30 patients evaluated in 7 centres was 15.7 ± 0.9 out of 17 image criteria to be fulfilled for those examinations performed without any contrast medium while the average image quality score was 15.2 ± 1.9 out of 18 image criteria for the other 70 patients. These values are combined in Figure 29 where the distribution is given for the average percentage of the total number of criteria met by images at a given installation. The mean percentage of the criteria met, averaged over all installations, was 86.9 ± 9.7% with a range from 66.7 to 100%.

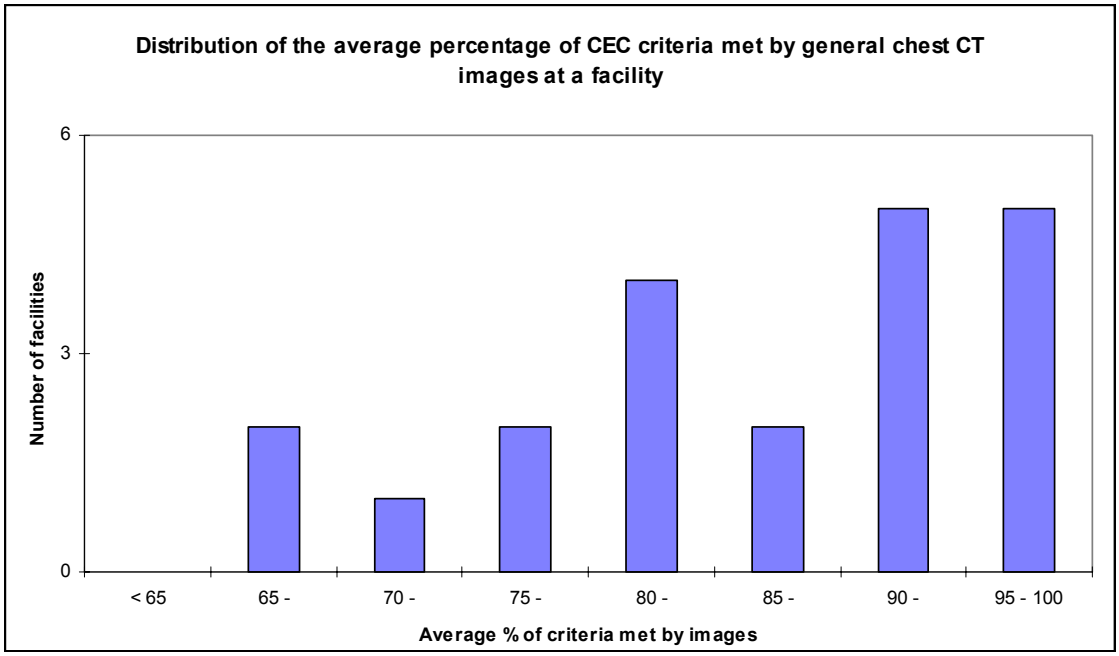

FIG. 29. The distribution of the average number of EC criteria (expressed as a percentage of the possible number) met by the images at each installation for the general chest CT examination.

TABLE XIII. AVERAGE IMAGE QUALITY SCORE FOR EACH CT SCANNER FOR THE GENERAL CHEST CT EXAMINATION

Country	Image quality (mean value; maximum score 17/18)
China /1	16.6 out of 17
China /2	17 out of 17
China /3	16 out of 17
Czech Rep. /1	15.1 out of 17
Czech Rep. /2	15.3 out of 17
Czech Rep. /3	14.1 out of 17
Czech Rep. /4	15.5 out of 17
India /1	14.2 out of 18
India /2	16.4 out of 18
Malaysia /1	18 out of 18
Malaysia /2	15.8 out of 18
Malaysia /3	17.4 out of 18
Morocco /1	13.2 out of 18
Morocco /2	14.6 out of 18
Morocco /3	13.8 out of 18
Thailand /1	15.2 out of 18
Thailand /2	17 out of 18
Thailand /3	15 out of 18
Vietnam /1	12 out of 18
Vietnam /2	12.4 out of 18
Vietnam /3	17.6 out of 18

For 13 scanners (in 4 countries) data were reported that allowed the determination of the proportion of images that met a given number of criteria. For example, out of 62 examinations 7 (11%) met all the criteria and 19 (30%) either met all criteria or failed only one. The full distribution of these data is given in Figure 30.

While quality criteria for conventional radiographic images have been developed over a period of about 10 years, complete with reported trials [11], the extension of the approach to CT imaging has essentially been one of supposition [7]. An obvious difference between conventional radiography and CT is that, with the latter, images are able to be viewed both on a monitor at a work station and on film. There are no published data available for comparison with the results reported here. However some comments from a group of radiologists at a single centre suggest that the use of the CT image criteria may be more limited than the radiography image criteria. Their informal feedback included the comment that evaluation of images on the workstation invariably resulted in 100% of the criteria being met and hence that the criteria were not able to distinguish between a good CT examination and a non-optimized examination.

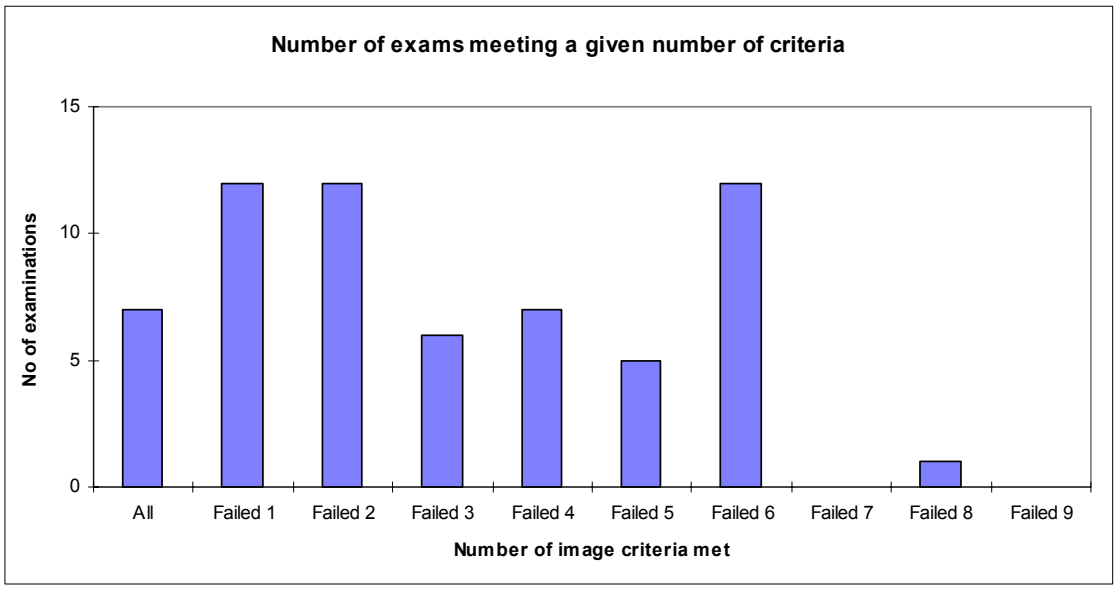

FIG. 30. Distribution of the number of general chest CT examinations whose images met a given number of the EC criteria for 13 installations.

ADDENDUM

Several application specific quantities have been found useful in the past for measurements in diagnostic radiology. However, there has been ambiguity in the names of the quantities and their (sometimes incorrect) use. ICRU and IAEA [16] are developing two new recommendations on dosimetry in diagnostic radiology. Both documents provide a consistent set of dosimetric quantities that are specific to applications on the basis of the air kerma. In addition, air kerma is the primary dosimetric quantity in the diagnostic energy range and all calibrations at national laboratories of dosimeters for use in diagnostic radiology are provided in terms of air kerma.

5. CONCLUSIONS

Despite some practical limitations within the CRP and obvious difficulties connected with the implementation of a new programme in countries in different parts of the world, with different levels of radiological protection infrastructure, the results of this project have shown that it is possible to implement a coordinated programme of optimization of radiological protection in diagnostic radiology.

In general radiography, considerable reductions (20–69%) in patient dose were achieved at low cost and still with acceptable image quality consistent with the clinical purpose of the examination. The methodology, based on patient dose measurements, comparison with reference values, assessment of image quality, the introduction of QC and corrective actions, if needed, and re-evaluation of patient doses and image quality, has demonstrated its effectiveness for optimization of radiological protection programme.

