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INTERNATIONAL CENTRE FOR THEORETICAL PHYSICS
34100 TRIESTE (ITALY) · P.O.B. 586 · MIRAMARE · STRADA COSTIERA 11 · TELEPHONE: 2240-1
CABLE: CENTRATOM · TELEX 460392-I

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Results of a Trial Set up by a Study Group of the Radiation Protection

C. MACCIA

CEPN, Fontenay aux Roses, France

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*C.Maccia.
*CEPN-INSERM B.P. 48 - 92263 Fontenay aux Roses. FRANCE.

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

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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)

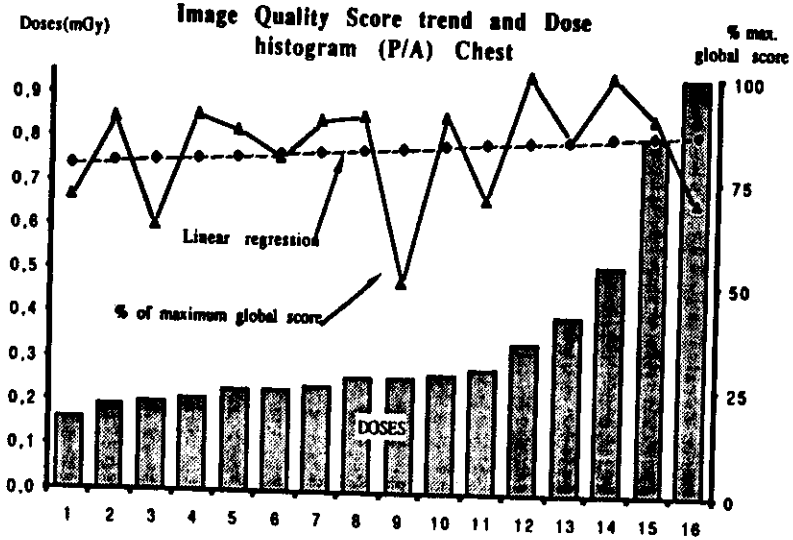

Figure 2 : Histogram of doses and Image Quality Score trend. IVU (before injection)

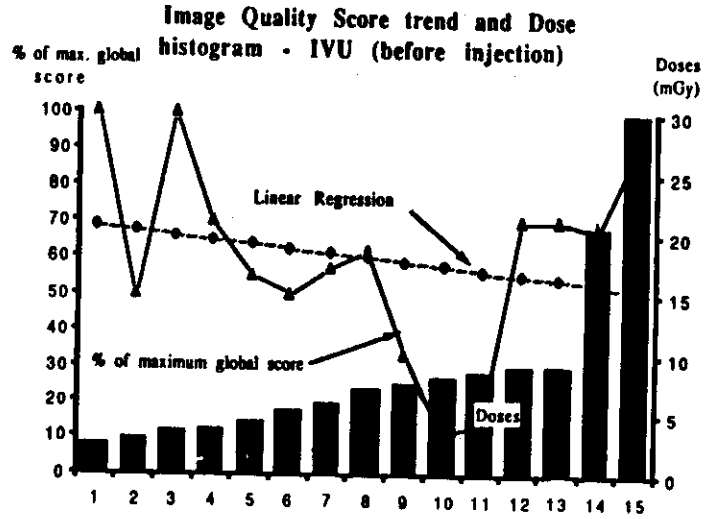

Figure 3 : Selecting procedure results for the chest (p/a).

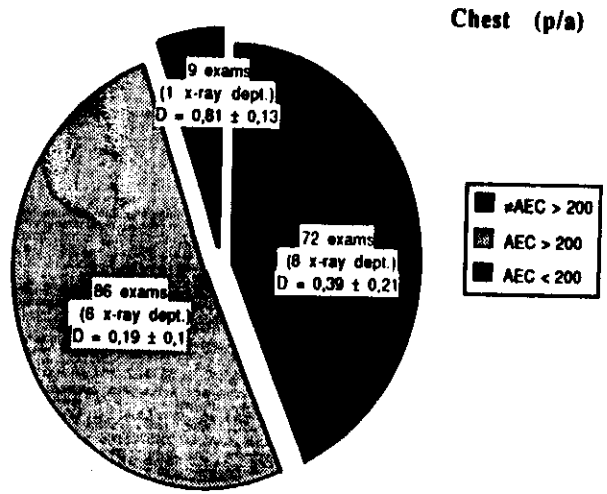

Figure 4 : Selecting procedure results for IVU (before injection).