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An Assessment of Methods for Monitoring Entrance Surface Dose in Fluoroscopically Guided Interventional Procedures

J C Waite*, M Fitzgerald
Radiological Protection Centre (RPC), Department of Medical Physics and Bioengineering, St George's Hospital, London, SW17 0QT, England, UK[1]

1. Abstract

In the light of a growing awareness of the risks of inducing skin injuries as a consequence of fluoroscopically guided interventional procedures (FGIPs), this paper compares three methods of monitoring entrance surface dose (ESD) It also reports measurements of ESDs made during the period August 1998 to June 1999 on 137 patients undergoing cardiac, neurological and general FGIPs. Although the sample is small, the results reinforce the need for routine assessments to be made of ESDs in FGIPs. At present, the most reliable and accurate form of ESD measurement would seem to be arrays of TLDs. However, transducer based methods, although likely to be less accurate, have considerable advantages in relation to a continuous monitoring programme. It is also suggested that there may be the potential locally for threshold dose area product (DAP) values to be set for specific procedures. These could be used to provide early warning of the potential for skin injuries.

2. Introduction

In fluoroscopically guided interventional procedures, patients are being exposed to highly localised X-ray sources for extended periods of time long enough to cause possible skin injuries. A number of cases of severe skin injuries have been reported, which illustrate the importance of dose saving techniques and monitoring procedures [1],[2].

The severity of deterministic skin injuries increases with increasing absorbed dose and has a threshold level under which no noticeable effects occur. Above a dose of 2 Gy, a transient erythema can develop within hours of the procedure. This erythema is temporary and will fade within a week or two. Skin injuries such as dermal necrosis and talangiectasis occur at much higher doses of between 12 Gy and 20 Gy[3] and although cases have been reported of patients receiving serious skin injuries suggestive of such high doses [4], most patients receive ESDs, which are significantly below this level. A dosimetry study was undertaken comparing several methods of monitoring patient dose with a view to identifying the most reliable and 'user-friendly' method for routine use in a clinical environment.

3. Methods and Materials

Doses were measured in one of three ways.

3.1. Thermoluminescent Dosemeters (TLD)

Lithium Fluoride (LiF) dosemeter chips were arranged in arrays of up to 35 chips. The number of TLDs in each array and the position on the patient was optimised for each procedure, based on a number of previous experimental trials. Patient details and exposure factors were noted together with DAP meter readings. The maximum TLD reading was used for comparison with the other measurement methods.

3.2. McMahon Medical 'Skin Dose Monitor' (SDM) Model 104-101

* Medical Physics Directorate, St Thomas' Hospital, London, SE1 7EH, UK [email: Julie.Waite@gstt.sthames.nhs.uk]
[1] Project partly funded by the Department of Health, UK

The sensor contains a small scintillator in a reflective plastic housing, linked by a fibre optic to a meter. The sensor is placed at the centre of the field on the skin using a disposable pad. The energy range of the sensor is given by the manufacturer as being between 50 and 150 kVp with a dose-rate range between 0.1 $mGymin^{-1}$ and 3 $Gymin^{-1}$. Calibration of the SDM was carried out using a calibrated ionisation chamber. The SDM was used in conjunction with a TLD array on each patient for direct comparison.

3.3. PTW M4-KDK Dose Area Product (DAP) Meter

The M4-KDK consists of two parallel plates, separated by a non-sensitive region. The plates each have two chambers, connected to an electrometer. The central chamber is entirely within the x-ray beam and measures the air kerma at the output face of the x-ray tube; an inverse square calculation is performed to calculate ESD.

4. Results

4.1. ESD Measurements

ESD measured for cardiac, neurological and general procedures are shown in Tables I-III. Results shown were obtained using the TLD arrays. Most ESD values are below 1 Gy.

Table I. ESDs measured during cardiac procedures

Procedure	RF Ablation	Angioplasty	PTCA	Diagnostic LHC	EPS	Diagnostic LHC & Grafts
Range (Gy)	0.03 – 1.01	0.38 – 1.10	0.02 – 0.94	0.06 – 0.33	0.37 – 0.42	0.24 – 0.34
Mean ESD (Gy)	0.13	0.73	0.31	0.18	0.40	0.29
Sample Size	6	3	19	9	2	2

Table II. ESDs measured during neurological procedures

Procedure	Angiogram	Embolisation	GDC Coiling
Range (Gy)	0.02 – 0.36	0.08 – 1.28	0.62 – 1.65
Mean ESD (Gy)	0.14	0.72	1.20
Sample Size	19	3	4

Table III. ESDs obtained for two types of general interventional procedures

Procedure	Aortic Stent Graft	PTA Iliac Artery
Range (Gy)	0.37 – 3.34	0.23 – 0.97
Mean ESD (Gy)	3.09	0.42
Sample Size	3	4

Some monitored procedures do not appear in the above tables as insufficient numbers of patients have been monitored. The highest ESD recorded (4Gy) was for a patient undergoing a Renal PTA and Aortic Stent Graft.

A more simple method of monitoring ESD would be to establish a relationship between measured ESD and DAP reading or fluoroscopy time. Correlation was determined through an ordinary least squares regression model. No correlation between ESD and DAP data was obtained for cardiac PTCA procedures. Some degree of correlation between ESD and fluoroscopy time for general interventional procedures was found ($R^2 = 0.75$, 16 patients) and between DAP and ESD readings for neurological procedures using a 20cm field of view ($R^2 = 0.87$, 10 patients).

5. Assessment of Monitoring Equipment

5.1. Thermoluminescent Dosemeters (TLD)

Each TLD was measured to be within 6% of the mean for each batch. TLD arrays were considered the most consistent and accurate means of measuring ESDs. Consequently, the SDM was compared against them. In addition, TLD arrays were the method of choice by clinical staff. However, TLD arrays suffer from the substantial drawback of requiring labour intensive post-exposure processing. Obviously, this will lead to delays before ESDs are available for assessment.

5.2. McMahon Medical 'Skin Dose Monitor' (SDM) Model 104-101

The SDM was placed on a phantom at the centre of the field together with a calibrated ionisation chamber and readings were compared. The SDM and chamber response agreed at ≥90 kV but deviated at lower kVs. Monitor reproducibility was within ± 1% over a five-hour period. Stability was also tested and was found to agree with specifications. In the clinical environment, the SDM was simple to operate. However, the fixing bracket designed to allow the electrometer to be attached to the table rail was inconvenient and not used. Instead, clinical staff tended to position the meter on the table.

5.3. PTW M4-KDK DAP Meter

The M4-KDK was found to have a similar uncertainty in its response to that of conventional DAP meters. There was a slightly greater dependence of response with field area at field sizes less than 200 cm^2.

6. Discussion

During cardiac procedures, the majority of patients received skin doses below the level of 1 Gy. Results for neurological procedures show that monitoring every patient may not be necessary for angiograms but routine monitoring of GDC coilings and embolisations should be carried out. ESD values show the highest skin doses occurring during general interventional procedures with most readings either approaching or exceeding 1 Gy. Although routine monitoring is carried out by a DAP meter, the ESD is not usually known. The results show that routine ESD monitoring should be considered, particularly for patients undergoing multiple procedures. Although the threshold for transient erythema is recognised to be 2 Gy, individual sensitivities may vary[5]. Therefore ESDs greater than 1 Gy should be recorded.

Correlation between ESD and DAP or fluoroscopy time could not be established for certain. The best correlation between DAP and ESD seemed to be for neurological examinations. This is not surprising since these examinations are unlikely to have large variations in field size. On the whole, the correlation of DAP and measured ESD seems relatively poor. Therefore, monitoring ESD, in addition to DAP and fluoroscopy time is necessary for interventional procedures where there is a risk of high

skin doses. However, the use of DAP to monitor threshold values should not be discounted, especially if threshold values can be set for individual centres and for specific examinations. The validity of this approach will probably need to be established locally.

The most reliable method for monitoring skin dose was the use of TLDs. This was the most popular method with clinical staff, although the slowest method, perhaps best suited to 'sample monitoring'.

The SDM compared favourably with a calibrated ionisation chamber in the laboratory. It was easy to use and produced a real time running total of the ESD. However, there were a number of significant issues surrounding its design. The sensor had a small surface area and therefore monitored a limited area of the skin. The success of the result was highly dependent upon the skill of the radiographer in positioning the monitor correctly. This was not always possible. The bracket supplied with the SDM was too bulky and was not used by any of the departments. The fibre optic cables are fragile and in practice, should be replaced more often than recommended. Cables were crushed underfoot or were coiled too tightly by staff. In some procedures, the weight of the patient reduced the life of the cable significantly due to crushing. Many procedures produced zero readings, attributable to cable damage.