In the case of fluoroscopy and CT, the project assessed their current status in the participating countries and introduced QC to these areas. Completion of the optimization methodology in fluoroscopy and CT was outside the scope of the programme, primarily because of the limited duration of the project. However, the introduction of QC across general radiography, fluoroscopy and CT in the participating centres was a significant step towards establishing a culture of quality control and quality assurance in diagnostic radiology in the respective countries.

At the practical level, the programme has shown that in all countries there was considerable scope for dose reduction and improvement in the efficacy and modernity of radiological equipment, confirming the need to promote such initiatives at the international level.

It was evident from some of the country reports that there were inadequacies or deficiencies in experimental technique, and understanding of how to perform some of the measurements, and what instrumentation is appropriate for given situations. The programme has proved to be valuable as a learning process for those taking part and has also provided them with tools and practical protocols which can be used in the implementation of a national QC programme in diagnostic radiology in the future.

There is a need for adequate training to be given to users, especially in the more specialized areas of quality control and dosimetry in fluoroscopy and CT. As part of the whole optimization process, it is evident that radiologists and radiographers would greatly benefit from training in quality assurance, including training in the use of image quality criteria.

To ensure that patient dosimetry is reliable, calibrations and intercomparisons need to be provided by an external institution.

5.1. PATIENT DOSES

The decision to use simple, easily measured dose quantities to assess patient dose was vindicated by the relatively high success rate that participants had in measuring the quantities.

Practical training and significant instructions are required for obtaining useful data from the use of dose-area product meters, and on the determination of the various forms of CTDI.

It seems desirable that different patient dose reference values be considered for Asian populations since the weight of the Asian average man is significantly different from the weight of the European average man. Results presented in this report could represent a first step towards specifying reference values for Asian populations.

5.2. IMAGE QUALITY EVALUATION

5.2.1. General radiography

Evaluation of image quality in general radiography using the clinical criteria of the EC [5] has been shown to be a sound method for confirming an adequate level of diagnostic information in the images. In this study, assessments were only performed by local radiologists. Due to logistics and legal impediments, it was not possible to perform central viewing of all images within a country, and pooled viewing of all participating countries films, as originally planned. Comparison of and analysis of the image evaluation in many different countries without a means of standardizing the assessments may not be meaningful because the EC image quality criteria could have been applied with differing levels of rigour.

In future programmes, the difficulties (such as legal implications) that made it impossible to have centralized viewing and assessment of images may be overcome so that some evaluation by a panel of experts could be done.

5.2.2. Fluoroscopy

In fluoroscopy, image quality evaluation was performed using test objects. Unfortunately several different test objects were used, and there was insufficient consistency on how they were used. This prevented any comprehensive comparison of results from participating countries.

In the assessment of image quality in fluoroscopy, the attention on what results from the test objects are to be obtained and planning the work accordingly will be helpful, particularly when it is difficult to have an identical or similar set of test objects.

5.2.3. Computed tomography

The results of image quality evaluation for general chest CT have been reported by seven countries and the scores obtained represent one of the first results in the application of quality criteria proposed by the European Commission [7].

REFERENCES

[1] FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, INTERNATIONAL ATOMIC ENERGY AGENCY, INTERNATIONAL LABOUR ORGANISATION, OECD NUCLEAR ENERGY AGENCY, PAN AMERICAN HEALTH ORGANIZATION, WORLD HEALTH ORGANIZATION, International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources, Safety Series No. 115, IAEA, Vienna (1996).

[2] INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION, 1990 Recommendations of the International Commission on Radiological Protection, Publication 60, Pergamon Press, Oxford and New York (1991).

[3] INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION, Radiological Protection and Safety in Medicine, Publication 73, Pergamon Press, Oxford and New York (1996).

[4] INTERNATIONAL ATOMIC ENERGY AGENCY, Radiation Doses in Diagnostic Radiology and Methods for Dose Reduction, IAEA-TECDOC-796, Vienna (1995).

[5] OFFICE FOR OFFICIAL PUBLICATIONS OF THE EUROPEAN COMMUNITIES, European guidelines on quality criteria for diagnostic radiographic images, Report EUR 16260 EN, Luxembourg (1996).

[6] UNITED NATIONS, "Medical Radiation Exposures", Volume I, Annex D, Sources and Effects of Ionizing Radiation, 2000 Report to the General Assembly, Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), UN, New York (2000).

[7] OFFICE FOR OFFICIAL PUBLICATIONS OF THE EUROPEAN COMMUNITIES, European Guidelines on Quality Criteria for Computed Tomography, Report EUR 16262, Luxembourg (1999). ISBN 92-828-7478-8.

[8] BAUER, B., et al. (Eds), Reference doses and quality in medical imaging – what the referring practitioner and directing medical staff should know, Report EUR 18532 EN, Radiation Protection Dosimetry, **80**, Nos. 1-3 (1998).

[9] NATIONAL RADIOLOGICAL PROTECTION BOARD-R249, Survey of CT Practice in the UK. Part 2: Dosimetric Aspects. P.C. Shrimpton et al. ISBN 0-85951-342-4 (1991).

[10] UNITED NATIONS, Medical Radiation Exposures, Annex III, Sources and Effects of Ionizing Radiation, 1993 Report to the General Assembly, Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), UN, New York (1993).

[11] MACCIA, C., MOORES, B.M., WALL, B.F., The 1991 CEC trial on quality criteria for diagnostic radiographic images: detailed results and findings, Report EUR 16635 EN, Office for Official Publications of the European Communities, Luxembourg (1997).

[12] VAÑÓ, E., GUIBELALDE, E., MORILLO, A., ALVAREZ-PEDROSA, C.S., FERNÁNDEZ, J.M., Evaluation of the European image quality criteria for chest examinations, British Journal of Radiology, **68**, (1995) 1349-1355.

[13] THE INSTITUTION OF PHYSICS AND ENGINEERING IN MEDICINE (IPEM), Measurement of the performance characteristics of diagnostic X ray systems, Report 32, Part 2: Image intensifier television systems, 2nd Edition, York (1996).

[14] NATIONAL RADIOLOGICAL PROTECTION BOARD, Occupational, Public and Medical Exposure, Documents of the NRPB, **4,** no. 2, Chilton, Didcot (1993).

[15] ImPACT (Imaging Performance Assessment of CT scanners), Website http://www.impactscan.org.

[16] ZOETELIEF, J. et al., Dosimetry in Diagnostic and Interventional Radiology – International Commission on Radiation Units and IAEA activities (IAEA-CN-96/39), Proceedings of the International Symposium on Standards and Codes of Practice in Medical Radiation Dosimetry, Vienna, 25-28 November 2002. IAEA, Vienna (2003), 387-404.

GLOSSARY

Definitions of terms and acronyms used in this publication

The following definitions apply for the purposes of the present publication:

Absorbed dose

The fundamental dosimetric quantity *D*, defined as:

$$D = \frac{d\varepsilon}{dm}$$

where dε is the mean energy imparted by *ionizing radiation* to matter in a volume element and dm is the mass of matter in the volume element. The energy can be averaged over any defined volume, the average *dose* being equal to the total energy imparted in the volume divided by the mass in the volume. *Absorbed dose* is defined at a point; for the average dose in a tissue or organ, see *organ dose*. Unit: J/kg, termed the *gray (Gy)* (formerly, the *rad* was used).

Acceptance test

Test to determine whether a product such as X ray equipment conforms to technical specification. Formally, acceptance testing includes the listing of characteristics which determine the fitness for use of the product, interpretation of the specification of these characteristics, performance testing according to a recognized protocol and reporting of results. The results are useful subsequently as reference values against which the performance of the equipment may periodically be assessed.

Additional filtration

Quality equivalent filtration due to added filters and other removable materials in the radiation beam which are between the radiation source and the patient or a specified plane.

Anti-scatter grid

Device to be placed before the image reception area in order to reduce the incidence of scattered radiation upon that area and thus increase the contrast in the X ray pattern.

Artefact

Any unwanted structure or pattern visible in an image, not including noise.

Automatic exposure control (AEC)

A device which determines and provides automatically the exposure needed to produce an image of adequate optical density, by sampling the X ray intensity at the image receptor.

Base density

The optical density due to the supporting base of the film alone.

Base plus fog density

The optical density of a film due to its base density plus any action of the developer on the radiographically unexposed emulsion.

Baseline value

Reference value of a functional performance characteristic, which is obtained immediately following an acceptance test in one or a series of constancy tests and used as a base for comparisons for the evaluation of results of consecutive constancy tests.

