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Image Quality Criteria Status of the CEC Project

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ABSTRACT

Since well established conventional x-ray techniques significantly contribute to the total effective dose equivalent that an average individual may annually receive from all man-made radiation sources, a Study Group of the Radiation Protection Programme of the C.E.C. took the initiative of setting up a project which aimed at optimizing both radiographic diagnostic information and patient exposure.

In this context a trial was conducted on about 900 patients examined at 17 different European x-ray departments and data were gathered on the following six common types of x-ray examination : chest, breast, lumbar spine, pelvis and sacrum, skull and urinary tract.

This paper will present the main results obtained in this trial.

Findings of the radiological techniques used in performing these examinations throughout 10 European countries as well as of the entrance skin doses directly measured on the patient will be analyzed.

On the basis of a "medical scoring system" defined by a group of radiologists, each radiographic projection will be assessed in order to approach the "most efficient" way of performing the examination.

This will be carried out taking into account the most relevant physical parameters which may affect the patient's received dose (kV, automatic exposure control system film-screen combinations ....), as well as the quality of the radiographic image.

INTRODUCTION

In 1987 a Study Group of the Radiation Protection Programme of the Commission of the European Communities (CEC), initiated a project on the establishment of quality criteria for diagnostic radiographic images.
The main goal of this project was to provide practitioners with a provisional acceptable list of both radiological and technical requirements (including dose values) which could be useful to judge the quality of the radiographs routinely undertaken in diagnostic radiology while keeping the patient received dose as low as reasonably achievable. Through this project, the existing exposure ranges which have been described by several authors (Maccia et al, 1988; Padovani et al, 1987; Shrimpton et al, 1986), would be restricted without limiting the choice of the radiological technique.
Since conventional x-ray techniques significantly contribute to the total effective dose equivalent that an average individual may annually receive from other man-made radiation sources, the project was orientated towards only those examinations which are still commonly and frequently carried out in every day radiological practice: chest, skull, lumbar spine, pelvis and sacrum, urinary tract, breast.
In order to evaluate the suitability of the requirements listed in a draft-document of the CEC, the Group set up a trial which collected information on more than 900 x-ray examinations performed in 10 European countries. A questionnaire has therefore been circulated to 24 different European x-ray departments which have activily participated in the project by checking, for each examination type, the suggested image quality criteria and commenting on their relevance.
This is believed to be the first time that a trial of this type, involving at the same time radiologists and physicists, and using the same approach, has been carried out in so many different practicing radiology countries.

Material and Method

From the methodological point of view, two main problems were to be solved in structuring the questionnaire.
The first one dealt with the definition of an acceptable list of radiological requirements which refer, for each projection of each examination type, to important characteristic features of the "normal" radiographic image. This first task implicitly required that all CEC Study Group radiologist members

agreed, besides any abnormality or pathology, upon the anatomical patterns that should be visible on a given radiograph.

This very positive and fruitful exercice revealed, on one side, the necessity of harmonizing the European radiological terminology and, on the other side, pointed out differences existing in the radiology schools in describing, in a very simple manner, what kind of information a "normal" x-ray film must contain.

Concerning requirements of important image details, the questionnaire was limited to provide the dimensions of specific normal and abnormal structures projected on the film or image receptor. This specific point has been further developed by Stieve (Stieve, 1988).

The second important problem was to find out a relevant dose quantity which could be easily measured on a patient undergoing an x-ray examination and, at the same time, could be useful to check the compliance with the quality criteria for diagnostic radiographic images listed in the questionnaire.

The suggested quantity was the "Entrance Surface Dose" (ESD) which has already been demonstrated to be a rather appropriate indicator of the relative risk for the examined patients. It was therefore decided to collect this kind of information using thermoluminescent dosimeter chips stuck on the x-rayed patient's skin.

Three European dosimetry laboratories namely the NRPB (U.K.), the GSF (F.R.G.) and the USL n°7 in Udine (I) were strongly involved in this part of the trial which needed to handle and read out thousands of dosimeters sent throughout Europe. In order to achieve this step, a preliminary dosimetry intercomparison between the mentioned laboratories was made to ensure reliability of measurements.

Finally, patient dose data and completed questionnaires were collected and centralised at the CEPN (F) for the evaluation of the trial.

Results

1. General statistics.

Despite the rather complex management problems, the trial was successfully completed and a satisfactory number of questionnaires was collected for each x-ray examination category considered. Table I, hereafter, summarizes the actual number of patients for whom both quality image criteria and doses were recorded in the questionnaires and gives the number of x-ray departments that participated.

More detailed data are also presented in Table II for each projection type of each examination. First of all, one may notice the reject rate values which compare well with those generally found in the literature (Belletti et al, 1985). It can be, therefore, deduced that there was no bias associated with the trial, either in terms of excessive attention paid by radiographers in performing the examinations, or in terms of particular severity required by radiologists for the quality of radiographic images. This encouraging finding, nevertheless, raises the more general problem of the reject rate level which should always be kept as low as possible in diagnostic radiology to limit unnecessary patient exposures.

Concerning the percentage of radiographs having met all diagnostic criteria, the observed values clearly show that there were no particular projections for which the criteria were too difficult to meet. It might be argued that, considering the resulting average figure, all examinations together (72%), the criteria were more restrictive than the implicit ones spontaneously used by radiologists to judge the quality of the radiographic image as expressed by the reject rate figures. There is, therefore, no evident correlation between image criteria relevance and image quality .

On the other hand, if one excludes the breast examination, for which the provisional CEC dose requirement was probably too restrictive, compliance rates with this latter may vary markedly (close to a factor of 2) depending on the projection considered. Here again, there exists no significant correlation between the dose score and image quality score as determined by compliance with the "Diagnostic requirement".

In the light of these preliminary findings, "hospital by hospital" data analysis was carried out to evaluate the relevance of the image criteria. A "multi-score system", which will be discussed later, was therefore developed for each criterion and implemented for a selected number of projections.

2. The image scoring system

Basically, the idea was to define, for each image criterion, a numerical index which would be able to reproduce the "step by step" process implicitly followed by the radiologist when checking radiographic image quality. More precisely, a tentative attempt was made to determine schematically the basic elements which underlie the acceptability of the film for diagnosis. In splitting such a process up into different components, one may note that it requires that all potentially visible anatomical structures should be shown on the film (medical

component), all abnormal or pathological details should be adequately contrasted (technical component) and, finally, the part of the body projected on the film should correspond to the field size ("positioning" component). From such a basis, it was therefore decided to translate this process into a multi-numerical scoring system related to the previously mentioned components. A group of practicing radiologists actively participated to the establishment of this scoring system. An example of this scoring system for the chest image criteria is given in the Table III.

As shown in the table, each criterion has three scores corresponding to the basic components mentioned before and each score may range from 0 (irrelevant component) to 3 (fundamental component).

Supposing the M-T-P scoring system reliable, it can be seen that the same image criterion, for instance the visually sharp reproduction of the peripheral vessels, the border of heart and the diaphragm, have not the same relevance for the radiologist when medical or technical view point is taken into account. This would theoretically imply that, when the M-T-P scores are generally low, the answer to a criterion might be negative without having any impact on the final result of the film, that is to say, its acceptability for the diagnosis. Conversely, when a particular criterion scores higher, for instance visualisation of the retrocardial lung and the mediastinum, a negative answer will strongly affect the acceptability of the x-ray film.