The PTW M4-KDK proved difficult to place since most fluoroscopy units had an integral DAP meter and did not have the required rails at the output face of the tube. Consequently, this method will be unsuitable for some departments. Laboratory results show that corrections may be required at field sizes less than $200cm^2$.

7. Conclusion

The periodic assessment of ESD is strongly encouraged. The most suitable method for this would seem to be TLD arrays. This method also seems to be favoured by clinical staff. However, TLD arrays are not suitable for continuous monitoring of, for example, general FGIPs. Instruments such as a twin chamber DAP meter or a SDM, design and positioning considerations apart, should be more suitable for this application especially if used only to provide an early warning of potential skin injury. In addition, it may be possible to set threshold DAP readings locally for specific examinations to alert clinical staff of the potential for a skin injury.

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ESTIMATION OF SKIN DOSE IN INTERVENTIONAL NEURO AND CARDIAC PROCEDURES

P J Marsden, Y Washington† and J Diskin§*

* Department of Medical Physics and Bioengineering, UCL Hospitals NHS Trust, London, England.
† Department of Imaging, UCL Hospitals NHS Trust, London, England.
§ Formerly UCL Hospitals NHS Trust, now at The Walton Centre for Neurology and Neurosurgery, Liverpool, England

Fax: +44 20 7679 6455. Email: pmarsden@medphys.ucl.ac.uk

Abstract
The dose thresholds for inducing deterministic effects such as erythema and epilation are now within the range of some interventional radiology procedures. It is important to identify those procedures where such dose levels are possible so that more detailed dosimetry and dose reduction can be introduced to minimise the risk of such effects. This paper presents results of work on anthropomorphic phantoms to establish a link between a commonly measured dose indicator (dose-area product) and skin dose, for equipment and geometries commonly used for cardiac and neurological interventional radiology procedures. The results indicate that a conversion to skin dose is equipment specific and furthermore depends on field size and projection. By auditing a sample set of patient data, however, it is possible to identify potentially high dose procedures.

1 Introduction

The increased use of radiology for the guidance of interventional procedures, and the increase in complexity of such use, has led to higher patient doses in recent years, with reported cases of deterministic effects in patients [1,2]. The US Food and Drug Administration (FDA) have issued guidance for those procedures where there is a likelihood of significant skin doses [3]. Implementation of the Medical Exposures Directive [4] in member states of the European Union requires us to define standard operating protocols and to apply reference doses to diagnostic (including interventional) procedures.
This paper presents measurements made on anthropomorphic phantoms which can be used to link dose area product (DAP) values to skin dose for situations typically encountered in both interventional neuroradiology and cardiac procedures.

2. Method

For both cardiac and neurological procedures typical exposure conditions were set up by experienced operators on dedicated radiology equipment. In each case the patient was represented by an appropriate Temex anatomical phantom comprising a skeleton encased in rubber. For the chest phantom there were appropriate air cavities to represent the lungs. Skin doses were measured directly using a Skin Dose Monitor (SDM supplied by McMahon Medical) placed on the entrance surface at the centre of the field of view. DAP readings were obtained simultaneously from pre-installed meters (Diamentor, PTW).
Cardiac measurements were performed on an Advantx LC+ (General Electric Medical Systems). Neurological measurements were performed on an angiographic biplanar system (Toshiba Medical Systems) and on an Advantx single plane system (General Electric Medical Systems). Measurements were taken for various geometric configurations and at all field sizes and dose and fluoroscopy pulse rates in normal clinical use.

3. Results

The skin dose measurements from the cardiac system are presented in Table I, and from the neuro systems in Tables II (single plane) and III (biplane).

Table I: Entrance Surface Dose Rates in Cardiac Fluoroscopy.

Projection	mGy/min for field size of diameter:		
	23cm	15cm	11cm[a]
PA	2.4	4.2	18.4
RAO 30^0 + 25^0 CAU	3.0	3.6	10.0
RAO 10^0 + 10^0 CAU	2.0	3.4	13.8
Lateral	18.8	23.0	56.0
LAO 45^0	3.2	4.4	10.8
LAO 45^0 + 25^0 CAU	6.2	9.2	27.2
RAO 30^0	2.4	3.2	9.4

[a] All fluoroscopy on the 11cm diameter field is performed using high detail mode, which was measured in separate tests to be 66% higher than the standard medium detail fluoroscopy mode.

Table II: Entrance Surface Dose Rates in Neurological Fluoroscopy Procedures (Single Plane System).

Projection	mGy/min for field size of diameter:		
	30cm	23cm	15cm
Lateral	3.0	6.0	15.4
PA (Townes)	-	4.4	11.6

Table III: Entrance Surface Dose Rates in Neurological Fluoroscopy Procedures (Biplane System).

Projection	mGy/min for field size of diameter:			
	30	23cm	15cm	13cm
PA (Townes)	3.2	6.4	10.8	17.8
OM	4.2	8.6	12.6	19.0
Obliques	2.0	3.6	7.2	13.6
Lateral	5.6	10.0	11.2	19.0
Lateral 11^0 CRA/CAU	-	8.6	9.6	-

In all cases the dose rate is seen to rise as the field size is reduced, and is higher for lateral projections, particularly of the thorax.

The biplane system used for neuro-angiography has the facility for dose reduction via pulsed fluoroscopy, with selectable pulse rates of 30, 15, and 7.5 pulses per second. The data presented in Table III above relates to continuous fluoroscopy. It was confirmed by separate measurements on a water phantom that the dose varies in direct proportion to pulse rate, with 30 pulses per second giving an entrance surface dose rate equivalent to that obtained with continuous fluoroscopy.

Simultaneous recording of Dose-Area Product or Dose-Area Product rate, enabled a conversion factor to be calculated from DAP to skin dose for each of the projections given above. These conversion factors are given in Tables IV, V and VI for cardiac, neuro (single plane) and neuro (biplane).

Table IV: DAP to Skin Dose Conversion Factors in Cardiac Fluoroscopy.

Projection	mGy per Gycm^2 for field size of diameter:		
	23cm	15cm	11cm
PA	4.67	7.63	10.93
RAO 30^0 + 25^0 CAU	4.11	6.64	9.33
RAO 10^0 + 10^0 CAU	4.13	6.37	9.53
Lateral	7.64	12.43	17.39
LAO 45^0	3.56	5.73	7.86
LAO 45^0 + 25^0 CAU	3.55	6.08	8.27
RAO 30^0	3.02	5.00	7.21

Table V: DAP to Skin Dose Conversion Factors in Neurological Fluoroscopy Procedures (Single Plane System).

Projection	mGy per Gycm^2 for field size of diameter:		
	30cm	23cm	15cm
Lateral	5.06	4.48	10.91
PA (Townes)	-	3.23	5.15

Table VI: DAP to Skin Dose Conversion Factors in Neurological Fluoroscopy Procedures (Biplane System).

Projection	mGy per Gycm^2 for field size of diameter:			
	30	23cm	15cm	13cm
PA (Townes)	2.47	4.13	7.62	12.29
OM	3.03	5.19	9.09	15.22
Obliques	1.71	3.03	5.60	9.54
Lateral	3.91	5.57	9.33	16.07
Lateral 11^0 CRA/CAU	-	5.33	8.47	-

Similar data was accumulated for angiographic runs with acquisitions at frame rates used commonly in clinical practice. DAP to skin dose conversion factors were found to be similar to those established for fluoroscopy with the same geometry.
Measurements confirmed that the conversion factors were independent of fluoroscopy dose rate and of acquisition frame rate.

4. Conclusions

The results presented above illustrate the variation that can occur in both skin dose rate and in the relationship between DAP and skin dose between equipment of different types and between different geometries on the same piece of equipment. In order to derive a reasonable estimate of skin dose based on DAP readings, it will be necessary to have details of the equipment used and of the proportion of total DAP at a given field size and projection. The ease with which such data could be recorded for a limited number of cases will depend on the complexity of the radiological technique. It would clearly be more difficult to achieve for a cardiac procedure than for neuro-embolisation where there is a more limited number of projections and field sizes used. Our results indicate that knowledge of dose rates or frame rates or of the fluoroscopy:acquisition ratio is not as significant. The values presented are for a typical adult sized patient and the variation with patient size or exposure parameter (kV or mA) has not been included.
These measurements were performed as part of an extended quality assurance programme focussing on equipment and procedures with the potential to deliver high dose rates to the skin of patients. In such cases it would be ideal to measure skin dose directly, but this can be expensive, labour

intensive, and inconvenient, particularly for complex cardiac procedures where the angulation of the X-ray beam, and thus the site of skin exposure, varies considerably. A large number of hospitals have adopted DAP as the unit for their dose reference levels in fluoroscopic procedures, making DAP data readily available. By the process of establishing conversion factors as described in this paper it is possible to identify those procedures which may result in high skin doses such that efforts at more detailed dosimetry and dose reduction can be targeted effectively. It is not intended that the derivation of skin dose from DAP values be used as an alternative to more direct methods of skin dose measurement.