Beam alignment

The degree of overlap between the X ray beam and the image receptor such that the whole X ray field is both centred and contained within the image receptor.

Characteristic curve

A graph of the relationship between the optical density of the X ray film (ordinate) and the logarithm of the exposures given to the film (abscissa).

Consistency of output

The variation in measured X ray output when a number of measurements are performed on an X ray tube and generator with a dosimeter capable of demonstrating a high degree of precision and the radiographic factors remain constant.

Consistency

The degree of variation of a measured parameter when a number of measurements under identical conditions are performed with an instrument capable of demonstrating a high degree of precision.

Constancy test

Quality test, repeated at specific intervals, to establish and document changes of the initial status of a piece of equipment or its components, described by baseline values.

Contrast detail phantom

A test object used in the assessment of imaging systems, which employs details of different sizes and contrasts.

Density control setting

The control which enables the optical density which is produced by an AEC system to be varied in discrete steps.

Depth dose

Absorbed dose at a specified depth beneath the entrance surface of an irradiated object, usually on the radiation beam axis.

Diagnostic reference levels

Dose levels in medical radiodiagnostic practices or, in the case of radiopharmaceuticals, levels of activity, for typical examinations for groups of standard-sized patients or standard phantoms for broadly defined types of equipment. These levels are indicative of good practice when not exceeded, for standard procedures when good and normal practice regarding diagnostic and technical performance is applied.

Dose-area product

Product of the area of a cross-section of a radiation beam and the average value of a dose-related quantity over that cross-section.

Entrance surface air kerma

The air kerma measured free-in-air (without backscatter) at a point in a plane corresponding to the entrance surface of a specified object, e.g. a patient's breast or a standard phantom.

Entrance surface dose

Absorbed dose in the centre of the field at the surface of entry of *radiation* for a patient undergoing a radiodiagnostic examination, expressed in air and with backscatter.

Equivalent dose, H_T

The quantity $H_{T,R}$, defined as:

$$H_{T,R} = w_R \cdot D_{T,R}$$

where $D_{T,R}$ is the *absorbed dose* delivered by *radiation* type R averaged over a tissue or organ T and w_R is the *radiation weighting factor* for *radiation* type R. When the *radiation* field is composed of different *radiation* types with different values of w_R the *equivalent dose* is:

$$H_T = \sum_R w_R \cdot D_{T,R}$$

The unit of *equivalent dose* is J/kg, termed the *sievert (Sv)*. The *rem*, equal to 0.01 Sv, is sometimes used as a unit of *equivalent dose* and *effective dose*.

A measure of the *dose* to a tissue or organ designed to reflect the amount of harm caused.

Values of *equivalent dose* to a specified tissue from any type(s) of radiation can therefore be compared directly.

Exposure factors

The settings of X ray tube voltage (kV), tube current (mA) and exposure time (s).

Film gamma

The gradient of the "straight line" portion of the characteristic curve of an X ray film.

Film latitude

Steepness of a characteristic curve, determining the range of exposures that can be transformed into a visually evaluable range of optical densities.

Film processor

An automated device which makes visible the latent image on a film, by transporting it in a controlled manner through specialized sections where developing, fixing, washing and drying of the film occur.

Film shelf life

Duration of viability of X ray film under particular storage conditions.

Filtration

Modification of characteristics of ionizing radiation on passing through matter.

Fog

The density added to a radiographic image due to unwanted action of the developer on the radiographically unexposed film emulsion or by light, ionizing radiation or heat exposure during storage, handling and processing.

Grid ratio

For a linear grid, ratio of the height of the strips to the width of the gaps at the central line.

Guidance level for medical exposure

A value of dose, dose rate or activity selected by professional bodies in consultation with the regulatory body to indicate a level above which there should be a review by medical practitioners in order to determine whether or not the value is excessive, taking into account the particular circumstances and applying sound clinical judgement.

Half-value layer

Thickness of a specified material which, under narrow beam conditions, attenuates photon radiation according to its energy spectrum to an extent that the kerma rate, exposure rate or absorbed dose rate is reduced to one half of the value that is measured without the material.

High frequency generator

An X ray generator in which the frequency of the high voltage wave form is in the kilohertz region.

Inherent filtration

The filtration provided by permanent materials through which the radiation beam must pass before emerging from the radiation source. For X ray tubes it is the filtration inherent in the structural components of the X ray tube head: the glass of the X ray tube, the insulating oil, the seal of the X ray port.

Kerma

The quantity K, defined as:

$$K = \frac{dE_{tr}}{dm}$$

where dE_{tr} is the sum of the initial kinetic energies of all charged ionizing particles liberated by uncharged ionizing particles in a material of mass dm.

Unit: gray (Gy)

Originally an acronym for kinetic energy released in matter, but now accepted as a word.

Kilovoltage (kV) compensation

The ability of an AEC to maintain constant optical density on the films when the kV setting has been changed

Light field indicator

Device to delineate by means of visible light the extent of the field to be irradiated.

Light leaks

Sources of stray light which may contribute to film fog.

Light tightness

Physical property of the cassette which prevents any infiltration of light rays.

Limiting value

Value of a parameter which, if exceeded, indicates that corrective action is required.

Medical exposure

Exposure applying to the following groups: patients as part of their own medical diagnosis or treatment; individuals as part of occupational health surveillance; individuals as part of health screening programmes; healthy individuals or patients voluntarily participating in medical or biomedical, diagnostic or therapeutic, research programmes; individuals as part of medico-legal procedures.

Qualified expert in radiodiagnostic physics (Medical physics expert)

An expert in radiation physics or radiation technology applied to exposure, whose training and competence to act is recognized by the competent authorities, and who, as appropriate, acts or gives advice on patient dosimetry, on the development and use of complex techniques and equipment, on optimization, on quality assurance, including quality control, and on other matters relating to radiological protection, concerning exposure.

National standard

Standard recognized by a national decision to serve, in a country, as the basis for assigning values to other standards of the quantity concerned.

Net optical density

Total film density minus base plus fog density.

Object contrast

The inherent differences in X ray attenuation in the object being imaged.

Optical density

The degree of blackening of processed X ray or photographic film. Numerically equal to the decadal logarithm of ratio of light incident on the film to that transmitted through the film.

Optimization

Any process or procedure which ensures that doses due to appropriate medical exposure for radiological purposes are kept as low as reasonably achievable (ALARA) consistent with obtaining the required diagnostic information, taking into account economic and social factors.

Organ dose

The mean *absorbed dose* D_T in a specified tissue or organ T of the human body, given by:

$$D_T = \frac{1}{m_T} \int_{m_T} D \, dm$$

where m_T is the mass of the tissue or organ and D is the *absorbed dose* in the mass

element dm.

Phantom

Used to absorb and/or scatter radiation equivalently to a patient, and hence to estimate radiation doses and test imaging systems without actually exposing a patient. It may be an anthropomorphic or a physical test object.

Qualified expert

Person having the knowledge and training needed to carry out physical, technical or radiochemical tests enabling doses to be assessed, and to give advice in order to ensure effective protection of individuals and the correct operation of protective equipment, whose capacity to act as a qualified expert is recognized by the competent authorities. A qualified expert may be assigned the technical responsibility for the tasks of radiological protection of workers and members of the public.

Quality assurance

Planned and systematic actions necessary to provide adequate confidence that an item, process or service will satisfy given requirements for quality, for example, those specified in the licence.

This definition is slightly modified from that in ISO 921:1997 (Nuclear Energy: Vocabulary) to say “an item, process or service” instead of “a product or service” and to add the example. A more general definition of *quality assurance* and definitions of related terms can be found in ISO 8402:1994.

A systematic programme of controls and inspections applied by any organization or body involved in the transport of radioactive material which is aimed at providing adequate confidence that the standard of safety prescribed in these Regulations is achieved in practice.

Quality control

Part of *quality assurance* intended to verify that systems and components correspond to predetermined requirements.

This definition is taken from ISO 921:1997 (Nuclear Energy: Vocabulary) [11]. A more general definition of *quality control* and definitions of related terms can be found in ISO 8402:1994.

Quality criteria

Criteria which characterize a level of acceptability for radiological images which could answer to any clinical indication. The characteristics include diagnostic requirements (image criteria, important image details), criteria for radiation dose to the patient (reference dose value), and examples of good imaging technique.

Quality equivalent filtration

A quantity indicating for a material or an object the effect of its filtration, expressed as the thickness of a particular reference material, the filtration of which is known to have the same effect on radiation quality under specific conditions of measurement.