3. The image criteria evaluation

A comparison between the dosimetric results and the image quality evaluated using the previously mentioned scoring system was carried out for the following projections : chest (p/a) and IVU (before injection film). The corresponding results are presented in figures 1 and 2 .

3.1 The chest (p/a).

Figure 1 shows the average entrance skin doses histogram, all techniques together, measured for the chest (p/a) projection in 16 hospitals which participated to the trial. It also gives, for each hospital, the percentage of x-ray films having obtained the maximum global score, i.e. the rate of examinations for which all diagnostic image criteria listed in the questionnaire were met.

Despite the idea that this examination type would technically be the most

"standardized" one, rather wide range of doses was measured in the considered x-ray departments with a minimum average dose of 0.16 mGy, and a maximum of 0.95 mGy. In only two out of sixteen hospitals, compliance with all the image criteria, was achieved for all examinations (continuous line), but unfortunatly, all the corresponding entrance skin dose values were above 0.3 mGy which corresponds to the dosimetry requirement indicated in the CEC document. Three other hospitals did not meet the same dose requirement but their image quality index was generally lower. However linear regression curve of the image quality index values (dotted line) shows an increasing trend with the increasing doses. This finding suggests that a "rather" good image quality may also be obtained using different techniques which involve higher doses.

3.2 The IVU (before injection film)

First of all, it must be pointed out that no comparison is allowed between the previous histogram and this one: the 15 hospitals considered being not necessarily the same ones as before.
As far as the dose range is concerned, inter-hospital average dose estimates markedly vary from 2.5 mGy to 30 mGy (factor 10). Conversely to the chest (p/a) projection, 2 hospitals out of 15 achieve the maximum image score, and 2 other different hospitals fail to meet dose requirements. The best quality of image was generally found for the low dose techniques. This is clearly demonstrated by the linear regression curve trend which goes down with the increment of the dose.

4. Selecting the most "efficient" technique.

In this final step of the evaluation of the image criteria relevance, the scoring system was used to select the most "efficient" technique which would correspond to that complying with both radiographic and dosimetric requirements recommended for the trial. In doing so, priority was given to the medical component of the score to reflect, in a more realistic manner, the quality of the radiological information which is essential to guarantee the acceptability of the film. In other words, for all chest (p/a) and IVU (before injection) x-ray films, a sub-set was created keeping only those films for which the medical score was equal to the maximum or within 1 of the maximum value. To this sub-set obviously belong all films complying with all image

criteria, and some other films for which a minor image criterion, from the medical view point, was not met.

Considering the radiological equipment and the film/screen sensitivity classes, four categories were defined in order to compare results obtained with so many different radiological units.

Basically, discrimination was made between the x-ray tables equipped with an Automatic Exposure Control system (AEC) and those manually operated. Concerning the film/screen sensitivity classes, attention was paid to the CEC document requirements, namely : minimum sensitivity class of 400 for the IVU and minimum sensitivity class of 200 for the chest.

Results of this selection are summarized in the figure 3 for the chest and in the figure 4 for the IVU.

Implementing the selecting procedure led to keep 167 high image quality score chest x-rays out of 208 acceptable films corresponding to three groups of technique shown in the "chest pie" chart.

First of all, no people were found to work exclusively manually and using a low sensitivity film/screen class, and very few examinations were carried out using low sensitivity films with the AEC system actually installed (1 x-ray department).

The great majority of the selected high image quality score films were taken either with an operating AEC system or with a manual operating equipment but always with sensitivity film class above 200. For these two categories of technique dose hierarchy was respected with an average figure of 0.19 mGy (AEC system) and 0.39 mGy (without AEC system) respectively. This clearly shows the strong impact of the AEC techniques in improving dose reductions when the appropriate film/screen combinations are used.

By implementing the same procedure to the IVU, 95 high image quality score x-rays out of 139 acceptable films were selected and three different radiological techniques were identified. Unfortunately, despite their "good" image quality score, 27 out of 95 examinations were found to be performed by using a very irradiating technique i.e. low sensitivity film/screen class (below 400) and manual operating equipment. Almost all entrance skin dose values associated to these x-ray films were actually higher than the suggested CEC dose requirements : 85% of the doses were above 10 mGy. This clearly demonstrates the relevance of the CEC dose requirements when selecting the most "efficient" technique and suggests that such a radiological practice, requiring unacceptable and unnecessary dose level, should be avoided if one wants to keep patient doses associated to this complexe examination as low as

reasonably achievable.

Finally it can be deduced from the figure 4 that both manually and automatically operating systems may be comparable from both radiological and dosimetric view point i.e. delivering very similar average entrance skin dose values to the patient (5.1 mGy and 6.3 mGy respectively) for the same quality of image as deduced from the selecting procedure. This proves that rather different radiological techniques may be valuable when the adequate sensitivity film/screen class are used (above 400) and when quality control and quality assurance procedures are carried out in diagnostic radiology.

References

Belletti, R., Gallini, R & Giugni, U. Operative programme of quality control in the radiodiagnostic field in a general hospita : results and proposals. British Journal of Radiology, Supplement No 18 131-133.

Maccia, C., Benedittini, M., Le Faure, C. & Fagnani. F. 1988. Doses to patients from diagnostic radiology in France. Health Physics, 4, 397-408.

Padovani, R., Contento, G., Fabretto,M., Malisan, M. R., Barbina, V. & Gozzi, G. 1987. Patient doses and risks from diagnostic radiology in North-East Italy. British Journal of Radiology, 60,155-165.

Shrimpton, P., Wall, B. F., Jones, D. G., Fisher, E. S., Hillier, M. C. & Kendall, G.M. 1986. A national survey of doses to patients udergoing a selection of routine X-ray examinations in English hospitals. NRPB-200 (HMSO, London).

Stieve, F. E. 1988. Radiological requirements for the specification of image quality criteria. (submitted to the British Journal of Radiology)

Table I : General characteristics of the trial.

Examination Type	Number of Countries	Number of X-ray Dept.	Number of Patients	*Number of Dose measurements
Breast	8	15	160	160
Chest	8	16	211	300
Urin. Tract	7	15	155	191
Skull	5	12	117	223
Lumbar Spine	7	14	149	204
Pelvis	6	13	139	134
All examinations	10	24	931	1,212

* All projections together.

Table II. General results of the trial.

Examination Type	Reject Rate (%)	Radiographs meeting all diagnostic criteria * (%)	Hospitals meeting dose requirements ** (%)
Breast	5	79	33
Chest (p/a)	2	79	69
Urin. Tract			
(before inject.)	6	62	87
Skull (a/p)	10	74	89
Skull (p/a)	10	65	56
Skull (lateral)	5	67	75
Lumbar Spine			
(a/p)	10	69	50
(lateral)	4	77	69
Pelvis (a/p)	6	77	58
Pelvis (lateral)	5	83	67

Table III : Example of the image criteria scoring system (chest (p/a)).