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HOW WILL THE INTRODUCTION OF MULTI-SLICE CT AFFECT PATIENT DOSES?

Walter Huda[1] PhD and Patricia J Mergo[2] MD
[1]Department of Radiology, SUNY Upstate Medical University
750 E Adams St, Syracuse, NY 13210

[2]Department of Radiology, University of Florida
Gainesville, FL 32610
[WH FAX (315) 464 7068; Email hudaw@mail.upstate.edu]

Abstract

Imaging protocols for patients undergoing CT examinations on a conventional single section scanner (GE CT/i) were compared with those developed after a multi-slice scanner (GE LightSpeed) was introduced into clinical practice. For multi-slice CT, the reduction in patient scan time was a more than a factor of two for head scans, and approximately 25% for body scans. The number of images available for review on the multi-slice CT system increased by approximately 40%. Use of this multi-slice CT scanner resulted in an effective dose of 1.2 mSv for head examinations and 9.1 mSv for body examinations. The increase in patient effective dose after the introduction of multi-slice CT was approximately 30% for head CT examinations and 150% for body examinations. Higher patient doses were due to a shorter CT geometry, x-ray beam profiles that are greater than the detector width, and the use of a pitch ratio of only 0.75. Since multi-slice CT offers major reductions in scan time as well as improved image quality, it is anticipated that both individual and collective doses from CT will continue to increase for the foreseeable future.

1. Introduction.

Multi-slice CT systems, which were introduced into routine clinical work in 1999 [1], significantly improve utilization of the x-ray tube output. These multi-slice systems typically use *multiple detectors* that can cover between 20 mm and 40 mm of axial distance, and can acquire four simultaneous sections for each 360° revolution of the x-ray tube. In this study, we investigated the how the introduction of multi-slice CT affected radiation doses to patients undergoing head and body CT examinations.

2. Method

2.1 CT scanners. We compared the protocols used for patients undergoing CT examinations on a conventional single section scanner (GE CT/i) with those introduced after a multi-slice scanner (GE[1] LightSpeed) was installed at the University of Florida. The single section scanner generated axial sections for head CT scans, whereas spiral CT was used for chest and abdomen examinations. The LightSpeed was operated in axial mode for head imaging, and in helical mode with a pitch ratio of 0.75 for body imaging (i.e., collimator is 20 mm & table increment of 15 mm per 360° x-ray tube rotation).

Computed Tomography Dose Index (CTDI) data are shown in summary form in Table 1. The CT/i dose data are for a section thickness of 10 mm, and the LightSpeed data are for four 5 mm

[1] General Electric Medical Systems, Milwaukee, WI.

sections (≡ 20 collimator thickness). These data show that for the same techniques (kVp/mAs), the LightSpeed has a 20% higher head dose and 40% higher body dose.

Table 1. CTDI doses for the CT/i and LightSpeed scanners (@ 120 kVp and 340 mAs).

Phantom size	Location	CTDI for CT/i	CTDI for LightSpeed
Head	Periphery	40 mGy	48 mGy
Head	Center	40 mGy	48 mGy
Body	Periphery	20 mGy	32 mGy
Body	Center	11 mGy	14 mGy

2.2 Spiral/Axial protocols. Head CT scans were performed at 120 kVp using axial scans. In the posterior fossa, 15 sections (3 mm thick) were obtained with a table increment distance of 5 mm, a tube current of 200 mA and a scan time of 2 seconds. The rest of the brain was covered using 8 sections (10 mm thick) with a table increment of 10 mm, a tube current of 140 mA and a scan time of 2 seconds.

Chest CT scans were performed at 120 kVp in helical mode with a pitch ratio of 1.5. In the shoulder region, approximately 10 x 7 mm sections were acquired using 400 mA and in the lung region, 50 x 7 mm sections were acquired using 230 mA. The scan time was 1 second, and the total coverage length (420 mm) required 41 rotations of the x-ray tube. Abdominal CT scans were performed at 120 kVp in helical mode with a pitch ratio of 1.5. A total of 36 x 7 mm sections were acquired using 320 mA and a scan time of 1-second which required 25 x-ray tube rotations.

2.3 Multi-slice protocols. With the introduction of multi-slice, CT imaging typically uses 4 x 5 mm thick detector which acquire data for four images in one rotation of the x-ray tube (1 second). Total z-axis coverage distance remained the same as for single slice CT, with all scans performed at 120 kVp. Head CT scans used 140 mA and 2 seconds and contiguous sections. Total axial distance covered (155 mm) requires 8 rotations of the x-ray tube. Chest CT scans have a 1-second scan time with the shoulder region using 400 mA and the lung region using 220 mA. The scan length of 420 mm requires a total of 29 rotations at a pitch of 0.75. Abdomen CT scans are performed using 240 mA and a 1-second scan time, and require 18 rotations of the x-ray tube.

2.4 Patient doses. Patients undergoing CT examinations were modeled as uniform cylinders of water with a diameter of 17.6 cm for the head [2], 21 cm for the chest [3] and 27.7 cm for the abdomen [4]. The mean dose for a single section for the CT/i was obtained using published Monte Carlo dosimetry data [5]. CT/i mean section dose data were scaled for the LightSpeed using a factor of 1.2 for head CT scans, and 1.4 for body CT scans.

Mean section dose data were used to compute the energy imparted for a single section [6] using CTDI data given in Table 1. The total energy imparted to a patient was obtained by taking into account the mAs, scanned section thickness and total number of rotations of the x-ray tube. Energy imparted was converted into the corresponding values of effective dose using conversion factors of 9.1 mSv/J for a head CT examination and 18 mSv/J for a body CT examination [7].

3. Results

3.1 Scan times/images. Table 2 shows the scan times and total number of images generated for the conventional and multi-slice CT scanners. For multi-slice CT, the reduction in patient scan time was a more than a factor of two for head scans, and 25% for body scans. The average number of images from the multi-slice CT system increased by approximately 40%.

Table 2. Scan times and # of images for spiral/axial and multi-slice CT.

Examination type	Spiral/Axial	Multi-slice
Head	~70 seconds/23 images	~30 seconds/32 images
Chest	~40 seconds/60 images	~30 seconds/84 images
Abdomen	~25 seconds/36 images	~20 seconds/50 images

3.2 Effective doses. Table 3 provides a summary of the effective doses for the three types of CT examination for the conventional and multi-slice CT scanners. Current multi-slice CT scanners result in average effective dose of 1.2 mSv for head examinations and 9.1 mSv for body examinations. The average increase in patient effective dose from the introduction of multi-slice CT was approximately 30% for head CT examinations and 150% for body examinations.

Table 3. Radiation dose summary for spiral/axial and multi-slice CT.

Examination type	Spiral/Axial	Multi-slice
Head	0.9 mSv	1.2 mSv
Chest	3.9 mSv	10.5 mSv
Abdomen	3.5 mSv	7.7 mSv

4. Discussion.

Published CTDI doses for the LightSpeed are between 20% and 40% higher, which is partly due to a shorter geometry. The increased CTDI value is also due to the use of wide x-ray beam profiles which are needed to maintain a constant radiation dose for an irradiated section whilst the focal spot moves during the rotation of the x-ray tube [1, 8]. In the future, it can be expected that the multi-slice CT systems will be designed to have collimation systems that move with the focal spot size [8], which will help ensure that no unnecessary radiation is incident on the patient.

Another important reason for higher patient doses on the LightSpeed system is because of the use of a low pitch ratio in helical scanning (i.e., 0.75). The LightSpeed system offers a pitch ratio of 1.5, and use of this scanning mode would reduce patient effective doses by a factor of two! In the future, it is likely that pitch ratios $\geq$ 1.0 will be used, which will help to reduce patient doses. Nonetheless, patient doses for multi-slice CT will still likely be larger than for single slice CT systems. Multi-slice systems have thinner sections, and the mAs will need to be increased to maintain a constant level of quantum mottle. In addition, the increased utilization of the x-ray tube output results in shorter scan times allowing higher tube currents to be used.