Quality management

All activities of the overall management function which determine the quality policy, objectives and responsibilities, and implement them by such means as quality planning, quality control, quality assurance and quality improvement within the quality system.

Radiation output (X ray output)

The air kerma measured free-in-air (without backscatter) per unit of tube loading at a specified distance from the X ray tube focus and at stated radiographic exposure factors.

Radiographic contrast

The difference of optical density between two adjacent elements of a radiographic image.

Reference dose value

Value of a specific dose quantity obtained by patient dose evaluation, which may be used to quantify the diagnostic reference level.

Reproducibility

Indicates the reliability of either a measuring method or test equipment. The results under identical conditions should be constant.

Resolution

The degree to which fine detail of an object can be reproduced in a radiographic, fluoroscopic, television or other image. The smallest object or highest spatial frequency of a given contrast that is just perceptible.

Safe light

Source of illumination which provides visibility in a darkroom without modifying appreciably the optical density of the film.

Screen film contact

The close proximity of the intensifying screen to the emulsion of the film, necessary to reduce blur.

Screen film sensitivity

The sensitivity S is equal to the quotient Ko/Ka where Ko = 1mGy and Ka is the air kerma free-in-air for the net density D = 1.0, measured in the film plane.

Secondary standard

Standard whose value is assigned by comparison with a primary standard of the same quality.

Speed class

Defined range of sensitivity values of a screen film system.

Standards dosimetry laboratory

A laboratory designated by the relevant national authority for the purpose of developing, maintaining or improving primary or secondary standards for radiation dosimetry.

Thermoluminescent dosimeter (TLD)

A radiation dosimeter which contains a substance that, when properly annealed and exposed to ionizing radiation, emits light after thermal stimulation in proportion to the radiation dose received.

Tolerance

The maximum allowed variation in a measured value expressed as a fraction of a mean value of an appropriate number of measurements.

Total filtration

The sum of effective thickness of materials traversed by the primary X ray beam before it enters the patient.

Note: The sum of effective thickness is the sum of aluminum equivalent thickness of inherent and additional filtration.

Tube loading

The tube current-exposure time product (mAs) that applies during a particular exposure.

Tube potential

The potential difference (kilovolt, kV) applied across the anode and cathode of the X ray tube during a radiographic exposure.

ANNEX I

THERMOLUMINESCENT DOSIMETER INTERCOMPARISON

I-1. Dosimetry systems

The general technical characteristics of the thermoluminescent dosimeter (TLD) systems are presented in Table I-1.The great majority of the participants used Harshaw TL-readers, and all patient dose measurements were performed using natural LiF. With the exception of China which used GR200, a high sensitivity LiF with Cu dopant, all countries used TLD100.

From 1 to 5 dosimeters were used for each measurement of patient dose for each X ray projection. After each reading, the annealing procedures were performed according to manufacturer's recommendations and routine calibration using βeta, gamma or X-radiation was carried out by all the countries.

I-2. TLD calibration and intercomparison exercises

The first calibration and intercomparison exercise for Asian participants took place during February-March 1996. Participants supplied 10 chip sets, each containing 5 dosimeters. Chip sets 1 to 5 were to provide calibration factors for x-irradiations covering the diagnostic energy range, with a range of doses from 0.1 to 50 mGy. Chip set 6 was to provide a reference exposure to ^{60}Co. Chip sets 7, 8 & 9 were exposed to representative beam qualities and doses likely to be encountered during the project when measuring entrance surface doses on patients. The participating countries were advised the doses given to chip sets 1 to 6. However the doses to chip sets 7, 8 and 9 were not disclosed to the participants, although the energy and an approximate dose range were indicated. Chip set 10 was for assessing background and transportation dose. Once the TLDs were irradiated, they were returned to the respective countries.

A second exercise took place in January 1997, following the same approach as in the first exercise, with one difference. The ^{60}Co irradiation was not performed, and was replaced with a beam quality representative of CT irradiations.

TABLE I-I. TECHNICAL CHARACTERISTICS OF TLD SYSTEMS

Country	China	Czech Rep.	India	Indonesia	Malaysia	Morocco	Pakistan	Romania	Thailand	Vietnam
TL reader	Toledo 654	Harshaw 2000	Harshaw 5500	Harshaw 4000	Harshaw 3500	Harshaw 2271	Harshaw 2000	Harshaw 2000	Harshaw 5500	Toledo
TL material	LiF GR200	LiF TLD100	LiF TLD100	LiF TLD100	LiF TLD100	LiF TLD100	LiF TLD100	LiF TLD100	LiF TLD100	LiF TLD100
SD of batch (%)	<4	2.4		1.76	2.0			<5	3.81	<6
Annealing procedure	240° C/10min	400°C/1h 100°C/3h		400°C/1h 200°C/2h	400°C/1h 100°C/2h	400°C/1h 80°C/24	400°C/1h 100°C/3h	400°C/1h 80°C/24h	400°C/1h 100°C/2h	300°C/1h
Annealing after each reading (Y/N)	Y	Y	Y	Y	Y	Y	Y	Y		Y
Reading process:										
- T_{MAX}	240°C	300°C	300°C	380°C	300°C	300°C	200°C	300°C	300°C	260°C
- time	20s	15s	20s	30s	33s	10-30s	25s	30s	20s	16s
- N_2 (Y/N)	N	Y	Y	Y	Y	Y	N	N	Y	N
Reading period after exposures (days)	1	1-15	0	2 (ave)	3-10	1-3	2-5	3-10	1-15	1
Calibration after each annealing procedure (Y/N)	Y	Y		N		N	Y	Y	Y	Y
Source used for calibration	X rays	^{137}Cs	^{90}Sr	X rays NZ		^{90}Sr	^{60}Co	^{137}Cs	^{60}Co	^{137}Cs
Cleaning procedure (Y/N)	Y	Y	N	Y	N	N	N	Y	N	N

Table I-2 gives details of the irradiation conditions for the Asian participants in the two calibration and intercomparison exercises.

TABLE I-2. IRRADIATION CONDITIONS FOR THE CALIBRATION AND INTERCOMPARISON OF THE TLD SYSTEMS OF THE PARTICIPATING ASIAN COUNTRIES

Chip set	kVp	filtration mmAl	HVL mmAl	keV	Nominal Dose mGy
1	50	2.0	1.513	25.7	50
2	80	3.0	2.896	33.0	50
3	120	5.0	5.613	44.5	50
4	80	3.0	2.896	33.0	0.1
5	80	3.0	2.896	33.0	5
6 - 1st	^{60}Co			1250	50
6 - 2nd	120	3.0			10
7	60	2.0	1.71	26.9	1–5
8	80	3.0	2.896	33.0	15–30
9	100	5.0	4.80	41.6	0.5–3.0
10	Bkg				

Similarly, two calibrations and intercomparison exercises took place during the project for the Eastern European and African participants. Participants supplied 11 chip sets, each containing 5 dosimeters. Chip sets 1 to 6 were to provide calibration factors for x-irradiations covering the diagnostic energy range, with a range of doses from 0.1 to 50 mGy. Chip set 7 was to provide a reference exposure to ^{137}Cs. Chip sets 8, 9 & 10 were exposed to representative beam qualities and doses likely to be encountered during the project when measuring entrance surface doses on patients. The 11th set was for background and transportation dose assessment. The participating countries were advised the doses given to first 7 chip sets at the time of the irradiations, and at a later date for the sets 8, 9 & 10. Once the TLDs were irradiated, they were returned to the respective countries.

Table I-3 gives details of the irradiation conditions for the eastern European and African participants in the two calibration and intercomparison exercises.

TABLE I-3. IRRADIATION CONDITIONS FOR CALIBRATION AND INTERCOMPARISON OF THE TLD SYSTEMS OF THE PARTICIPATING COUNTRIES IN EASTERN EUROPE AND AFRICA

Chip set	kVp	Filtration mmAl	HVL mm Al	keV	Nominal Dose (mGy)
1	60	2.0	1.75	26.8	10
2	80	3.0	2.95	32.8	50
3	80	3.0	2.95	32.8	10
4	80	3.0	2.95	32.8	5
5	80	3.0	2.95	32.8	0,1
6	135	1.0+ 0.2Cu	0.425 Cu	57.0	10
7	^{137}Cs			660	10
8	60	2.0	1.75	26.8	2
9	80	3.0	2.95	32.8	20
10	100	0.15 Cu	0.20 Cu	43.0	15

Table I-4 presents the coefficients of variation for the calibration exposures. The dosimetric systems used were able to measure doses at the 50 mGy level with a coefficient of variation in the range 2–8%, as assessed in the first calibration exercise, with this range being reduced to 1–4% by the second calibration. For a 5 mGy dose, the respective coefficients of variation were 1–10% and 3–6%, and for the 0.1–0.2 mGy dose range, 2–50% and 2–7%. At the outset of the programme a performance requirement was a coefficient of variation of less than 30% at dose levels of 0.1 mGy.