IMAGE CRITERIA (p/a)	M *	T **	P ***
- Symmetrical reproduction of the thorax	2	2	2
- Reproduction of vascular pattern in the lung periphery	2	2	0
- Reproduction of the costopleural boundary from the apex of the lung to the diaphragm	2	3	1
- Visually sharp reproduction of the peripheral vessels, the border of heart and the diaphragm.	1	2	1
- Visualisation of the retrocardial lung and the mediastinum	3	3	1
- Performed at inspiration (min 6 anterior costal arches)	2	2	2
GLOBAL SCORE	12	14	7

Scoring system : 0 = irrelevant ; 1 = minor ; 2 = important ; 3 = fundamental.

* T : Technical Score; ** P : Positioning Score; *** M : Medical Score.

Figure 1: Histogram of doses and Image Quality Score trend. Chest (p/a)

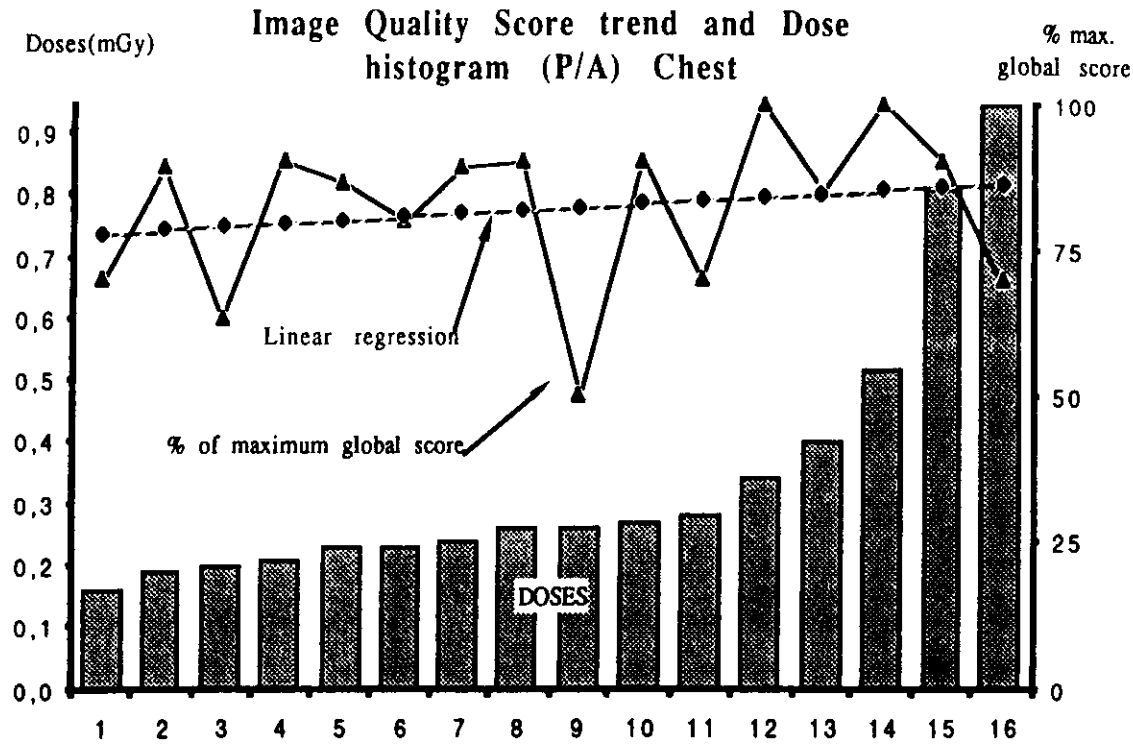


Figure 2 : Histogram of doses and Image Quality Score trend. IVU (before injection)

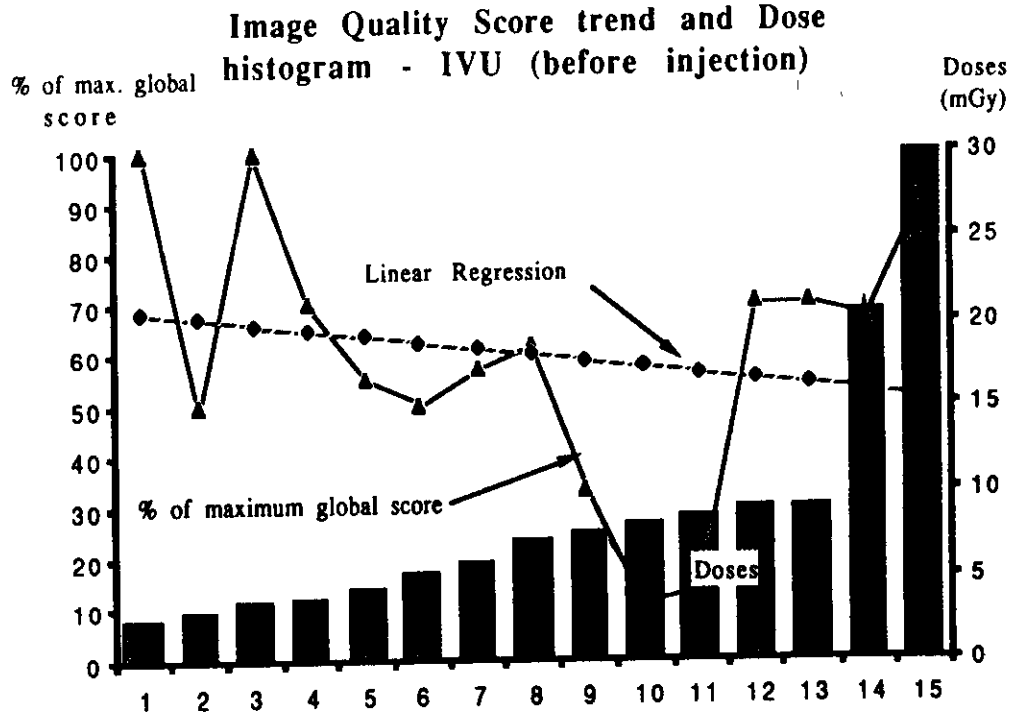


Figure 3 : Selecting procedure results for the chest (p/a).