In the United Kingdom, CT examinations have been reported to account for 4% of all radiographic examinations, yet account for up to 40% of the collective dose from medical exposure [9]. It is notable that multi-slice CT reduces scan times, improves z-axis resolution and provides the radiologists with more images. In the future, CT scans performed on a given patient are therefore likely to use more radiation (e.g., multi-phase liver scans or general body surveys). In addition, the improved imaging performance will also serve to have CT replace conventional radiographic examinations [10, 11]. The data presented here indicate that individual and collective patient effective doses from CT examinations are likely to continue to increase for the foreseeable future. It is therefore important that the radiology profession reviews patient

scanning protocols to ensure that patient exposures are justified by the diagnostic information that is obtained during CT examinations, and that all radiation doses are kept as low as reasonably achievable (ALARA).

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PATIENT DOSES IN DIGITAL CARDIAC IMAGING.

Walter Huda[1] PhD
Kishor Phadke[2] MD
Kent M Ogden[1] PhD
Marsha L Roskopf[1] BS

Departments of Radiology[1] and Medicine[2]
SUNY Upstate Medical University
750 E Adams Street, Syracuse
NY 13210, USA

[WH FAX (315) 464 7068; Email hudaw@mail.upstate.edu]

Abstract

In this pilot study, we obtained estimates of entrance skin doses and the corresponding effective doses to patients undergoing *digital* cardiac imaging procedures on a GE Advantx LC/LP Plus system. Data were obtained for six patients undergoing diagnostic examinations and six patients who had interventional procedures. For each patient examination, radiographic techniques for fluoroscopic and digital cine imaging were recorded, together with the irradiation geometry. The projection with the *highest* exposure resulted in an average skin dose of 0.64 ± 0.41 Gy (maximum of 1.6 Gy). The average patient skin doses taking into account overlapping projections was 1.1 ± 0.8 Gy (maximum of 3.0 Gy). The exposure area product (EAP) incident on the patient was converted into the energy imparted to the patient and the corresponding effective dose. The average patient effective dose was 28 ± 14 mSv (maximum 62 mSv), with the resultant average fatal cancer risk estimated to be of the order of 8×10^{-3}. Average doses for interventional procedures in cardiac imaging are higher than those associated with diagnostic examinations by approximately 50%.

1. Introduction

Cardiac imaging is recognized as a procedure that results in relatively high patient doses [1]. Cine film is currently being replaced by *digital* x-ray imaging equipment, and the resultant images are increasingly being viewed using (soft copy) display stations. It is therefore of interest to obtain doses to patients who undergo *digital* cardiac imaging procedures, and to produce quantitative estimates of the corresponding patient radiation risks.

In this pilot study, we quantified the entrance skin doses that predict the possibility of inducing a deterministic effect to the skin, as well as patient effective doses that quantify the stochastic risk of inducing cancer and genetic effects. Cardiac imaging may be performed for obtaining a diagnostic information (i.e., diagnostic) or during procedures that attempt to treat the patient (i.e., interventional), and data were obtained for both types of examination.

2. Method

2.1. Cardiac imaging workload.

Each year, about 860 diagnostic examinations and 160 angioplasty examinations are performed in the catheterization suite at University Hospital, Upstate Medical University, Syracuse NY. The imaging is performed on a GE Advantx LC/LP Plus[1] system that was installed in 1999. In this pilot study, data was collected on twelve randomly selected patients undergoing digital cardiac imaging. Six patients underwent diagnostic examinations and the other six patients underwent interventional procedures (e.g., angioplasty).

X-ray beam characteristics were measured at the x-ray tube potential used clinically. The x-ray output was determined in terms of air kerma (μGy) per unit mAs, where an exposure of 1 R (2.58×10^{-4} C kg^{-1}) corresponds to an air kerma of 8.73 mGy. For the frontal plane operated at 80 kVp, the measured output at 60 cm was 130 μGy/mAs at a distance of 60 cm, and the corresponding Half Value Layer was 3.4 mm Al.

2.2. Skin doses.

In fluoroscopy, information was recorded for the selected x-ray tube potential (i.e., kVp), tube current (mA) and total fluoroscopy time. In digital imaging, information was recorded for the average x-ray tube potential (kVp), tube current (mA), exposure time per frame (s), and the total number of image frames acquired.

The source to patient skin distance was determined from the source to image receptor distance (SID), together with the air gap between the patient and the image intensifier. Patients were modeled as elliptical cylinders with dimensions of 27 cm (Anterior-Posterior) and 40 cm (Lateral).

Data were recorded for each separate projection. For any patient, the projection with the maximum skin dose was termed projection 1, the second highest skin dose was projection 2 and so forth. Since it is inappropriate to arithmetically sum all entrance skin doses [2], we explicitly estimated the *maximum* skin dose by taking into account any overlap of the x-ray projections used for each patient [3].

2.3. Effective doses.

Data on the image receptor size and x-ray tube output permitted the exposure-area product (EAP) incident on the patient to be determined. The EAP was converted into the corresponding value of energy imparted taking into account both the x-ray beam quality (HVL) and the patient thickness [4], with the effective density in the cardiac region taken to be 800 kg m^{-3}. Values of energy imparted were converted into effective doses using a conversion factor of 19 mSv J^{-1}, which is a representative value of the effective dose per unit energy imparted in cardiac imaging [5].

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3. Results & Discussion

3.1. Skin doses.

Table 1 summarizes the entrance skin doses for the twelve patients included in this study. Data in Table 1 show that the entrance skin doses falls off rapidly with projection number. For example, the mean dose for the fifth projection was <20% of the value of the average dose for projection 1.

Table 1. Entrance skin dose (Gy) summary for twelve patients, when *no* account is taken of any overlap of different projections.

Projection	# of patients	Mean ± σ	Minimum	Maximum
1	12	0.64 ± 0.41	0.28	1.6
2	12	0.48 ± 0.35	0.12	1.4
3	12	0.23 ± 0.11	0.07	0.47
4	7	0.21 ± 0.14	0.03	0.44
5	5	0.11 ± 0.08	0.02	0.21

For most patients, there was some overlap of entrance skin doses between adjacent projections (e.g., PA & RAO 45° or LAO 45° & LAO 25°). Taking into account projection overlap, the average *maximum* skin doses was 1.1 ± 0.8 Gy. The highest *maximum* skin dose was 3.0 Gy, and the lowest *maximum* skin dose was 0.38 Gy.

3.2. Effective doses.

The average effective dose for digital cardiac imaging was 28 ± 14 mSv. The minimum patient effective dose was 7.8 mSv and the maximum patient effective dose was 62 mSv. The nominal radiation risk coefficient for an adult working population is taken to be 4% per Sv [6]. Taking into account the demographic data for patients undergoing medical examinations would likely reduce the radiation risk. In this study, we used a risk reduction factor of ~0.34 as a representative value for a population undergoing x-ray studies [7]. The average stochastic risk of inducing fatal cancer for patients undergoing digital cardiac imaging is therefore of the order of 8×10^{-3}.

3.3 Diagnostic examinations vs Interventional procedures.

The data in Table 2 show average dose parameters for patients undergoing diagnostic examinations and interventional procedures. Average doses for interventional procedures are higher than those associated with diagnostic examinations by approximately 50%. It is also notable that the variability in patient doses is considerably higher for interventional procedures than for diagnostic procedures.

Table 2. Comparison of patient doses between diagnostic and interventional procedures.

Dose parameter	Diagnostic procedures	Interventional procedures
Effective dose	23 ± 4 mSv	33 ± 19 mSv
Projection 1 skin dose	0.54 ± 0.20 Gy	0.74 ± 0.56 Gy
Maximum skin dose	0.84 ± 0.20 Gy	1.3 ±1.0 Gy

4. Conclusions.

Digital cardiac imaging results in relatively high skin doses and effective doses. The highest skin doses observed in this study are comparable to threshold doses for the induction of deterministic effects such as skin erythema [8]. Effective doses in cardiac imaging are much higher than those encountered in most areas of diagnostic radiology and nuclear medicine [1, 9].

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Administered Activity and Estimated Radiation from Nuclear Medicine Diagnostic Procedures to the Israeli Population

Jolie Weininger, Avi Ben Shlomo, Jean Koch, Yair Shamai and Tuvia Schlesinger
Radiation Safety Division, Soreq NRC, Israel

Abstract

The distribution of administered activity levels for nuclear medicine diagnostic procedures and their contribution to the radiation doses to the Israeli population in 1998-2000 were analyzed. Diagnostic reference levels and the concept of collective effective dose per capita are discussed as a way to optimize patient protection.