TABLE I-4. CHARACTERISTICS OF TLD SYSTEMS EVALUATED DURING THE CALIBRATIONS

Coefficient of variation (%) of TLD readings at doses of:	China	Czech Republic	India	Indonesia	Malaysia	Thailand	Vietnam	Average over all countries
50 mGy -1st cal	2.5	3.1	2.5	4.0	3.5	3.3	7.4	3.8
50 mGy -2nd cal	1.1	2.7	2.7	2.8	6.0	3.3	3.8	3.2
5 mGy -1st cal	3.5	3.9	10.0	5.2	3.4	2.8	0.7	4.2
5 mGy -2nd cal	2.8	4.3	4.7	3.0	4.9	2.9	5.8	4.0
0.1 mGy -1st cal	4.5	5.6	52.1	12.9	6.1	1.5	10.5	13.3
0.2 mGy -2nd cal	5.2	5.2	3.8	2.0	3.1	5.3	7.4	4.6

The results from the two intercomparisons are given in Tables I-5 and I-6 below. In each case the estimate of the dose is given for each country, together with the uncertainty (at the 95% level) based on an analysis of the raw TLD readings for each country.

TABLE I-5. TLD INTERCOMPARISON RESULTS, 1ST EXERCISE

	Actual dose (mGy)	Uncertainty in estimate	Actual dose (mGy)	Uncertainty in estimate	Actual dose (mGy)	Uncertainty in estimate
	4.23	±%	25.6	±%	2.26	±%
China	4.41	4.9	24.7	3.5	2.26	4.2
India**	4.16	13.1	26.8	2.6	2.54	18.2
Indonesia 1	4.39	6.8	25.2	3.5	2.32	6.3
Indonesia 2*	3.88	10.9	24.5	5.5	2.09	13.3
Malaysia	7.66	24.1	26.1	5.7	2.00	7.7
Thailand			26.8	4.0	2.13	4.8
Vietnam	4.28	6.1	26.5	9.0	2.26	4.8
	2.0		19.9		15.0	
Czech Rep.	2.14	4.8	20.0	2.7	15.2	2.3

* Doses were 4.20, 25.8 & 2.25 mGy.

** Doses were 4.21, 25.4 & 2.33 mGy.

TABLE I-6. TLD INTERCOMPARISON RESULTS, 2ND EXERCISE

	Actual dose (mGy)	Uncertainty in estimate	Actual dose (mGy)	Uncertainty in estimate	Actual dose (mGy)	Uncertainty in estimate
	4.59	±%	25.1	±%	35.8	±%
China	4.52	4.2	24.1	1.5	34.3	3.5
India	4.72	1.6	24.9	3.5	36.4	6.9
Indonesia	4.62	3.1	24.4	5.1	34.2	4.6
Malaysia	4.37	9.0	25.1	9.0	35.1	8.2
Thailand	4.98	6.9	25.8	3.9	37.0	3.5
Vietnam	4.44	7.5	24.7	6.5	35.8	2.6
	2.0		20.0		15.0	
Czech Rep.	2.14	4.9	21.6	2.8	15.0	2.5

ANNEX II

DIAGNOSTIC GUIDANCE LEVELS FROM THE BASIC SAFETY STANDARDS (BSS)

TABLE II-1. GUIDANCE LEVELS OF DOSE FOR DIAGNOSTIC RADIOGRAPHY FOR A TYPICAL ADULT PATIENT

Examination	Entrance surface dose per radiograph[a] (mGy)	
Lumbar spine	AP	10
	LAT	30
	LSJ	40
Abdomen, intravenous urography and cholecystography	AP	10
Pelvis	AP	10
Hip joint	AP	10
Chest	PA	0.4
	LAT	1.5
Thoracic spine	AP	7
	LAT	20
Dental	Periapical	7
	AP	5
Skull	PA	5
	LAT	3

PA: posterior-anterior projection; LAT: lateral projection; LSJ: lumbo-sacral-joint projection; AP: anterior-posterior projection.

[a] In air with backscatter. These values are for conventional film-screen combination in the relative speed of 200. For high-speed film-screen combinations (400-600), the values should be reduced by a factor of 2 to 3.

TABLE II-2. DOSE GUIDANCE LEVELS FOR COMPUTED TOMOGRAPHY FOR A TYPICAL ADULT PATIENT

Examination	Multiple scan average dose[a] (mGy)
Head	50
Lumbar spine	35
Abdomen	25

[a] Derived from measurements on the axis of rotation in water equivalent phantoms, 15 cm in length and 16 cm (head) and 30 cm (lumbar spine and abdomen) in diameter.

TABLE II-3. DOSE RATE GUIDANCE LEVELS FOR FLUOROSCOPY FOR A TYPICAL ADULT PATIENT

Mode of operation	Entrance surface dose rate[a] (mGy/min)
Normal	25
High level[b]	100

[a] In air with backscatter.

[b] For fluoroscopes that have an optional 'high level' operational mode, such as those frequently used in interventional radiology.

ANNEX III

ADDITIONAL COUNTRY DATA

This Annex provides the following information for the participating countries:

- Persons involved in the project
- Hospitals that participated
- Radiographic equipment details
- Fluoroscopic equipment details
- CT details.

Country: China

Chief investigator: Wei Kedao

Research team: Zhou Qipu
Yue Baorong
Cheng Yuxi
Wang Zuoling
Ge Lijuan
Hou Changsong
Qi Xuesong

Institutions: Laboratory of Industrial Hygiene, Ministry of Health, 100088 Beijing

Names of Hospitals: The First Teaching Hospital, Beijing Medical University (A)
The People's Hospital, Beijing Medical University (B)
The Third Teaching Hospital, Beijing Medical University (C)
The Sino-Japanese Friendship Hospital (D)
Beijing Xuanwu Chinese Medicine Hospital (E)
Beijing Anzhen Hospital (F)
Shenzhen People's Hospital (G)
Beijing No. 262 Hospital (H)
Beijing Dewai Hospital (I)

Radiology staff involved in the programme:

Xuexiang Jiang
Zhenming Zhao
Xuechang Cai
Huisheng Zhou
Yunsheng Shi
Lianghou Liu
Jun Zhao
Yongmei Wang
Yisheng Wang

TABLE III-1. CHINA: CHARACTERISTICS OF THERADIOGRAPHIC X RAY EQUIPMENT

Hospital	X ray room	X ray unit					Processor	
		Type	Installation date	Generator (pulses)	Total filtration (mm Al)	Focus spot size (mm) small/large	Type	Installation date
A	1	Shimadzu	1994	3 phase	3.5	1.0/2.0	Kodak	1992
	2	CGR	1985	3 phase	2.2	1.0/2.0		
B	1	Shimadzu	1973	3 phase	2.5	0.5/1.0	Kodak	1993
	2	Siemens	1991	3 phase	2.0	0.6/1.0		
C	1	GE	1986	3 phase	3.0	0.6/2.5	Kodak	1992
	2	GE	1986	3 phase	3.0	0.6/1.0		
D	1	Toshiba	1984	3 phase	2.9	0.6/1.3	Kodak	1991
	2	Toshiba	1984	3 phase	2.9	0.6/1.3		

TABLE III-2. CHINA: CHARACTERISTICS OF THE FLUOROSCOPY EQUIPMENT

Hospital	X ray room	X ray system				
		Model	Installation date	Type of system	Nominal II field sizes (cm)	Age of II (y)
A	1	Shimadzu	1992	RCT	23, 30	6
	2	Toshiba	1984	RCT	23	14
	3	China	1994	RCT	23	4
	4	Siemens	1989	C-arm	13, 17, 30	3
	5	Shimadzu	1990	RCT	23	8
	6	Shimadzu	1994	RCT	23	4
	7	CGR	1985	RCT	23	13
B	1	Toshiba	31991	RCT	23	7
	2	Shimadzu	1996	RCT	23, 30	2
	3	Philips	1997	C-arm	17, 25, 38	1
	4	Shimadzu	1996	RCT	23	2
	5	Shimadzu	1985	RCT	23	13
H	1	Toshiba	1996	RCT	23	2
	2	Toshiba	1996	C-arm	15, 23, 30	2
	3	Beijing	1980	DV	none	-
I	1	Shimadzu	1995	RCT	23	3