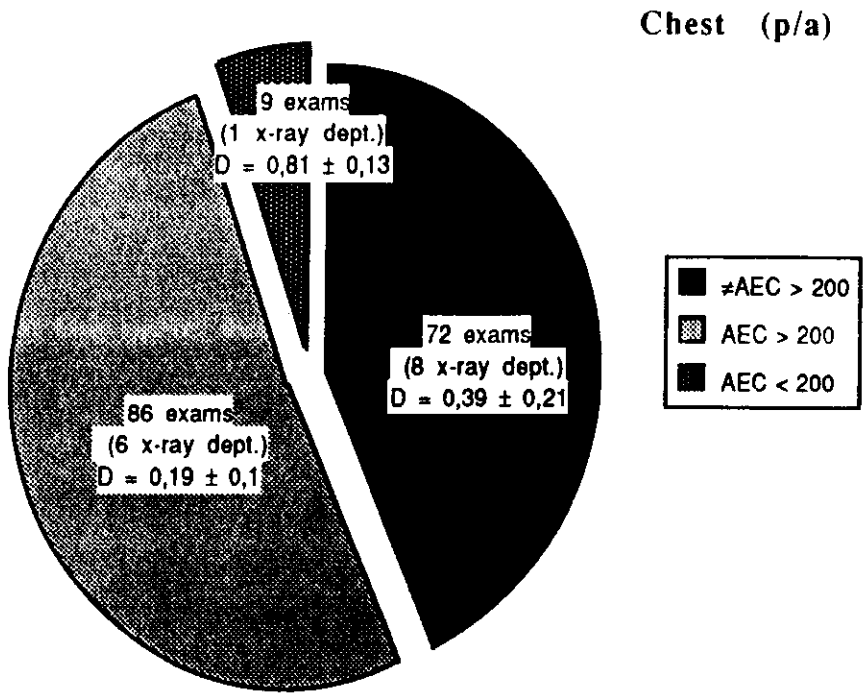
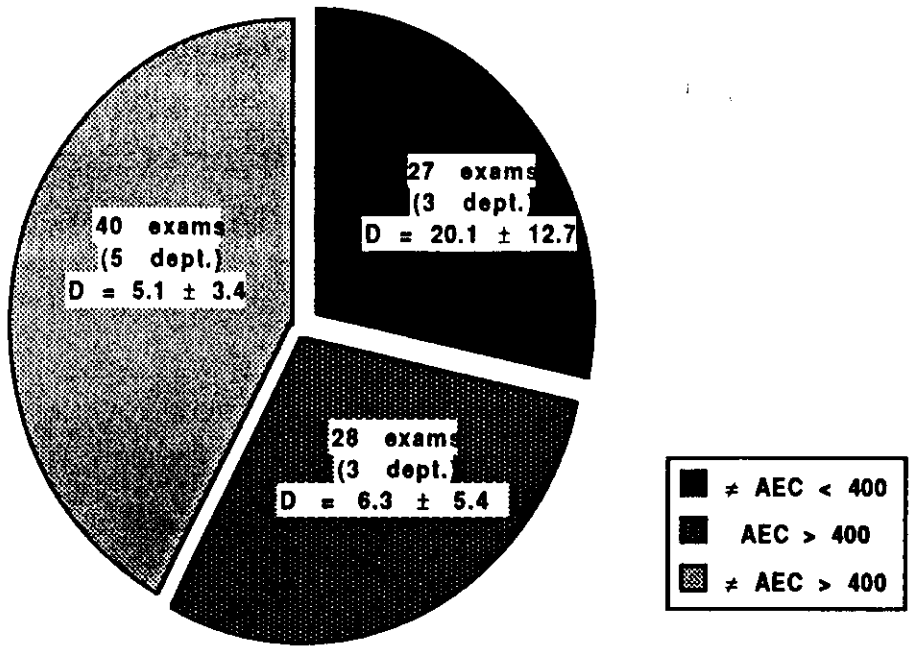


Figure 4 : Selecting procedure results for IVU (before injection).



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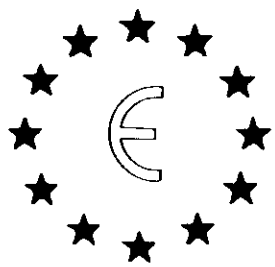
QUALITY CRITERIA

FOR

DIAGNOSTIC RADIOGRAPHIC IMAGES



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CONTENTS

INTRODUCTION

The three basic principles of radiation protection are: justification, optimisation and dose limitation(1) (2). It is accepted that no diagnostic exposure of a patient is justifiable without a valid clinical indication, no matter how good the imaging performance may be. Guidance on referral criteria for adult and paediatric patients can be found in WHO Reports 689 (3) and 757 (4) respectively and guidelines for making the best use of a department of radiology are available from the Royal College of Radiologists, London (5).

In respect to diagnostic examinations there are no dose limits, therefore, once a diagnostic X-ray examination has been clinically justified, the subsequent process of imaging and interpretation must be optimised. The optimal use of ionising radiation involves the interplay of three important aspects of the imaging process:

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

This Document provides guidance on all three of these aspects for a number of selected radiographic projections used in the course of routine types of X-ray examination.

OBJECTIVES

Guidance, presented in this Document, is primarily directed to the technical and clinical staff involved in taking the radiographs and in reporting on them. It will also be of interest to those responsible for the design of X-ray imaging equipment and for the maintenance of its functional performance. It will be helpful to competent authorities who have responsibility for equipment specification and purchase.

The guidance presented in this Document is a demonstrably achievable standard of good practice which can be used as a basis for further development by the radiological community.

The image quality criteria presented for a particular type of image are those deemed necessary to produce a radiograph of standard quality. No attempt has been made to define the degree of acceptability for particular clinical indications.

The Guidelines on Radiation Dose to the Patient represent values, which with equipment currently in use, have been demonstrated to be at a level not exceeded in 75 % of examinations. They therefore can be

taken as a base-line from which progress might be pursued to possibly lower dose levels in line with the ALARA (As Low As Reasonably Achievable) principle.

The Examples of Good Radiographic Technique included in this Document have evolved from the results of the first European trial of the Quality Criteria. Compliance with the image quality criteria and the patient dose guidelines was associated with the employment of these technique factors.

To encourage widespread use, the image quality criteria have been expressed in a manner requiring personal visual assessment rather than checking compliance by using sophisticated measuring equipment.

Assessment of compliance with the Guidelines on Radiation Dose to the Patient for a specific examination unavoidably involves some form of dose measurement. This requires random sampling of the patient population. A variety of dose measurement methods are described in Appendix I.

Adherence to the guidelines presented in this Document will help to achieve:

- good image quality, comparable throughout Europe;
- low radiation dose per radiograph;
- accurate radiological interpretation of the image.

It is hoped that the application of these guidelines will provide the framework for their expansion to other types of X-ray examination.

GENERAL PRINCIPLES ASSOCIATED WITH GOOD IMAGING PERFORMANCE

The following general principles are common to all radiographic X-ray examinations. All those who either request, carry out, or report on the results of diagnostic X-ray procedures should be aware of them.

Specific aspects of these principles are discussed in greater detail in a number of publications by national and international organisations, some of which are listed in references (1) to (9) (see page 9).

Quality Control of X-ray Imaging Equipment

Quality control programmes form an essential part of dose-effective radiological practice. Such programmes should be instigated in every medical X-ray facility and should cover a selection of the most important physical and technical parameters associated with the types of X-ray examination being carried out. Limiting values for these technical parameters and tolerances on the accuracy of their measurement will be required for meaningful application of the Examples of Good Radiographic Technique presented in this Document. BIR Report 18 (8) provides useful information on this subject, e.g. Table VI of paper H.-St. Stender and F.-E. Stieve "The relationship between medical diagnostic requirements and limiting values of technical and physical parameters for image production". Similarly it is envisaged that a scheme for effective evaluation of image quality employing measurements of physical parameters could usefully underpin this Document.

Technical innovations

Technical innovations have enabled dose reduction to be achieved through the use of:

- rare earth screens,
- carbon fibre products in table tops, grid facing and interleaving, and cassette fronts,
- digital radiography,
- use of advanced photographic emulsions,

and which may also be accompanied by improvement of image quality.

Patient Positioning

Correct patient positioning plays a major role in determining the success of any radiological examination. Routine positioning may need to be altered in the light of specific clinical circumstances, in order to delineate an area of special interest. Correct positioning of the patient is the responsibility of the person who is physically directing the examination. The use of suitable immobilisation and compression techniques can have an important role to play in the production of satisfactory images. Training programmes as well as ongoing multidisciplinary evaluation programmes within a medical X-ray facility should regularly address these areas.