Introduction

In connection with an IAEA supported project aimed at developing a national program for radiation protection of the patient in diagnostic investigations, we previously reported radiation doses resulting from nuclear medicine imaging in Israel, in 1998 [1].
The contribution of nuclear medicine diagnostic investigations to the radiation doses to the population in Israel was estimated by using the effective dose and effective dose per capita concepts[2].
About 3% of the Israeli population underwent nuclear medicine diagnostic procedures in 1998, resulting in a contribution of about 1,800 person-Sv to the collective effective dose. Consequently, the effective dose per capita, due to nuclear medicine procedures, was estimated to be 0.3 mSv.
In nuclear medicine procedures the radiation dose to the patient is a function of the amount of the administered radiopharmaceutical and its body distribution. Therefore, in order to determine the source for the relatively high effective dose per capita to the Israeli population, and to advise possible ways to lower it, in the present work, we analyze the current levels of administered activity of radiopharmaceuticals in several common nuclear medicine diagnostic procedures. We also compare our results with the guidance levels published in the Basic Safety Standards (BSS) [3] and with data published by UNSCEAR 2000[4] for countries of health care Level I (1991-1996).

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Materials and Methods

Thirteen out of more than thirty functioning nuclear medicine and/or nuclear cardiology clinics supplied us with information about the radiopharmaceuticals used, the administered activity (AA) per procedure and the relative number of examinations performed in the period 1998-2000. Our results are derived by averaging and extrapolating these data.
The distribution of AA per procedure in the clinics surveyed was recorded and averaged, and the resulting effective doses were calculated.

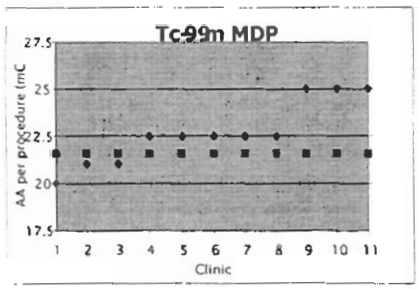
For a more accurate evaluation, when relevant, data available about single doses of radiopharmaceuticals purchased in one of the functioning central radiopharmacies, were also analyzed.
The effective doses were calculated based on the conversion tables presented in ICRP Publication 80[2].
Data related to the following eight radiopharmaceuticals, commonly used for diagnostic imaging procedures in Israel, were analyzed:

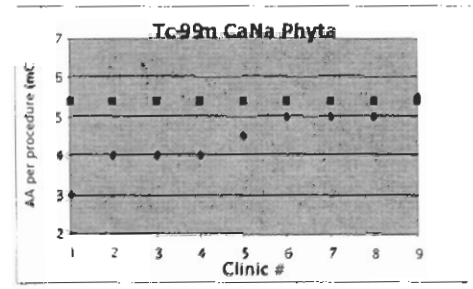
1. Tc-99m methylene diphisphonate (MDP) - bone imaging
2. Tc-99m calcium sodium phytate (CaNaPhy) - liver imaging
3. Tc-99m red blood cells (RBC) - blood pool imaging
4. Tc-99m macroaggregated albumin (MAA) - lung imaging
5. Tc-99m DTPA - kidney imaging
6. Tc-99m Sestamibi – myocardium imaging
7. Tl-201 chloride – myocardium imaging
8. Ga-67 citrate – tumor and inflammation imaging.

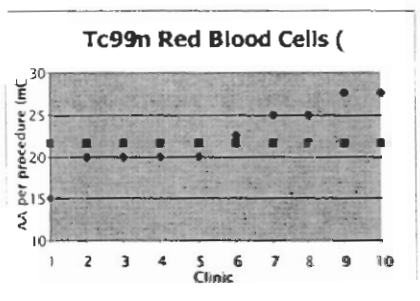
Results

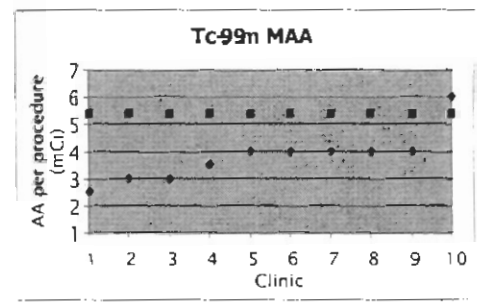
The eight radiopharmaceuticals we studied cover >90% of all nuclear medicine diagnostic imaging procedures, between the years 1998–2000 in Israel. The average administered activity of those radiopharmaceuticals per procedure in the various surveyed Israeli clinics and, for comparison, the corresponding BSS guidance level values are shown in Fig.1.
Table 1summarizes the current administered activity of radiopharmaceuticals per procedure (average, minimum and maximum) in Israeli clinics, the corresponding BSS guidance values and the UNSCEAR data for health care level I, the deviations of the normalized average Israeli data from these values (%) and the resulting calculated effective doses (mSv/procedure).
An uncertainty of up to 25% of all our estimates should be taken into account.
The range of the resulting absorbed doses per procedure in Israel is relatively wide: from less than 1 mSv for some procedures using Tc-99m to more than 30mSv for those using Ga-67 and Tl-201, but in good agreement with both BSS and UNSCEAR data.

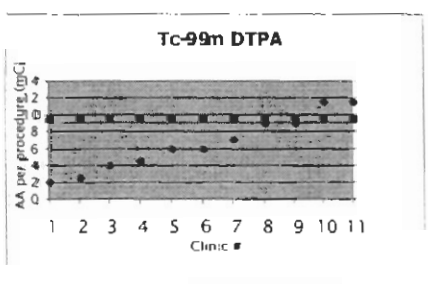
Fig. 1: The average administered activity (AA) of radiopharmaceuticals per procedure in Israeli clinics (1998-2000) and the corresponding BSS levels

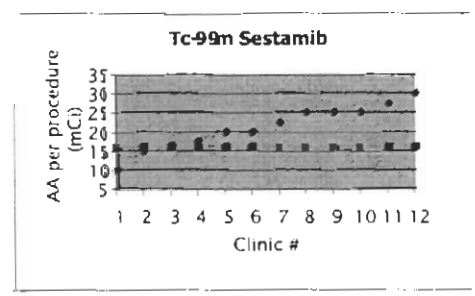


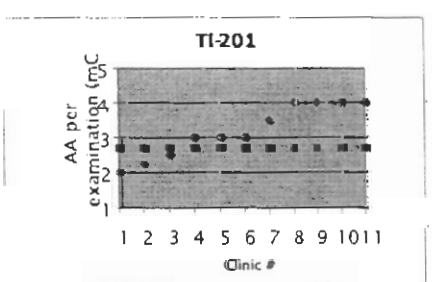












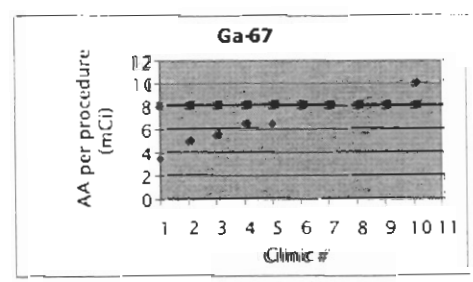


Table 1: Current Administered Activity in Common Nuclear Medicine Diagnostic Procedures and the Resulting Effective Doses per Procedure in Israeli Clinics (1998-2000) Compared to the Corresponding BSS Guidance Levels[3] and to the UNSCEAR Data for Health Care Level I[4]

Radiopharmaceutical	Average Administered Activity per procedure (mCi)			Deviation of the normalized average from BSS	Deviation of the normalized average from UNSCEAR	Effective dose per procedure[2] (mSv)		
	Israel (min – max)	BSS[3]	UNSCEAR[4]			Israel (min – max)	BSS	UNSCEAR
Tc-99m MDP	22.9 (20-25)	21.6	19.4	+ 6%	+13%	4.8 (4.2-5.3)	4.6	4.5
Tc-99m CaNaPhytate	4.6 (3-5.5)	4.5	3.8	- 14.2%	+23.8%	2.4 (1.6-2.9)	2.3	1.7
Tc-99m RBC	22.5 (15-27.5)	21.6	6.8 – 29.8	+ 4%		5.8 (3.9-7.1)	5.6	2.9 – 8.0
Tc-99m MAA	4 (2.5-6)	5.4	3.2	- 17.4%	+20.3%	1.6 (1.0-2.4)	2.2	1.5
Tc-99m DTPA	7.6 (2-11.5)	9.5	4.9	- 10.5%	+43%	1.4 (0.4-2.1)	1.7	1.5
Tc-99m Sestamibi	21.3 (10-39)	16.2	16.8	+ 31.5%	+32.8%	6.7 (3.2-9.4)	5.1	7.6 - 10
Tl-201 chloride	3 (2-4)	2.7	2.7	+11%	+16.8%	24.4 (16.3-32.6)	22.0	6.9 – 20 3
Ga-67 citrate	7 (3.5-10)	8.1		-13.6%		31.1 (15.6-44.4)	36.0	

Discussion

The three basic principles of radiation protection for all types of diagnostic investigations, as recommended by the International Commission on Radiological Protection (ICRP), are justification, optimization of protection and dose limits. The dose limit concept is implemented for keeping the radiation dose to the patient as low as reasonably achievable (ALARA), while providing the necessary clinical information. For this purpose the use of diagnostic reference levels was recommended [3,5,6].

