Optimization of Patient Protection in Diagnostic Radiology by Application of Guidance Levels

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INTRODUCTION

It is well recognized that, apart from natural background, medical exposures are at present by far the largest source of exposure to ionizing radiation of the population and that several radiation protection measures should be taken by each country to prevent unnecessary or unproductive medical radiation exposure.

The main tools generally to achieve this aim are justification of practices, optimization of protection and the use of dose limits. As dose limits do not apply to medical exposures, individual justification (good clinical indication) and optimisation are even more important than in other practices using ionising radiation.

According to ICRP Publication 60 (1), optimisation means keeping the dose « as low as reasonably achievable, economic and social factors being taken into account ». For diagnostic medical exposures this is interpreted as being a dose as low as possible, which is consistent with the required image quality (2) and necessary for obtaining the desired diagnostic information.

In the context of optimisation of patient protection in diagnostic radiology, an important step was the introduction of Diagnostic Guidance Levels (DGLs), following the recommendation of the ICRP in its Publication 73 (3).

According to the definition, in X-ray diagnosis, a Diagnostic Guidance Level (DGL) is a dose level set for standard procedures and for groups of standard-sized patients or a standard phantom (4,5):

-entrance surface dose per radiograph, for diagnostic radiography;
-entrance surface dose rate, for fluoroscopy;
-average glandular dose per cranio-caudal projection, for mammography;
-multiple scan average dose, for computed tomography.

DGLs practically should assist in the optimisation of the patient protection, by helping to avoid unnecessarily high doses to the patient. The system for using DGLs includes:

-estimation of patient doses, as part of a regular quality assurance programme ;
-comparison of obtained doses with the internationally recommended guidance levels ;
-corrective actions whenever guidance levels are consistently exceeded.

Since the beginnings of 1990 (6,7), the Institute of Public Health-Bucharest participated to the research co-ordinated programme on Radiation Doses in Diagnostic Radiology and Methods for Dose Reduction (8), initiated by the International Atomic Energy Agency, in co-operation with European Commission.
Some of the recent results are presented below.

MATERIAL AND METHODS

The investigations were performed in 5 main hospitals from Bucharest, Cluj-Napoca and Iassy, during several X-ray examinations (fluoroscopy, standard radiography and computed tomography) and consisted in patient and in-phantom dose measurements and in comparisons with internationally recommended guidance levels (4).

The experimental set-up for patient dose measurements is shown in Fig.1. It includes the X-ray tube, the variable additional filtration, a PTW area x dose meter, a TLD on patient, at centre of the X-ray beam, the patient and the image detection system.

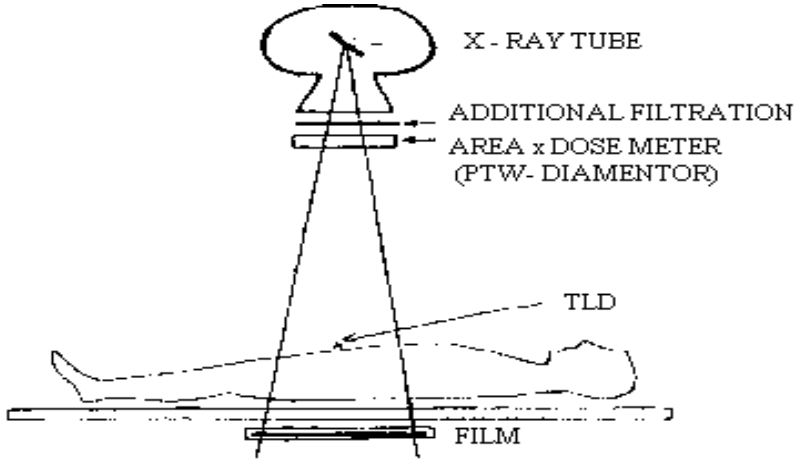
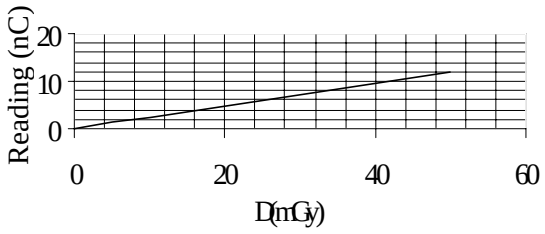


Fig. 1 EXPERIMENTAL SET-UP FOR PATIENT DOSE MEASUREMENTS

The Patient Entrance Dose was directly measured by means of TL dosimeters, after an intercalibration of all participating laboratories to the IAEA-CEC pragramme (8). A set of dosimeters from each participant was exposed in the same laboratory to different beams (25,60,80 and 120 kV and ^{137}Cs) and different doses (0,1,5 and 50 mGy). The obtained calibration curve is given in Fig.2.