X-ray Beam Limitation

Image quality is improved and the radiation dose to the patient is reduced by limiting the X-ray beam to the smallest field giving the required diagnostic information. Limitation of the radiation beam should also consider the need to exclude radiosensitive organs from primary irradiation whenever possible. On no occasion should the X-ray beam fall outside the image receptor area. The use of an automated beam limitation device is of help. A requirement to visualise beam limitation on the radiograph is an alternative.

Protective Shielding

For radiation protection purposes radiosensitive tissues or organs should be shielded wherever possible. In particular, for patients of reproductive capacity, testes or ovary shields should be used in examinations which are likely to give a high radiation dose to the gonads.

Radiographic exposures per examination

The number of radiographic exposures within one examination must be kept to a minimum consistent with obtaining the necessary diagnostic information. This requires that those factors which can lead to high reject or retake rates are subject to reject analysis. This will help to delineate the areas of concern in each medical X-ray facility.

Film Processing

Optimal processing of the radiographic film has important implications both for the diagnostic quality of the image and for the radiation dose to the patient. Film processors should be maintained at their optimum operating conditions as determined by regular and frequent (i.e. daily) quality control procedures. Consistent imaging performance is not necessarily an indication of optimal performance, e.g. the developer temperature may well be set too low.

Image viewing conditions

The proper assessment of image quality and accurate reporting on the diagnostic information in the radiographs can only be achieved when the viewing conditions meet the following requirements:

a) The person viewing the radiographs requires an incident light intensity of about 100 cd/m². To achieve this uniform illuminance of the film illuminator a brightness of at least 2000 cd/m² is necessary;

b) The colour of the illumination should be white or blue and should be matched throughout a complete set of film illuminators;

c) Means should be available to restrict the illuminated area to the area of the radiograph to avoid dazzling;

d) Means for magnifying details in the displayed radiographic image should be available. These means should magnify by a factor of 2 to 4 and contain provisions to identify small image details of sizes down to 0.1 mm.

e) For viewing exceptionally dark areas in the radiographic image an additional spotlight with iris diaphragm providing a brightness of at least 10,000 cd/m² should be available.

f) A low level of ambient light in the viewing room is essential.

GUIDANCE ON IMPLEMENTATION

Quality Criteria are presented for a number of selected radiographic projections used in the course of routine types of X-ray examination. They apply to adult patients of standard size with the usual presenting symptoms for the type of examination being considered.

However, image quality criteria of this nature cannot be applied to all cases. For certain clinical indications a lower level of image quality may be acceptable, but this should always be associated with a lower radiation dose to the patient.

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

For each selected radiographic projection the criteria are divided into three parts:

1. Diagnostic requirements

   These list image criteria which in most cases specify important anatomical structures and details that should be visible in a radiograph to enable accurate diagnosis. A qualitative guide to the necessary degree of visibility of these essential structures and details is provided in the Description of Terms overleaf. These criteria can be used by radiologists as they report on radiographs to make a personal visual assessment of the image quality.

2. Criteria for good imaging performance

   These criteria provide quantitative information on the minimum sizes at which important anatomical details should become visible in the radiographic image. Some of these anatomical details may be pathological and therefore may not be present. Reference values are also provided for the entrance surface dose to a standard-sized patient. The derivation of these values is discussed in Appendix I.

   These criteria are to be used by radiologists, radiographers, and medical physicists, as a check on the performance of the entire imaging process and as an aid in identifying desirable technical specifications of X-ray equipment.

3. Example of good radiographic technique

   This provides an example of one set of radiographic technique parameters that has been found to result in good imaging performance that will meet 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 Good Imaging Performance are not met then the Example of Good Radiographic Technique can be used as a guide to how their techniques might be improved.

DESCRIPTION OF TERMS USED ON FOLLOWING PAGES

1. DIAGNOSTIC REQUIREMENTS

Image criteria

These refer to characteristic features of radiological images with a specific degree of visibility. At the present time there are no internationally accepted definitions. For the purpose of this Document the following are used:

Visualisation:	-	an anatomical feature is detectable but details are not fully reproduced
Reproduction:	-	[illegible] tomical features are visible but not necessarily clearly defined
Visually sharp reproduction	-	the anatomical details are clearly defined

2. CRITERIA FOR GOOD IMAGING PERFORMANCE

2.1 Important image details - define the minimum limiting dimensions in the image at which specific normal or abnormal anatomical details should be recognised.

2.2 Entrance surface dose for standard-sized patient - expressed as the absorbed dose (mGy) at the point of intersection of the X-ray beam axis with the surface of a standard-sized adult patient (or an equivalent phantom), backscatter radiation included. For further information see Appendix I.

3. EXAMPLE OF GOOD RADIOGRAPHIC TECHNIQUE

3.1 Radiographic device - device supporting the film-screen cassette and the anti-scatter grid.

3.2 Nominal focal spot value - defined as the edge length (mm), measured under specific conditions as indicated by the manufacturer.

3.3 Total filtration - the aluminum equivalence of the inherent and added filtration.

3.4 Anti-scatter grid - specified in terms of grid ratio 'r' and number of absorbing strips per cm.

3.5 Film-screen combination - the sensitivity of film screen combinations is defined in speed (see ANSI/ISO PH2-31, DIN 6867 (1985)). The speed of the film-screen combination is one of the most critical factors affecting the radiation dose to the patient. For convenience in this Document speed classes are used to take into account the variation in sensitivity which can occur with changes in X-ray beam energy for individual film-screen combinations (E. Borcke, BIR Report 18 (8)). Users should be encouraged to measure the absolute speeds of their film-screen combinations under standard conditions resembling those used in practice, to see how closely they match up to the manufacturers quoted values. Speed classes of 200 and above usually require the use of rare-earth or equivalent intensifying screens. Users are also encouraged to measure the resolution of their film-screen combination since this varies within any speed class.

3.6 FFD - Focus-to-film distance (cm). Numbers shown in brackets indicate equally satisfactory values. If a focussed grid is used, FFD must be within the range indicated by the manufacturers.

3.7 X-ray tube voltage - expressed as the peak kilo-voltage (kV) applied to the X-ray tube, preferably with a 6-pulse, 12- or multipulse or constant potential high voltage generator.

3.8 Automatic exposure control - the recommended selection of the measurement chamber in the automatic exposure control device.

3.9 Exposure time - the time indicated for the duration of the exposure (ms).

REFERENCES

The following is a limited reference list. References (7) to (9) contain extensive reference lists.