It must, however, be taken into account that the diagnostic reference level is an instrument for optimization, for improvement of the radiation protection situation of the patient, but it is not necessarily the same as a strict technical optimization.

In its Basic Safety Standards[3], the IAEA includes guidance levels of activity. These guidance levels are considered to be the same as the reference levels and the maximum usual activities in nuclear medicine investigations for a typical adult patient.

The average activities administered in nuclear medicine diagnostic procedures, for the surveyed clinics in Israel in 1998-2000, were close to the BSS guidance levels: deviations between –17 and +11% for all radiopharmaceuticals, except Tc-99m Sestamibi, where the deviation was about + 30%. Compared to the corresponding values published in the UNSCEAR 2000[6] for countries of health care Level I (1991-1996), average AA higher between 13 to 43% were reported in Israel.

The value reported in the UNSCEAR 2000 for the average effective dose per capita, for countries of health care Level I, was 0.08 mSv, which is low compared with 0.3 mSv, calculated by us, for the Israeli population in 1998. To determine the source of this difference, we analyzed the contribution of the different diagnostic procedures to the average effective dose per capita in Israel and compared them with the UNSCEAR results.

Of the total number of nuclear medicine procedures performed in Israel in 1998, 41.4% (compared with 26% reported in the UNSCEAR) was bone imaging. This procedure contributed to the collective effective dose by 19.6%. The normalized average dose for Tc-99m MDP procedures in Israel exceeded the average UNSCEAR administered activity by 13.6%.

In the same period, of the total number of procedures, 22.5% was myocardial imaging using Tl-201 chloride and 5.6% using Tc-99m Sestamibi. The contribution to the Israeli collective effective dose of the procedures using Tl-201 was 62%, and 4.4% of the Tc-99m Sestamibi procedures. The normalized average administered activity for Tl-201 in Israel exceeded.the respective average UNSCEAR value by 20.2%.

In Israel, for both, Tc-99m MDP and Tl-201 chloride, procedures, the annual number per 1,000 population was, in the period mentioned, higher than in the UNSCEAR: 12.42 compared with 5.85 for bone imaging, and, respective, 6.75 versus 0.007-1.88 for cardiovascular Tl-201 imaging procedures. The above mentioned procedures are the main contributors to the relatively high average effective dose per capita from diagnostic nuclear medicine procedures. The above mentioned differences are the reason for the discrepancy in the average effective dose per capita between Israel and UNSCEAR.

Two approaches may be considered with the aim of improving the radiation protection of the patient: the choice of the radionuclide /radiopharmaceutical to be administered

and lowering the administered activity to the patient as reasonably as possible, while preserving the diagnostic accuracy. However, the activity administered to patients may not be varied, i.e. lowered, too much without decreasing the diagnostic accuracy. But, similar procedures using different radionuclides / radiopharmaceuticals may result in very different radiation doses to the patient.

An example of a significant reduction of the radiation dose to the patient for myocardial imaging is the replacement of procedures post administration of 4 mCi Tl-201 chloride, with two studies (one at rest and one under stress) using a total of 30 - 50 mCi Tc-99m Sestamibi. For a wide range of pathologies, clinical studies generally proved that those procedures provide similar diagnostic information [7-11]. The above mentioned administered activity levels result in an effective dose of 34.1 mSv for Tl-201 and of 9.6-16 mSv for the Tc-99m Sestamibi procedures. Consequently, by replacing Tl-201 by Tc-99m imaging, the radiation dose to the patient per procedure could drop by 53-72%. The lower effective dose to the patient is one of the several reasons why more and more myocardial studies using Tc-99m are reported in the literature.

For example, in the analyzed frame, if Tl examinations would have been replaced, when possible, (in the majority of the cases it was), by Tc-been decreased by at least 730 person-Sv, resulting in an average effective dose per capita of 0.18mSv .

Conclusions

1. The current level of activity of radiopharmaceuticals administered to the patient per nuclear medicine diagnostic procedure in Israel is in good agreement with the BSS reference levels: except for Tc-99m Sestamibi, where it is about 30%; for all the procedures the deviations are between –17 to +11%.

2. The average AA per nuclear medicine diagnostic procedure in Israel, in 1998-2000, exceed the corresponding values as published in the UNSCEAR 2000 for countries of health care Level I (1991-1996), by 13 – 43%.

3. The effective dose per capita to the Israeli population resulting from nuclear medicine diagnostic procedures is relatively high, mainly because of the frequent use of high activity Tl-201 procedures.

4. By replacing, when possible, myocardial imaging with Tl-201 by Tc-99m agents, the radiation dose per procedure can be significantly lowered.

5. The guidance level of activity administered per procedure alone cannot assure the optimization of the dose to the population.

6. For a comprehensive evaluation of the radiation protection for diagnostic investigations of a certain population, the effective dose per capita should be used in addition to the guidance level of activity administered per procedure.

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Ten years investigation on radiological exposures to the embryo and fetus in pregnant women of Iran

Azim Arbabi
Department of Radiation Protection, Atomic Energy Organization of Iran.
Department of Radiation Oncology, Shaheed Beheshti University of Medical Sciences,
P.O. Box 17115-137 Tehran, Iran. E-mail: aarbabi@hotmail.com

Abstract

Over 1340 Iranian pregnant patients, exposed to diagnostic x-rays during 1984 to 1994, referred to me for investigation and estimation of the absorbed dose to their embryo or fetus. They were almost all the patients exposed to x-rays in the whole country in 10 years. Two sets of questioner filed for each patient and all the exposing condition and setting information obtained from the radiology centers concerned. The absorbed dose to embryo or fetus accurately calculated and in some cases measured in a phantom for each patient.
The youngest patient at the time of irradiation was 15 and the oldest was 51 with an average of 28.624 $\pm$ 5.961 years old.
The AP and lateral thickness of patient's abdomen on average were 18.078$\pm$ 0.162 cm and 24.630$\pm$8.365 cm respectively. The average weight of patients was 59.285$\pm$12.945 kg. ranging from 30 kg to 122 kg. The marriage age of the patients on average was 19.398$\pm$4.107 years ranging from 9 to 42 years old. The average age of fetus when exposed to x-rays was 31.22$\pm$18.76 days. About %20 of the patients had exposures in 2 to 4 more sessions.
The average fetal dose was 0.68$\pm$0.381 cGy with over %37 from 1 to 9 cGy.

Introduction

There have been great concern and anxiety amongst many pregnant patients exposed to ionizing radiation on the fate of their fetus over the last century. The sensitivity of the human embryo and fetus to ionizing radiation is an important topic in radiation protection. Observations on patients exposed to ionizing radiation during pregnancy as well as extensive experimental investigations on mammals have greatly increased our understanding of the effects induced when the mammalian embryo and fetus are irradiated. It is evident, in consequence, that ionizing radiation must be considered to be a teratogenetic agent [1, 2, 3, 4 & 5]. The sensitivity of the embryo to ionizing radiation depends on the day of gestation on which it has been exposed [6]. Epidemiological studies have indicated that exposure of pregnant women to diagnostic x-rays can increase the risk of induction of the late effects (cancer) in the children [7]. Besides, exposure of embryo or fetus to moderate doses of ionizing radiation can cause death, malformation, growth retardation and functional impairment. Information from Hiroshima indicates that measurable damage can be produced by doses of 10-19 cGy. [8] . Here I present only a part of a considerable amount of data obtained and filed over a period of 10 years (1984-1994). These data related to almost all pregnant patients in Iran. They were exposed to

diagnostic x-rays and referred to me for investigation, measurement and calculation of the absorbed dose to their embryo or fetus. The results reported to the authorities and the referring physician. In very rare cases, when the amount of absorbed dose was considerably high, therapeutic abortion recommended.