When performing measurements on patients, several relevant data were collected: equipment generator and X-ray tubes imaging system and processing, patient data and technical factors for each radiography.
After a comparison with guidance levels, an analysis of the results was performed, in order to identify the causes which most contribute to the dose and, if appropriate, dose reduction methods were applied, keeping the image quality.



$$y = 0.238x + 0.11 \qquad x_{(mGy)} = \frac{y^{(nC)} - 0.1}{0.238}$$

Figure 2. Calibration curve of TLDs for patient dose measurements

X-ray examination (Radiography)		Entrance surface dose (mGy) Range	Mean (M)	Guidance Level* (G)	Ratio (M/G)
Chest	**PA**	**0.47-4.16**	**2.0**	**0.4**	**5.0**
	LAT	**1.34-4.95**	**3.0**	**1.5**	**2.0**
Lumbar spine	**AP**	**5.80-17.87**	**10.9**	**10**	**1.0**
	LAT	**14.04-31.77**	**24.3**	**30**	**0.8**
Skull	**PA**	**2.60-11.86**	**5.5**	**5**	**1.1**
	LAT	**1.01-2.83**	**2.1**	**3**	**0.7**
Pelvis	**AP**	**3.30-7.75**	**6.2**	**10**	**0.6**

* International Basic Safety Standards for Protection Against Ionising Radiation and for the Safety of Radiation Sources, IAEA Safety Series No.115, Vienna, 1996, p.279

Table 1 - Results on the patient entrance surface doses and comparison with guidance levels

Hospital	Room	PA		LAT	
		Range	Mean	Range	Mean
1	**1**	**0.29-1.21**	**0.66**	**2.05-3.76**	**2.59**
	2	**0.20-1.02**	**0.47**	**0.41-2.92**	**1.34**
2	**3**	**0.30-5.44**	**1.84**	**1.00-17.8**	**4.46**
	4	**0.70-3.78**	**2.70**	**1.53-5.35**	**3.90**
3	**5**	**0.78-3.48**	**1.84**	**3.20-4.86**	**2.77**
	6	**0.21-7.70**	**2.48**	**0.57-8.99**	**4.27**
4	**7**	**2.67-6.8**	**4.16**	**3.40-10.0**	**4.95**
	8	**3.50-4.46**	**3.98**	**2.70-6.92**	**3.04**
5	**9**	**0.32-1.54**	**0.52**	**0.68-4.50**	**1.52**
	10	**0.40-3.02**	**1.51**	**0.95-2.61**	**1.78**

Table 2 – Summary of patient surface entrance dose (mGy) by hospital and by room, for chest radiography

RESULTS

Diagnostic radiography

A synthesis of the results regarding entrance patient doses in diagnostic radiography is given in Table 1.

As can be observed, the measured doses are well within the guidance level, excepting for chest radiography, where the measured mean dose is twice the guidance level for LAT projection and 5 times for PA projection.

A detailed analysis is presented in Table 2, including the patient doses by hospital and by room. The values may vary 8.8 times between several rooms from different hospitals and 3 times within the same hospital for PA chest radiography. The variation is smaller for LAT chest projection: 3.7 times between hospitals and up to 1.9 times within the same hospital.

The main explanations of the discrepancies, for chest radiography, between rooms, and between the results of Romanian hospitals and the guidance levels are given by the actual physical parameters used, presented in Table 3, in comparison with recommended values, for rooms 2 and 7.

	Room 2	Room 7	Guidance
FFD (cm)	**170**	**150**	**180 (140-200)**
KV	**95**	**70**	**125**
Speed of film/ screen combination	**200**	**200**	**400**

Table 3 – Physical parameters used and comparison with recommended values for chest radiography

The use of low “kV” value technique and of low speed of film/screen combination explains the obtained results.

As a simple, practical, dose reduction method, the increase of kV value and the reduction of the ratio field size/ film size (which was always before higher than unity) were applied. Consequently, a dose reduction up to 30 % was obtained for chest radiography, keeping the speed of film/screen combination.

A dose reduction up to 50 % was obtained by increasing the screen/film sensitivity for an AP urography. The results are presented in Table 4.

Hospital	X-Ray room	Examination	Dose prior to QC(mGy)	Dose after QC (mGy)	Dose reduction (%)	Corrective actions
1	**1**	**Chest PA**	**0.95**	**0.67**	**30**	**Increase of kV and reduction of both mA.s and field size**
1	**2**	**Chest PA**	**0.77**	**0.69**	**10**	**Increase of kV and reduction of both mA.s and field size**
1	**2**	**Urinary Tract AP**	**17.98**	**9.29**	**48**	**Increase screen-film sensitivity**

Table 4 – Dose reduction actions

Fluoroscopy

Several measurements were performed for fluoroscopic procedures, with image amplifier, using the routine parameters for lung fluoroscopy.

The results are given in Table 5.

	Range	Mean dose rate mGy/ min
Lung fluoroscopy	**15-40**	**30**
Guidance level	**-**	**25**

Table 5 – Doses in fluoroscopy

Unfortunately, in Romania most of fluoroscopic units are without image amplifier and consequently the actual dose rates are higher.

Computed tomography

For CT abdomen, the measured CTDI 10 cm air (mGy/ mA.s) was 0.059. The calculated average dose, for the practical parameters used are ranged from 15 to 25 mGy and consequently very close to guidance level (25 mGy).

CONCLUSIONS

By comparing local practice against guidance levels of dose to patients, it was demonstrated that guidance levels are important quantitative guides for the optimisation of patient protection in diagnostic radiology.

As the guidance levels from basic safety standards are based on investigations in some developed countries, they are too restrictive for some other countries. Such guidance levels must be developed in the future in a more international scale, since they apply al over the world. National modifications in this case are possible mainly to reflect differences in medical practices.

The guidance levels should be understood as guidelines, rather than standards in medical diagnostic radiology, and they should be evaluated in relation with quality assurance programmes in each country, by professionals from both medical and physics communities.

There should also be an evaluating committee of professionals from both medical and medical physics communities, for evaluation of the situation in the country and to serve as advisory group to the National Regulatory Body. They should also be able to recommend even to stop a medical department from operating in case of extreme bad situation of patient radiation protection.

By increasing kV value and by reduction of both mA.s and field size parameters important practical dose reductions were obtained (up to 30 %) particularly for chest PA radiography, keeping the image quality.

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