(1) ICRP Publication 34, Protection of the Patient in Diagnostic Radiology, 1982 (Pergamon Press, Oxford)

(2) Council Directive of 3 September 1984 laying down basic measures for the radiation protection of persons undergoing medical examination or treatment (84/466 EURATOM) O.J. Nr L 265, p. 1, 05.10.1984

(3) WHO Report 689 "A Rational Approach to Radiographic Investigations"

(4) WHO Report 757 "Rational Use of Diagnostic Imaging in Paediatrics"

(5) Booklet on "Making the Best Use of a Department of Radiology", 1989 (Royal College of Radiologists, London)

(6) WHO Report "Quality Assurance in Diagnostic Radiology", 1982 (WHO, Geneva)

(7) Criteria and Methods for Quality Assurance in Medical X-ray Diagnosis, BJR Supplement No. 18, 1985

(8) Technical and Physical Parameters for Quality Assurance in Medical Diagnostic Radiology; Tolerances, Limiting Values and Appropriate Measuring Methods", BIR Report 18, 1989

(9) "Optimisation of Image Quality and Patient Exposure in Diagnostic Radiology", BIR Report 20, 1989

PA PROJECTION

1. DIAGNOSTIC REQUIREMENTS

Image criteria

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

1.2 Symmetrical reproduction of the thorax

1.3 Medial border of the scapulae to be outside the lung fields

1.4 Reproduction of the whole rib cage above the diaphragm

1.5 Reproduction of the vascular pattern in the whole lung, particularly the peripheral vessels

1.6 Visually sharp reproduction of

a) the trachea and proximal bronchi, the borders of the heart and aorta

b) the diaphragm and costo-phrenic angles

1.7 Visualisation of the retrocardiac lung and the mediastinum

2. CRITERIA FOR GOOD IMAGING PERFORMANCE

2.1 Important image details

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

high contrast : 0.7 mm diameter

low contrast : 2 mm diameter

Linear and reticular details out to the lung periphery:

high contrast : 0.3 mm in width,

low contrast : 2 mm in width

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

3. EXAMPLE OF GOOD RADIOGRAPHIC TECHNIQUE

3.1	Radiographic device	:	vertical stand with stationary or moving grid
3.2	Focal spot size	:	$\leq$ 1.3 mm
3.3	Total filtration	:	$\geq$ 3.0 mm Al equivalent
3.4	Anti-scatter grid	:	r = 12; 40/cm
3.5	Film-screen combination	:	speed class 200 - 400
3.6	FFD	:	180 (140 - 200) cm
3.7	Radiographic voltage	:	100 - 150 kV
3.8	Automatic exposure control	:	chamber selected - lateral
3.9	Exposure time	:	< 20 ms

LATERAL PROJECTION

1. DIAGNOSTIC REQUIREMENTS

Image criteria

1.1 Performed at deep inspiration and with suspended respiration

1.2 Arms should be raised clear of the thorax

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

2. CRITERIA FOR GOOD IMAGING PERFORMANCE

2.1 Important image details

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

high contrast : 0.7 mm diameter

low contrast : 2 mm diameter

Linear and reticular details out to the lung periphery:

high contrast : 0.3 mm in width,

low contrast : 2 mm in width

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

3. EXAMPLE OF GOOD RADIOGRAPHIC TECHNIQUE

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

PA PROJECTION

or AP Projection if PA not possible

1. DIAGNOSTIC REQUIREMENTS

Image criteria

1.1 Symmetrical reproduction of the skull, particularly cranial vault, orbits and petrous bones

1.2 Projection of the apex of the petrous temporal bone into the centre of the orbits

1.3 Visually sharp reproduction of the frontal sinus, ethmoid cells and apex of the petrous temporal bones and the internal auditory canals

1.4 Visually sharp reproduction of the outer and inner tables of the cranial vault

2. CRITERIA FOR GOOD IMAGING PERFORMANCE

2.1	Important image details	:	0.3 - 0.5 mm
2.2	Entrance surface dose for a standard-sized patient	:	5.0 mGy

3. EXAMPLE OF GOOD RADIOGRAPHIC TECHNIQUE

3.1	Radiographic device	:	grid table, special skull unit or vertical stand with stationary or moving grid
3.2	Focal spot size	:	0.6 mm
3.3	Total filtration	:	$\geq$ 2.5 mm Al equivalent
3.4	Anti-scatter grid	:	r = 8(12); 40/cm
3.5	Film-screen combination	:	speed class 200
3.6	FFD	:	115 (100 - 150) cm
3.7	Radiographic voltage	:	65 - 85 kV
3.8	Automatic exposure control	:	chamber selected - central
3.9	Exposure time	:	< 200 ms

LATERAL PROJECTION

1. DIAGNOSTIC REQUIREMENTS

Image criteria

1.1 Visually sharp reproduction of the outer and inner tables of the cranial vault, the floor of the sella, and the apex of the petrous temporal bone

1.2 Superimposition respectively of the contours of the frontal cranial fossa, the lesser wing of the sphenoid bone, the clinoid processes and the external auditory canals

1.3 Visually sharp reproduction of the vascular channels, the vertex of the skull and the trabecular structure of the cranium

2. CRITERIA FOR GOOD IMAGING PERFORMANCE

2.1	Important image details	:	0.3 - 0.5 mm
2.2	Entrance surface dose for a standard-sized patient	:	3.0 mGy

3. EXAMPLE OF GOOD RADIOGRAPHIC TECHNIQUE

3.1	Radiographic device	:	grid table, special skull unit or vertical stand with stationary or moving grid
3.2	Focal spot size	:	0.6 mm
3.3	Total filtration	:	$\geq$ 2.5 mm Al equivalent
3.4	Anti-scatter grid	:	r = 8(12); 40/cm
3.5	Film-screen combination	:	speed class 200
3.6	FFD	:	115 (100 - 150) cm
3.7	Radiographic voltage	:	65 - 85 kV
3.8	Automatic exposure control	:	chamber selected - central
3.9	Exposure time	:	< 100 ms

AP/PA PROJECTIONS

1. DIAGNOSTIC REQUIREMENTS

Image criteria

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

1.2 Visually sharp reproduction of the pedicles

1.3 Visualisation of the intervertebral joints

1.4 Reproduction of the spinous and transverse processes

1.5 Visually sharp reproduction of the cortex and trabecular structures

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

2. CRITERIA FOR GOOD IMAGING PERFORMANCE

2.1 Important image details : 0.3 - 0.5 mm

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

3. EXAMPLE OF GOOD RADIOGRAPHIC TECHNIQUE

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

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

LATERAL PROJECTION

1. DIAGNOSTIC REQUIREMENTS

Image criteria

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

1.2 Full superimposition of the posterior vertebral edges

1.3 Reproduction of the pedicles and the intervertebral foramina

1.4 Visualisation of the intervertebral joints

1.5 Visually sharp reproduction of the cortex and trabecular structures

1.6 Reproduction of the adjacent soft tissues

2. CRITERIA FOR GOOD IMAGING PERFORMANCE

2.1 Important image details : 0.5 mm

2.2 Entrance surface dose for a standard-sized patient : 30 mGy

3. EXAMPLE OF GOOD RADIOGRAPHIC TECHNIQUE

3.1	Radiographic device	:	grid table or vertical stand with stationary or moving grid
3.2	Focal spot size	:	$\leq$ 1.3 mm
3.3	Total filtration	:	$\geq$ 3.0 mm Al equivalent
3.4	Anti-scatter grid	:	r = 12(8); 40/cm
3.5	Film-screen combination	:	speed class 400 - 800
3.6	FFD	:	115 (100 - 150) cm
3.7	Radiographic voltage	:	90 - 100 kV
3.8	Automatic exposure control	:	chamber selected - normally central
3.9	Exposure time	:	< 1000 ms