1

Materials and Methods

During the 10 years, on average 3 patients together with their spouses visited and two questioner forms completed for each patient. The information obtained were:

1- Name, age, education, occupation, address and the telephone number of the patient.
2- Date of the last menstrual period (LMP), pregnancy test, weight and the thickness of the irradiated part of the patient's body.
3- The name of radiology center, the exact date of irradiation and the age of embryo or fetus at the time of irradiation.
4- The date of marriage, blood group, addictions (if any), contraceptives used and other family relation with the spouse.
5- Number of previous pregnancies, number and age of present children, history of any previous abortion and early delivery of any child.
6- History of other previous illnesses of the patient, the spouse and their first grade relatives.
7- Previous treatments and the drugs taken by the patient and her spouse.
8- Age, education, occupation, addiction (if any) and the blood group of the patient's spouse.
9- The total dose absorbed (in cGy) by the embryo or fetus during the radiological procedures.

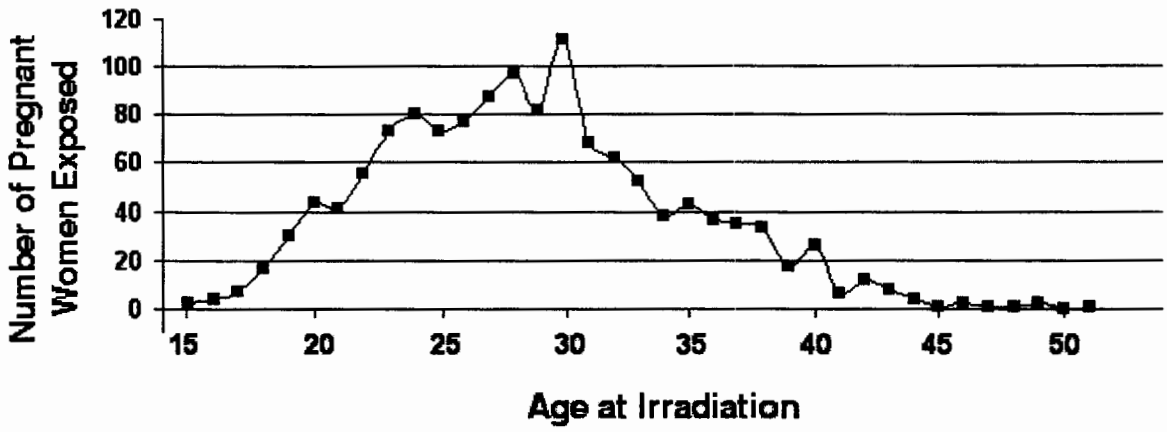
All the information obtained stored in a database using Fox Pro2 and the statistical analysis of each variable performed by SPSS/PC + vers. 3.0 software.

Results

Some of the results, which seems to be useful and relevant to this conference presented as following and the rest to be published in another paper:

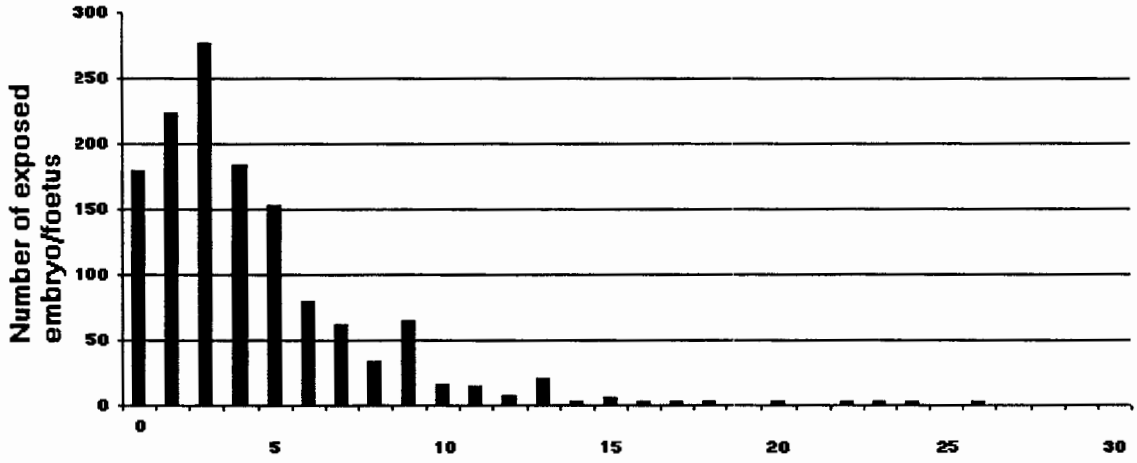
Patients Age:

Figure 1 shows the age distribution of the pregnant patients at the time of irradiation. The average age is 28.624±5.961. The age of the youngest patient was 15 and the oldest was 51 years.



Gestation Age:

The mean age of embryo or fetus at the time of irradiation was 31.22±18.76 days, the youngest was 7 and the oldest was 191 days. Figure 2, shows the gestation age distribution of the embryos and fetuses at the time of the irradiation.



Embryo or fetus absorbed dose:

As shown in Figure 3, the highest occurrence (%37.8) of absorbed dose to fetus is from 1 to 9 cGy and for absorbed dose from 0.1 to 1 cGy is %31.54. The mean fetal absorbed dose was 0.68+0.381 cGy.

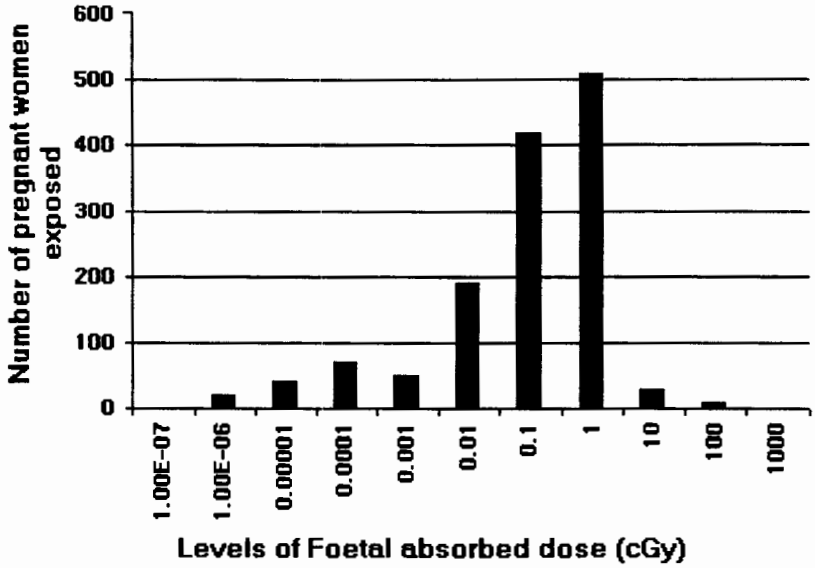


Figure 3. The absorbed dose by embryo and fetus during the radiological procedures (N =1341).

3

Discussion and Conclusions

The main reasons for the patients to undergo radiological examinations were:

1) Non malignant gastrointestinal problems (%32.75), where in most of the cases radiological examinations were not necessary and the cause illness had been the pregnancy itself.

2) Non malignant urologic problems (%19.44). 3) Back pains (%14.31).

4) Orthopedic problems (%11.83). 5) Accidents (%8.07).

6) Non malignant glandular problems except diabetes (%6.97)

The problem of lack of modern radiological systems in developing countries could also lead to higher doses in the patient's investigation.

The majority of the patients were not aware of their pregnancy before undergoing radiological examinations and the most of the radiologists did not consider it seriously. Otherwise in many of the above cases the radiological examinations could have ruled out or postponed to after the childbirth.

The health effects to be expected from the low levels of exposure prevalent in diagnostic radiology will not be observable in the short term. They will be delayed by some years and will usually be indistinguishable from those arising from other causes, rendering it difficult to pin-point their origin. Knowing the radiation effects, a great anxiety observed amongst the majority of the patients and their families for the fate of the child. Many of them decided to commit illegal abortion privately, even if the fetus absorbed dose was negligible.

These facts and the above figures show that we needed and could eliminate or reduce the patients dose and consequently the absorbed dose to the embryo or fetus considerably.