RCT = remote control table DV = direct viewing (no image intensifier)

TABLE III-3. CHINA: CHARACTERISTICS OF THE CT UNITS

Hospital	X ray unit			
	Model	Installation date	Date last calibration/ maintenance	Examinations/year
E	GE Pace	1996	1997	2000
F	Picker 1200SX	1994	—	4500
G	Siemens ART	1993	—	7500

Country: Czech Republic

Chief investigator:	Ivana Zachariasova
Research team:	Dusan Olegar Hana Podskubkova Otokar Vojtisek Dana Kroutilikava Josef Pacholik
Institutions:	National Radiation Prorection Institute, Prague VMK, Prague
Name of Hospitals:	Ceske Budejovice Pod Petrinem Na Frantisku Brandys Chomutov Kladno Pisek Na Homolce Motol Brno Sternberk Hradec Kralove Rymarov Pisek Cesky Krumlov Plzen FN Kral Vin Horovice Jablonec

Radiology staff involved in the programme:

D. Kasalova
J. Hyka
P. Dobisek
P. Codl
K. Hejny
L. Petr

TABLE III-4. CZECH REPUBLIC: CHARACTERISTICS OF THE RADIOGRAPHIC X RAY EQUIPMENT

Hospital	X ray room	X ray unit					Processor	
		Type	Installation date	Generator (pulses)	Total filtration (mm Al)	Focus spot size (mm) small/large	Type	Installation date
CB	1	Chiralux 2	1984	2	3	1.2/2	Compact 45	89
CB	2	Multipuls MP 15	1988	12	3	0.8/1.0	Compact 45	89
P	2	Multipuls MP 15	1989	12	3	0.8/1.0	Compact 45	91
NF	2	Multipuls MP 15	1991	12	3	0.9/1.0	Type 902	88

TABLE III-5. CZECH REPUBLIC: CHARACTERISTICS OF THE FLUOROSCOPY EQUIPMENT

Hospital	X ray system				
	Model	Installation date	Type of system	II field sizes (cm)	Age of II (y)
Bs	Chiralux 2	1997	Remote control table	27/17	2
Ch	Euraskop 3A	1998	Remote control table	27/17	1
Kl	Chiroskop	1975	Remote control table	27/17	24
Pi	Chiralux	1984	Remote control table	27/17	15
NH	GE Advantx-LC LFX	1997	Angiography	27/23/17	2
Mo	Toshiba Angiorex Super DF	1997	Angiography	30/23/17/12 (front) 23/17/12 (lat)	2
Br	Siemens Angiostar	1997	Angiography	30/23/17	2
St	APX HF II	1997	C-arm	23/16/11	2
HK	APX HF II	1997	C-arm	23/16/11	2
R	Multidigit	1997	C-arm	23/17/13	2
Pi	SK 7-3	1998	C-arm	15	1
CK	Operdigit	1997	C-arm	23/17/13	2

TABLE III-6. CZECH REPUBLIC: CHARACTERISTICS OF THE CT UNITS

Hospital	X ray unit			
	Model	Installation date	Calibration/maintenance	Examination/year
Mo	Elscint CT Twin	1996		6300
Pl	Elscint CT Twin II	1995		6500
FKV	Elscint Helicat II	1998		na yet
Ho	Elscint Select	1997		2600
J	Elscint Helicat II	1997		2700

Country: India

Chief investigator: M. Berry

Research team: M.M. Rehani
V. Choudhary
Sudha Suri

Institutions/Hospitals: All India Institute of Medical Sciences, New Delhi
Lok Nayak Jai Prakash Narain Hospital, New Delhi
University College of Medical Sciences, Delhi
Post Graduate Institute of Medical Education and Research, Chandigarh

Radiology staff involved in the programme: as above

TABLE III-7. INDIA: CHARACTERISTICS OF THE RADIOGRAPHIC X RAY EQUIPMENT

Hospital	X ray room	X ray unit				Processor	
		Type	Installation date	Generator (pulses)	Total filtration (mm Al)	Type	Installation date
AIIMS	84(I)	Siemens Tridoros 6R	1994	6	3.0	Kodak M-35	1993
AIIMS	84(II)	Siemens Tridoros 6R	1988	6	3.5	45-Compact Protec	1995
AIIMS	60	Siemens Polymat-501	1997	CP	2.2	45-Compact Protec	1994
AIIMS	61	Siemens Tridoros 6R	1978	6	3.5	2-Compact Protec	1997
LNJP	136	Pleophos D	1986	2	3.5	Compact 35 Max India	1996
LNJP	132C	Genius	1992	6	3.0		
LNJP	132	SRD 300	1985	6	2.5		
LNJP	126	Siemens Tridoros 6R	1995	6	3.5		
UCMS	1001	Wipro GE MST 1025	-	12	2.5	Manual	1985
UCMS	1011	Siemens Polydoros 505	-	CP	2.5	Manual	1987
PGI	4	Siemens Tridoros 6R	1984	6	3.0	Doosan	1987
PGI	6	MST 1025	1985	12	2.5		
PGI	8	Philips	1995	MF	2.5		

TABLE III-8. INDIA: CHARACTERISTICS OF THE FLUOROSCOPY EQUIPMENT

Hospital	X ray room	X ray system				
		Model	Installation date	Type of system	Max nominal I.I field size (cm)	Age of II (y)
AIIMS	44	Siemens Explorator 351	1993	Undercouch tube	35	5
AIIMS	80	Siemens Polystar	1992	C-arm, angiographic	40	6
AIIMS	75	Philips Diagnost 76 Plus	1992	Undercouch tube	23	5
AIIMS	39	Siemens Sireskop CX	1996	U-arm		1.5
UCMS	35	Siemens	1987	Undercouch tube	23	11
PGI	2	Siemens	1977		23	21
PGI	20	Siemens	1984		23	14

TABLE III-9. INDIA: CHARACTERISTICS OF THE CT UNITS

Hospital	X ray room	X ray unit			
		Model	Installation date	Date last calibration/maintenance	Examinations/year
AIIMS	8	Siemens Somatom Plus 4	1997	Every month	5500
PGI	12	Siemens Somatom HiQ	1993		4100

Country: Indonesia

Chief investigator: Nasukha

Research team: M. Fathony
Nurul Hayati, MD
Diah Dwi K.
Helfi Yuliati
Suyati

Institutions: Clinical Dosimetry Group, Centre for Standardisation and Radiation Safety Research (PSPKR)
National Atomic Energy Agency of Indonesia

Name of hospital(s): Cipto Mangunkusumo Hospital

Pelni Petamburan Hospital

Radiology staff involved in the pilot programme:

R. Soekonto, MD (Radiologist)
Rien Yuniantari, MD (Radiologist)
Kahar Kusumawijaya, MD (Radiologist)
M. Ilyas, MD (Radiologist)
Eddy R. Iskandar
Iwan Ridwan
Apud Kusairi

TABLE III-9. INDONESIA: CHARACTERISTICS OF THE RADIOGRAPHIC X RAY EQUIPMENT

Hospital	X ray room	X ray unit					Processor	
		Type	Installation date	Generator (pulses)	Total filtration (mm Al)	Focus spot size (mm) small/large	Type	Installation date
A	1A	Philips Super M80	1978	12	2.5	0.3/0.6	Agfa Curix 400	1995
A	1B	Shimadzu	1993	12	2.5	0.6/1.2		
A	11	Philips Super M80	1978	12	2.5	0.6/1.0		
B	1	Siemens	1960	6	2.6		Fuji FPM 2100	1993
B	2	Philips Super M70	1978	6	2.3	1.2/2.0		

TABLE III-10. INDONESIA: CHARACTERISTICS OF THE FLUOROSCOPY EQUIPMENT

Hospital	X ray room	X ray system				
		Make	Installation date	Model of II	Nominal I.I field sizes (cm)	Age of II (y)
C	5	Siemens	1992	Optilux	23	6
C	3	Trophy	1994	N600HF/R301MLP	23	4
C	9	Shimadzu	1992	IA-9VS11	23	6
C	Angio	Toshiba KXO2050	1995		30	3
P	4	Siemens	1991	Optilux	23	7
D	Endo	Toshiba	1992	TF-6TL-6	23	6
D	Gastro 1	Toshiba	1992	TF-6TL-6	23	6
D	Gastro 2	Toshiba	1992	TF-6TL-6	23	6
D	Uro	Siemens	1992		23	6
D	Mobile	Toshiba	1992	SXT-650	15	6
D	Mobile	Toshiba	1992	SXT-650	15	6
D	Angio	Toshiba	1992	TF-UA-2L	30	6