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

LATERAL PROJECTION OF LUMBO-SACRAL JUNCTION

This Projection may be indicated if the lumbo-sacral junction is not adequately visualised on the Lateral Projection of the lumbar spine

1. DIAGNOSTIC REQUIREMENTS

Image criteria

1.1 Reproduction by tangential projection of the inferior end plate of L 5 and the superior end plate of S 1

1.2 Visualisation of the anterior border of the upper sacrum

1.3 Reproduction of vertebral pieces of the upper sacrum

2. CRITERIA FOR GOOD IMAGING PERFORMANCE

2.1 Important image details : 0.5 mm

2.2 Entrance surface dose for a standard-sized patient : 40 mGy

3. EXAMPLE OF GOOD RADIOGRAPHIC TECHNIQUE

3.1	Radiographic device	:	grid table or vertical stand with stationary or moving grid
3.2	Focal spot size	:	$\leq$ 1.3 mm
3.3	Total filtration	:	$\geq$ 3.0 mm Al equivalent
3.4	Anti-scatter grid	:	r = 12(8); 40/cm
3.5	Film-screen combination	:	speed class 400 - 800
3.6	FFD	:	115 (100 - 150) cm
3.7	Radiographic voltage	:	90 - 110 kV
3.8	Automatic exposure control	:	chamber selected - central
3.9	Exposure time	:	< 1000 ms

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

AP PROJECTION

1. DIAGNOSTIC REQUIREMENTS

Image criteria

1.1 Symmetrical reproduction of the pelvis

1.2 Visualisation of the sacrum and its intervertebral foramina

1.3 Visualisation of the pubic and ischial rami

1.4 Visualisation of the sacroiliac joints

1.5 Reproduction of the necks of the femora which should not be distorted by foreshortening or rotation

1.6 Reproduction of spongiosa and corticalis, and visualisation of the trochanters

2. CRITERIA FOR GOOD IMAGING PERFORMANCE

2.1	Important image details	:	0.5 mm
2.2	Entrance surface dose for a standard-sized patient	:	10 mGy

3. EXAMPLE OF GOOD RADIOGRAPHIC TECHNIQUE

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

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

AP PROJECTION

Before administration of contrast medium

1. DIAGNOSTIC REQUIREMENTS

Image criteria

1.1 Reproduction of the area of the whole urinary tract from the upper pole of the kidney to the base of the bladder

1.2 Reproduction of the kidney outlines

1.3 Visualisation of the psoas outlines

1.4 Visually sharp reproduction of the bones

2. CRITERIA FOR GOOD IMAGING PERFORMANCE

2.1 Important image details : 1 mm

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

3. EXAMPLE OF GOOD RADIOGRAPHIC TECHNIQUE

3.1	Radiographic device	:	grid table
3.2	Focal spot size	:	$\leq$ 1.3 mm
3.3	Total filtration	:	$\geq$ 3.0 mm Al equivalent
3.4	Anti-scatter grid	:	r = 12(8); 40/cm
3.5	Film-screen combination	:	speed class 400 - 800
3.6	FFD	:	115 (100 - 150) cm
3.7	Radiographic voltage	:	70 - 90 kV
3.8	Automatic exposure control	:	chamber selected - central or both lateral
3.9	Exposure time	:	< 100 ms

Remarks Radiation Protection, where appropriate gonad shields should be employed for male patients.

After administration of contrast medium

1. DIAGNOSTIC REQUIREMENTS

Image criteria

Image criteria are to be referred to a series of radiographs

1.1 Increase in parenchymal density (nephrographic effect)

1.2 Visually sharp reproduction of the renal pelvis and calyces (pyelographic effect)

1.3 Reproduction of the pelvi-ureteric junction

1.4 Visualisation of the area normally traversed by the ureter

1.5 Reproduction of the whole bladder

2. CRITERIA FOR GOOD IMAGING PERFORMANCE

2.1 Important image details : 1 mm

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

3. EXAMPLE OF GOOD RADIOGRAPHIC TECHNIQUE

3.1	Radiographic device	:	grid table or vertical stand with moving grid
3.2	Focal spot size	:	$\leq$ 1.3 mm
3.3	Total filtration	:	$\geq$ 3.0 mm Al equivalent
3.4	Anti-scatter grid	:	r = 12(8); 40/cm
3.5	Film-screen combination	:	speed class 400 - 800
3.6	FFD	:	115 (100 - 150) cm
3.7	Radiographic voltage	:	70 -90 kV
3.8	Automatic exposure control	:	chamber selected - central or both lateral
3.9	Exposure time	:	< 100 ms

REMARKS Satisfactory reduction of overlying bowel gases and faeces is essential for adequate urinary tract reproduction. If reproduction is inadequate tomography or zonography might be useful.

Fulfillment of image criteria might require
more than one PROJECTION

1. DIAGNOSTIC REQUIREMENTS

Image criteria

1.1 Visually sharp reproduction of the whole glandular breast

1.2 Visually sharp reproduction of the cutis and subcutis

1.3 Nipple should be parallel to the film

2. CRITERIA FOR GOOD IMAGING PERFORMANCE

2.1	Important image details	: round details	:	3 mm diameter
		micro-calcifications	:	0.2 mm
2.2	Entrance surface dose for a standard-sized patient, 4.5 cm compressed breast, with anti-scatter grid		:	7 mGy

3. EXAMPLE OF GOOD RADIOGRAPHIC TECHNIQUE

3.1	Radiographic device	:	specially dedicated equipment Anode material : Mo
3.2	Focal spot size	:	$\leq$ 0.6 mm
3.3	Total filtration	:	0.03 mm Mo or 0.5 mm Al equivalent
3.4	Anti-scatter grid	:	specially designed moving grid (see REMARKS) might be necessary
3.5	Film-screen combination	:	dedicated high resolution film-screen combination with dedicated processing
3.6	FFD	:	$\geq$ 60 cm
3.7	Radiographic voltage	:	25 - 35 kV
3.8	Automatic exposure control	:	chamber selected - specially positioned
3.9	Exposure time	:	< 2 s
3.10	Breast compression	:	should be applied to a level which the patient can tolerate

REMARKS The choice of anode material, total filtration, tube voltage and the use of moving grid required to obtain satisfactory image quality at an acceptable level of average entrance surface dose will be greatly affected by the density and thickness of the breast under investigation:

- For more dense and/or thicker breasts (in excess of 6 cm compressed) a tungsten anode, aluminum or other special filtration, higher tube voltages and use of an anti-scatter grid might be preferable.
- For thinner breasts (less than 4 cm) the use of an anti-scatter grid will not be necessary.

GUIDELINES ON RADIATION DOSE TO THE PATIENT

Objective

The Criteria for Good Imaging Performance contained in the List of Quality Criteria for the selected radiographic projections include a reference value for the Entrance Surface Dose for a standard-sized patient. It is intended that this reference dose value is used as a guide to the level of radiation protection of the patient. If this value is significantly exceeded then investigations must be made to justify this level of patient exposure, or if it cannot be justified, to reduce it.

Reduction of doses below the reference value should always be pursued (ALARA principle) but attention should be paid to potential loss of clinical information with any dose reduction.