Country: Pakistan

Chief investigator:	Mumtaz-Ul-Haq
Research team:	Umar Hayat Khan Munawar Hussain Shah Zia Farooqi Abdul Rahim Amjad Waheed Rashid Najeeb
Institutions:	Institute of Nuclear Medicine and Oncology, Lahore
Name of hospital(s):	Sheikh Zaid Hospital, Lahore Shaukat Khanum Memorial Cancer and Research Centre, Lahore Jinnah Hospital, Lahore

Radiology staff involved in the pilot programme:

Mahmood Bhatti
Unzar Fatima
Sarfraz Danial
Shehzad
Qamar Majeed
Parveez Akhtar
Najam
Shamma Murad
Haroon
Farhan

TABLE III-11. PAKISTAN: CHARACTERISTICS OF THE RADIOGRAPHIC X RAY EQUIPMENT

Hospital	X ray room	X ray unit				Processor	
		Type	Installation date	Generator (pulses)	Focus spot size (mm) small/large	Type	Installation date
A	1	Hitachi Z6-S2	1987	2	1/2	Agfa Gevart	1987
A	ID	Toshiba DRX-61	1987	2	0.8/1.8		
B	4	Siemens	1985	2	1	Gevamatic-60	1985
B	OD	Siemens Tridoros 512MP	1985	12			
C	RF1	Siemens		2	0.6/11	Kodak Ka-270	
C	RF2	Siemens		2			
D	6	Dong Fang		2	3.2	Manual	
D	7	Shimadzu ED150L		2	0.6/1.2	Manual	

Country: Malaysia

Chief investigator:	Ng Kwan Hoong
Research team:	Wang Hwee Beng Premavathy Rassiah Pirunthavany Muthuvelu Ahmad Sharif Hambali
Institutions:	University of Malaya, Kuala Lumpur Ministry of Health, Malaysia
Name of hospital(s):	University Hospital, Kuala Lumpur Klang General Hospital Ipoh General Hospital Subang Jaya Medical centre

Radiology staff involved in the programme:

Basri Johan Jeet Abdullah
Arif
Ong Teong Oon
Leelavathy
Lee Ho Peng

TABLE III-12. MALAYSIA: CHARACTERISTICS OF THE RADIOGRAPHIC X RAY EQUIPMENT

Hospital	X ray room	X ray unit				Processor
		Type	Generator (pulses)	Total filtration (mm Al)	Focus spot size (mm) small/large	Type
U	1	GE MPG 80	CP	2.6	0.6/1.2	Kodak M6B
U	2	Philips Super 80CP	CP	2.5	0.6/1.3	
K	1	Philips DR 3T/1000	12-P	2.5	0.6/1.3	Agfa Curix 400
K	2	Philips DR 3T/1000	12-P	2.5	0.6/1.3	
I	1	Philips Super 50CP	CP	2.7	0.6/1.3	Alphatex AX 700
I	4	Philips Super 50CP	CP	2.7	0.6/1.3	
S	OP	Philips Medio CPH	CP	2.7	0.6/1.2	Fuji FPM 3000

TABLE III-13. MALAYSIA: CHARACTERISTICS OF THE FLUOROSCOPY EQUIPMENT

Hospital	X ray room	X ray system		
		Model	Installation date	Type of system
U	B1	GE Legacy Advantx	1997	undercouch tube
U	B2	Toshiba DTS-KDU	1987	undercouch tube
S	1	Shimadzu PS9	1994	undercouch tube

TABLE III-14. MALAYSIA: CHARACTERISTICS OF THE CT UNITS

Hospital	X ray room	X ray unit			
		Model	Installation date	Date last calibration/maintenance	Examination/year
U	C1	Siemens Plus 2	1995	Every 3 months	3300
U	C5	GE 9800	1987	Every 3 months	3500
K	1	Siemens Plus 4	1998	Every 3 months	660

Country: Morocco

Chief investigator: M. L. Yousfi Charif

Research team: Aicha Moustatia
Mohamed Ennhkhla

Institutions: Centre National de Radioprotection

Name of Hospitals: Institut d'Oncologie
Hôpital de Spécialités
Hôpital Averroes

Radiology staff involved in the programme:

M. Boujida
M. Hmamouchi

TABLE III-15. MOROCCO: CHARACTERISTICS OF THE RADIOGRAPHIC X RAY EQUIPMENT

Hospital	X ray room	X ray unit
		Type
I d'O	2	Philips
I d'O	3	Philips
H de S	2	Statorix
H de S	4	Philips
H de S	6	Philips
HA	8	Philips
HA	9	CGR
HA	10	Philips

TABLE III-16. MOROCCO: CHARACTERISTICS OF THE FLUOROSCOPY EQUIPMENT

Hospital	X ray system	
	Model	Installation date
H de S	CGR	1994
H de S	CGR	1994
H de S	CGR	1994
I d'O	Philips	1985
I d'O	CGR	1986

TABLE III-17. MOROCCO: CHARACTERISTICS OF THE CT UNITS

Hospital	X ray unit			
	Model	Installation date	Date last calibration/maintenance	Examinations/year
I d'O	Siemens Somatom AR	1993	Every month	3600
HA	Siemens Somatom	1992	Every month	3000
H de S	Siemens Somatom	1990	Every month	4000

Country: Romania

Chief investigator:	C. Milu
Research team:	V. C. Tomulescu A. Sorescu O. Iacob S. Ramboiu A. Paraschivescu M. Ifrim
Institutions:	Institute of Public Health, Bucharest Institute of Public Health, Iassy Institute of Public Health, Cluj-Napoca
Name of Hospitals:	Fundeni Hospital, Bucharest Coltea Hospital, Bucharest St Spiridon Hospital, Iassy Clujana Hospital, Cluj-Napoca Brasov Hospital Elias Hospital Municipal Hospital

Radiology staff involved in the programme:

S. Georgescu
N. Zaharia
M. Lesaru
B. Olteanu
B. Enachescu
M. Vladareanu
T. Kiss
F. Crumpei
T. Bostaca
L. Paduraru

TABLE III-18. ROMANIA: CHARACTERISTICS OF THE RADIOGRAPHIC X RAY EQUIPMENT

Hospital	X ray room	X ray unit					Processor	
		Type	Installation date	Generator (pulses)	Total filtration (mm Al)	Focus spot size (mm) small/large	Type	Installation date
F	1	Eltex - 400	1982	2	2.5	1.2/1.8	Agfa Curix 60	1994
F	2	Siemens	1995	12	> 2	0.6/1.0	Agfa Curix 160	1996
C	3	Eltex - 400	1980	2	> 2	1.2/1.8	Manual	
C	4	Eltex - 400	1979	2	> 2	1.2/1.8	Agfa Curix 160	1996
St S	5	Eltex - 400	1971	2	> 2	1.2/1.8	Manual	
St S	6	Diagnomax M-125	1972	2	> 2	1.8	Manual	
Cl	7	Neo Diagnomax	1978	2	> 3	1.2	Manual	
Cl	8	TUR D800	1977	12	> 3	1.2	Manual	

TABLE III-19. ROMANIA: CHARACTERISTICS OF THE FLUOROSCOPY EQUIPMENT

Hospital	X ray system			
	Model	Installation date	Nominal I.I field sizes (cm)	Age of II (y)
F	Eltex	1982		
F	Sireskop	1995	23	3
C	Sireskop	1996	23	2
C	Eltex	1975	23	11
StS	Eltex	1971		
StS	Diagnomax	1972		
Cl	Diagnomax	1978		
Cl	TUR	1977		
B	TUR	1976		
B	Siemens	1979		
E	Siemens	1994	17	4
E	Siemens	1997	17	1
M	Siemens	1996	23	2
M	Siemens	1982	23	8
M	Eltex	1978	23	2

TABLE III-20. ROMANIA: CHARACTERISTICS OF THE CT UNITS

Hospital	X ray unit		
	Model	Installation date	Examination/year
U	Siemens Somatom Plus D	1995	10 400
E	Siemens Somatom HiQ	1990	3 100
F	Siemens Somatom Plus	1995	4 300