Derivation of the Reference Dose Values

The patient Entrance Surface Dose including backscatter is the preferred dose quantity because it can be measured comparatively easily and much information is already available in terms of this quantity from recent patient dose surveys in Europe. Other dose quantities exist which may be more closely related to the radiation risk to the patient, eg. effective dose equivalent or the total energy imparted to the patient. They cannot however be measured directly and the various assumptions and uncertainties involved in their estimation can lead to ambiguity in their expression. Moreover, it was not possible to find sufficient data on typical European values for these dose quantities for the radiographic projections considered in this Document, to allow the derivation of suitable reference dose values.

For each of the selected radiographic projections dealt with in this Document (where the size and position of the radiation field is often defined in the Diagnostic Requirements), the patient Entrance Surface Dose is the most critical factor affecting the radiation risk. It therefore provides a realistic, easily measured guide to the relative level of patient protection being provided by the imaging techniques used in different facilities for the same projection.

A comprehensive survey of Entrance Surface Dose was carried out in Britain in 1983/1984 when measurements were made on 3200 patients undergoing 10 types of routine X-ray examination at 20 randomly selected hospitals[1]. As usual, wide variations in dose were observed (see Table 1) and the reference doses quoted in the Criteria for Good Imaging Performance have been provisionally set to coincide approximately with the 3rd quartile dose values. It is argued that if 75% of X-ray departments can operate satisfactorily below a certain dose level, then the remaining 25% should be made aware of their less than optimal performance and should be encouraged to alter their radiographic equipment or techniques to bring their doses in line with the majority. At the same time adherence to the image criteria will ensure

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[1] P.C. Shrimpton, B.F. Wall, D.G. Jones, E.S. Fisher, M.C. Hiller, G.M. Kendall, R.M. Harrison: "Dose to patients from routine diagnostic X-ray examinations in England", BJR 59 : 749-758, 1986

that diagnostic efficacy does not suffer. The median dose values quoted in Table 1 could form a desirable aim for further dose reductions.

Mammography was not included in the 1983/84 British patient dose survey. The values of Entrance Surface Dose shown for the breast examination in Table 1 were derived from a 1989 survey of about 30 British mammography screening centres by the UK Mammography Physics Group[2]. At each centre the Entrance Surface Dose required to obtain a satisfactory radiograph of a 4.5 cm compressed breast was estimated using a Perspex phantom (Polymethylmethacrylate). The doses for the breast examination in Table 1 consequently do not show such a wide variation as the individual patient dose measurements made for the other types of examination. All the mammography centres used anti-scatter grids and X-ray tubes with molybdenum anodes.

In a trial of the Quality Criteria at 20 hospitals spread throughout Europe in 1988[3], performed to help the preparation of this Document, measurements indicated that on average 30% rather than the previous 25% of X-ray departments failed to meet the reference dose criteria. This difference is not considered to be sufficiently great to warrant change in the provisional reference dose levels, except for the Lateral Projection of the Lumbo-Sacral Junction where the 3rd quartile dose value was in fact lower than in the British survey, at a value of about 40 mGy.

Methods of Dose Measurement to Check Compliance with the Guidelines

The objective of the measurements is to obtain a reliable indication of the Entrance Surface Dose that would be delivered to an average-sized adult patient using the radiographic technique parameters that are being tested against the Quality Criteria. Due to the different types of X-ray and dosimetric equipment that will be available in the various radiology departments, a number of alternative methods are suggested involving measurements on patients, phantoms or free-in-air and using either TLDs or ionisation chambers.

All of these are considered equally valid and should lead to comparable results as long as all values are quoted in terms of absorbed dose to soft tissue (ICRU[4] muscle is recommended) and the effect of radiation backscattered from the patient is included.

Measurements on patients are most easily achieved by TLDs attached directly to the skin at a point coincident with the centre of the incident X-ray beam. Since a patient of exactly standard size (assumed to be 20 cm AP trunk thickness and 70 kg weight) is unlikely to be available, measurements on a statistically significant sample of patients (minimum of 10) of close to standard size are recommended, preferably with an average weight that is 70 $\pm$ 3 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 the reference dose in the Quality Criteria. Such measurements should form part of an ongoing quality assurance programme.

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[2] D.R. Dance, Royal Marsden Hosp., London, personal communication

[3] C. Maccia, B.M. Moores, U. Nahrstedt, R. Padovani, B.F. Wall, CEC Quality criteria for diagnostic radiographic images and patient exposure trial, Report EUR 12952, 1990

[4] ICRU = International Commission on Radiological Units and Measurements

Phantoms consisting of the appropriate thickness of tissue-equivalent plastic or water can be used as a substitute for a standard-sized patient with suitable positioned TLDs for measuring the dose. Mammographic examinations are one area where the use of phantoms is particularly appropriate. It is recommended that a Perspex slab, 4.5 cm thick and of similar cross-sectional area to a compressed breast, is used as the dosimetric phantom in mammography. Entrance Surface Doses can be measured either with TLDs attached to the incident surface of the phantom or with a small volume ionisation chamber recessed into the incident surface of the phantom so that it receives the same degree of backscattered radiation as the TLDs. Care must be taken to ensure that the sensitivity of the dosemeter is known at the low X-ray qualities used in mammography. For the purpose of checking compliance with these guidelines, Entrance Surface Doses for mammography can be expressed in terms of absorbed dose to air. Since "muscle" is an inappropriate tissue for breast dosimetry.

For X-ray equipment employing manual selection of the tube potential, tube current and exposure time, it is possible to select the parameters that would be used for a standard-sized patient and to make a free-in-air dose measurement without any patient or phantom in the X-ray beam. The dosemeter should be positioned on the beam axis at a point coincident with the entrance surface of the patient. Either TLDs or suitable ionisation chambers can be used, calibrated in terms of absorbed dose to soft tissue. Dosemeters should be held in a scatter-free support. The measurement of absorbed dose to muscle, free-in-air, will have to be corrected to Entrance Surface Dose by multiplying by an appropriate backscatter factor. Backscatter factors vary between about 1.3 and 1.4 for the X-ray qualities used for the projections included in the List of Quality Criteria (except for mammography) so a single average value of 1.35 can be used in most situations without appreciable error. For mammography using X-ray tubes with molybdenum anodes (HVL < 0.45 mmAl) backscatter factors of between 1.05 and 1.10 would be appropriate.

Table 1
Entrance Surface Doses observed in British survey in 1983/1984
(Reference 1, p. 21)

		Entrance surface dose (mGy)				
Examination		Min. value	1st quartile	Median value	3rd quartile	Max. value
Chest	PA	0.03	0.13	0.18	0.26	1.43
Chest	LAT	0.14	0.49	0.99	1.46	10.6
Skull	PA	1.82	3.26	4.25	5.49	13.1
Skull	LAT	0.36	1.42	2.19	2.85	9.09
Lumbar spine	AP/PA	0.83	5.65	7.68	11.2	59.1
Lumbar spine	LAT	2.38	12.7	19.7	30.1	108
Lumbo-sacral junction	LAT	7.40	24.0	34.5	50.7	131
Pelvis	AP	0.85	4.19	5.67	7.86	31.6
Urinary tract	AP	0.71	4.69	6.68	10.5	82.4
Breast*		2.9	4.0	5.6	7.1	10.2

* Ref. 2, p. 22

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