Country: Thailand

Chief investigator: Jongjin Pataramontree

Research team: Somjai Wangsuphachart
Jajaval Apaiphonlacharn
Pannee Chaichan

Institutions: Department of Radiology, Chulalongkorn Hospital

Name of Hospitals: University Hospital - Chulalongkorn Hospital
University Hospital - Ramathibodi Hospital
University Hospital - Siriraj Hospital
City Hospital - Nakornpathom Hospital

Radiology staff involved in the programme:

Somjai Wangsuphachart
Rames Wacharasin
Saroj Vanapruks
Anchalee Churojana
Panumas Leungphaibul
Ekaraj Rongsirikul
Puangtong Kraipibul
Waragorn Yapao
Uraiwan Leksakulchai
Mantana Niratsai
Manee Aimachariyachai
Chanok Phopuet
Supawadee Karuwanarint
Venus Wisetsang
Danai Leelasomsiri
Saly Wongyara
Wiwich Thamwerawong

TABLE III-21. THAILAND: CHARACTERISTICS OF THE RADIOGRAPHIC X RAY EQUIPMENT

Hospital	X ray room	X ray unit					Processor	
		Type	Installation date	Generator (pulses)	Total filtration (mm Al)	Focus spot size (mm) small/large	Type	Installation date
C	4	Hitachi DR-155D	1989	2	2.3	1/1.8	Kodak M6	89
C	5	Hitachi DR-155D	1989	2	2.6	1/1.8		
C	Villa	Villa Genius 30HF	1989	12	3.4	0.6/1.2		
N	1	Shimadzu	1976	2	3.0	1.5/2.0	Agfa Curix	85
N	2	Shimadzu	1985	12	3.0	0.9/1.3		
R	4	Siemens Polyphos 50	1990	12	3.0	0.8/1.2	Kodak M6B	90
R	7	Philips Medio 65CP-H	1994	12	2.7	0.6/1.3	Kodak M8	90
S	228	Shimadzu	1983	12	2.9	0.6/1.3	Kodak M6	83
S	235	GE	1979	2	2.8	-/2.0		

TABLE III-22. THAILAND: CHARACTERISTICS OF THE FLUOROSCOPY EQUIPMENT

Hospital	X ray room	X ray system							
		Model	Installation date	Type of system	Model of II	Nominal I.I field sizes (cm)	Model of TV camera	Operating mode	Age of II (y)
C	1	Siemens Sireskop SX	1998	Remote table, undercouch tube	Sirecon 33-4 HDR	33, 22, 17, 13	Videomed Sx	Auto kV, auto mA	new
C	2	Toshiba KXO-80N	1997	Remote table, overcouch tube	Toshiba RTP 14301 H-G1E	35, 25, 18	CCD model MTV 500 A/XL	Auto kV, auto mA	1 year
C	SL-R	Shimadzu IDR 700	1997	Undercouch tube	Shimadzu IA-16VMA11	41, 31, 23, 15	CCD model SF-3000SD	Auto kV, auto mA	1 year
C	SL-L	Shimadzu UD150L-10	1993	Undercouch tube	Shimadzu IA-9VS11	23	Chalnican XT 3000SC	Auto kV, auto mA	5 years
N	3	Shimadzu	1992	Undercouch tube	Shimadzu IA-9VS4		Unknown	Auto kV, auto mA	6 years
R	10	Philips Super 80CP, Multi Diagnost 3	1995	Angiography, C-arm	Philips	38, 25, 17	Plumbicon	Auto kV, auto mA	3 years
R	14	Siemens Polydoros 80, Angioskop D33	1989	Angiography, C-arm	Siemens	33, 23, 17	Vidicon	Auto kV, auto mA	9 years
R	15	Toshiba KXO-80G	1995	Undercouch tube	Toshiba	35, 25, 15	Saticon	Auto kV, auto mA	3 years
S	231	GE Advantx SFX 30/8735	1994	Undercouch tube	GE	23, 15, 12	GE	Auto kV, auto mA	4 years

Hospital	X ray room	X ray system							
		Model	Installation date	Type of system	Model of II	Nominal I.I field sizes (cm)	Model of TV camera	Operating mode	Age of II (y)
S	233	Acoma UNI 500	1989	Undercouch tube		14	Acoma 12M30BA	Auto kV, auto mA	9 years
S	235	Philips Diagnost 76 plus	1998	Undercouch tube		36, 25, 17	Philips XTV 11S	Auto kV, auto mA	new
S	2	Toshiba KXO-15	1993	Undercouch tube	Toscope 204	23, 18, 15	Unknown	Auto kV, auto mA	

TABLE III-23. THAILAND: CHARACTERISTICS OF THE CT UNITS

Hospital	X ray room	X ray unit			
		Model	Installation date	Date last calibration/maintenance	Examinations/year
C	CT 2	GE Sytec 4000	1993	Every 3 months	3870
R	CT	GE 9800 Quick	1987	Every month	2400
S	CT1	Philips Tomoscan CX/Q	1993	May 1998	3000-3500

Country: Vietnam

Chief investigator: Dang Thanh Luong

Research team: Pham Quang Dien
Nguyen Phuong Dung
Nguyen Hao Quang
Ha Ngoc Thach
Tran Ngoc Toan
Phan Thi Tuong Van
Duong Van Vinh

Institutions: Vietnam Atomic Energy Commission

Institute for Nuclear Sciences and Techniques

Name of Hospitals: Hospital K
Hospital Viet Duc
Hospital Tran Hung Dao
Hospital Bach Mai
Hospital Traditional Medicine
Hospital Centre Ophthalmic
Hospital 198

Radiology staff involved in the programme:

Nguyen van Hach
Toan
Hoang van To
Tran Duc Thien
Nguyen Dinh Tuan
Nguyen Manh Truong
Nguyen Manh Phuc
Nguyen Van Sang
Tran Quang Viep
Hoang Ky
Pham Ngoc Hung
Kieu Duc Hung

TABLE III-24. VIETNAM: CHARACTERISTICS OF THE RADIOGRAPHIC X RAY EQUIPMENT

Hospital	X ray unit			Processor	
	Type	Installation date	Generator (pulses)	Type	Installation date
K	Neo Diagnomax	> 15 years	2	Agfa Curix 60	1995
K	Trophy N800HF	1995	CP		
VD	BT20-XG125	1995	2	Kodak RP-XOmat	1995
VD	Trophy N800HF	1995	CP		
THD	RYM 20	> 20 years	2	Manual	
THD	Mediront	> 20 years	1	Manual	
THD	TUR-D351	1991	2	Manual	
THD	Tanka RC-1100	> 20 years	2	Manual	
THD	TUR-1001	> 20 years	6	Manual	

TABLE III-25. VIETNAM: CHARACTERISTICS OF THE FLUOROSCOPY EQUIPMENT

Hospital	X ray system			
	Model	Installation date	Nominal I.I field sizes (cm)	Age of II (y)
1	TUR D 351	1980	18	19
1	Shimadzu Digitex 2400 UX	1994	21	5
1	Picker	1980	18	19
2	Trophy N500HF	1995	18	4
3	Shimadzu	1996	18	3
3	Shimadzu	1996	18	3
3	Shimadzu	1997	18	2
3	Elemma Treplex	1974	18	>19
4	TFX15 GE	1995	18	4
5	Shimadzu	1997	18	2

TABLE III-26. VIETNAM: CHARACTERISTICS OF THE CT UNITS (1999)

Hospital	X ray unit			
	Model	Installation date	Date last calibration/ maintenance	Examinations/year
1	Siemens Somatom AR T	1994	1997	2000
3	GE Sytec 4000i	1995	1997	3000
5	GE Prospeed S Fast	1997	1998	1000

CONTRIBUTORS TO DRAFTING AND REVIEW

LeHeron, J.	National Radiation Laboratory, New Zealand
Maccia, C.	Centre d'Assurance de Qualité des Applications Technologiques dans le Domaine de la Santé, France
Oresegun, M.	International Atomic Energy Agency
Ortiz López, P.	International Atomic Energy Agency
Padovani, R.	Hospédale S. Maria della Misericordia, Italy
Pernička, F.	International Atomic Energy Agency
Rehani, M.M.	International Atomic Energy Agency
Vañó Carruana, E.	Universidad Complutense de Madrid, Spain

Consultants Meetings

Vienna, Austria: 4–8 September 1995
Manila, Philippines: 8–12 September 1995
Udine, Italy: 10–14 February 1997
Kuala Lumpur, Malaysia: 3–7 March 1997