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Dosimetric Assessment of Swallowing Examinations with Videofluoroscopy

M.M.B. Costa, D.Sc.*; L.V. Canevaro, D.Sc.**, A. C. P Azevedo, D. Sc., ***

*Laboratório de Motilidade Digestiva/Imagem, Departamento de Anatomia do ICB, e Laboratório de Videofluoroscopia do Serviço de Radiodiagnóstico do HUCFF, CCS, UFRJ, 21941-590 Rio de Janeiro, Brasil, mcosta@anato.ufrj.br

**Laboratório de Ciências Radiologicas, Departamento de Biofísica e Biometria Instituto de Biologia, UERJ, Rio de Janeiro, Brasil, canevaro@lcr.uerj.br

***Departamento de Radiologia, Faculdade de Medicina, Universidade Federal do Rio de Janeiro, HUCFF, 21941-590, Rio de Janeiro, Brasil, anacecilia@hucff.ufrj.br

Dosimetric analysis measurements of the Dose-area-product (DAP) of 7 individuals were estimated for the deglutition dynamic using the videofluoroscopic method. The aim of this study is to stablish in a preliminary way, typical DAP values, for this kind of study. The DAP values were obtained attaching to the X ray tube exit, an ionization chamber from PTW and a Diamentor M4 meter. The typical DAP values obtained during the videofluoroscopic evaluation of the deglutition dynamic including its three phases was 4101 +/- 881 cGy.cm^2 and the typical DAP rate was 577 +/- 94 cGy.cm^2/min. These values refer to a standard patient (1.57 cm height, 56 Kg. weight) and a protocol that can be performed in about 7 minutes. The values, defined herein as typical refer to the used protocol. To our knowledge, the mean DAP rate is a good parameter to estimate radiation exposure from videofluoroscopic study of swallowing process.

1. Introduction

The efficiency and the quality of a semiotic method is represented by its ability of solving questions and indicating solutions. Videofluoroscopy has been accepted as the "gold standard" for the evaluation of the oral and pharigeal phases of the swallowing process. Its efficiency is unquestionable for the study of the esophageal phase, as well.

To study swallowing in its three phases, including the esophageal one in the disphagia protocol evaluation, in spite of increasing the examination time, is indeed an important decision. Not seldom, oro-pharingeal disphagias are associated with some morfological or functional involvement of the esophagus. Besides this, low tract disphagias of esophageal origin are commonly refered to, by the patient, as high disphagia due to upper transmission. These facts are more than adequate justifiactions to the inclusion of the esophageal evaluation in the protocol for disphagia studies, by the videofluoroscopic method.

However, in radiological examinations, exposure time to radiation must be taken into account in the cost-benefit analysis. Therefore it is important to evaluate the radiation doses to which the patients will be exposed when evaluated by a protocol that includes swallowing in its three phases. On the other hand, medical procedures are the most important causes of human exposure to artificial radiation sources.

The Commitee of Radiological Protection from the Pan American Health Organization[1], points out that a radiological examination, clinically justified, generally causes a benefit to the patient and compensates the associated radiation exposure risk. The fact of recognizing the possibility of harmful effects, is the resposible for safety in radiodiagnostic methods nowadays.

Radiation interacts with the body determining the energy absorption by mass unit in a given tissue or organ, characterizing the absorbed dose. The dose received in a given kind of examination is distributed in a variable mode in the body being maximun at the skin surface. Dose in tissues greatly depend on the radiographic technique. The unit of absorbed dose is the Gray (J/Kg).

Costa et al [2,3,4] have evaluated patient doses using TLD's the videofluoroscopic method and compared the results with the deglutogram which uses radiograpic film, and concluded positively, with respect to the videofluoroscopy.

The low radiation in videofluroscopy was shown more evident when compared to classical radioscopy, the method where the images in the fluorescent screen were directly observed in dark room. It was observed [2] that the method that uses fluoroscopy with image intensifier causes an exposure around 13 times lower than the classical radioscopy.

The overall radiation emitted during an examination can be measured with a "dose x area meter", an equipment that registers in $cGy.cm^2$ the radiation quantity that may reach the patient during an examination. The DAP (Dose Area Product) is a dosimetric quantity specifically related to patient exposure. It reflects the greater or smaller exposure determined by the procedure. Therefore, not only the radiation dose but also the field size in cm^2, are important in the evaluation of radiation exposure produced by a given examination.

The most appropriate parameter to evaluate patient exposure in fluoroscopic examinations is the DAP, that registers the absorbed dose in the air multiplied by the total irradiated area during the examination. The DAP, generally expressed in $cGy.cm^2$, must not be mistaken with the concept of radiation dose per area expressed in cGy/cm^2 , that is the dose per unit area where each cm^2 receives the dose. The DAP does not measure the dose in a particular body region, the expressed value is proportional to the total energy imparted to the patient during the whole procedure.

In this regard, we have tried to adopt, for patient radiological protection the reference doses, and standardize the radiation that is needed to correctly perform a given type of examination [5,6].

Dosimetric data depend on the kind of radiological equipment, the degree of patient cooperation, the radiologist ability and the exposure time. Preliminary results [3,10], coincide with data from the European Comunity are of the order of 1100 $cGy.cm^2$ for an esophagography, of 4000 $cGy.cm^2$ for barium meal and 6000 $cGy.cm^2$ for barium enema. In these examinations, radiographies represent 20-50 % of DAP [7,8].

In a dynamic examination, different regions with distinct densities are exposed to radiation. Therefore, different DAP are to be expected. Different registred DAP are summed up by the DAP meter allowing the quantification of the total overall radiation produced during a videofluoroscopic examination. This characteristic of summing up in the examination time the DAP variations, makes the videofluoroscopic method an excelent standard to study deglutition dynamic. For these reasons, the present study can offer in preliminary values of typical DAP which could represent this type of examination.

2. Materials and Methods

The videofluoroscopic examinations were performed using an X ray equipment from Medicor model UV 56M, type FR2 with undercouch tube model D19-12/50-150. The tv system is Vidiomed 2, with image intensifier type RBV 23/13. It uses a Vidicon tube with 525 lines, 60 Hz, interlacing 2:1. The images were registered in the VHS format with a video/monitor Samsung high speed mechanism model-CXE 1331. The DAP values were obtained attaching to the X ray tube exit a Diamentor model M4 from PTW.

Radiation exposure of 7 persons were analyzed during the videofluorsocopic examination, two men and 5 women, with ages between 21 and 72. The individuals were evaluated for the three phases of swallowing (oral, pharingeal and esophageal). One woman, a volunteer, had no complain and the remaining 6, refered to disphagia related to Parkinson disease.

The oral, pharingeal and esophageal phases were examined with a previously defined protocol [9] which includes observation during deep nasal inspiration and expiration and deglutition of saliva, water and contrasted home made test bolus (moisturized and homogenized bread with powder barium sulfate in soft consistency) from 0.5 to 2,5 cm diameter as well as barium sulfate solution.

The radiation doses to which the patients were exposed were calculated using the relation : ($DAP = DAP_m \times 0{,}97 \times 1{,}14$) where DAP represents the actual value, DAP_m is the measured value without correction. Correction factors are 0,97 determined by the manufacturer for undercouch tubes and 1,14 is the ionization chamber calibration factor.

3. Results and Discussion

To our knowledge, there is no similar protocol for the evaluation of either DAP of swallowing, radiographic nor videofluoroscopic methods. For this reason, results obtained here can serve as a reference and a basis for future evaluations. It is necessary to take into account, the kind of protocol employed in the evaluation of swallowing when comparing DAP. Does the protocol include the three phases of swallowing? What kind of equipment is used for registering the events?

Protocols that do not include the three phases of swallowing can present lower values of DAP, limiting information that could be obtained in exchange of a shorter examination time. Observation with fluoroscopy first and then registration in a radiographic film causes a loss of dynamic information and the use of a higher dose rate to sensitize the radiographic film that, depending on the used protocol, can cause in a higher DAP.

Aiming the reduction of this possible discrepancy we have considered DAP rate (cGy.cm^2/min). Therefore, the exclusion of one examination phase would generate reduced DAP but similar values of DAP rate.

An analysis of table 1 allows the evaluation of sample quality, radiological technique, time variations necessary for fulfilling the proposed protocol and data registred by the Diamentor for each one of the individuals in cGy.cm^2. This table also shows the DAP rate in cGy.cm^2/min. Table 1 shows also the normalized values obtained by the product of examination time multiplied by the mean DAP rate. Results show new values for DAP comparable to the measured in each examination.This table, points out to the fact that, in the evaluation of swallowing which occurs in head, neck and mediastinum regions, where the contrasted esophagus is visualized in its cranio-caudal transit, the mean DAP does not change much with individual physical completion. Its variation depends on a larger scale on the changes of employed technique. Therefore, even a small sample was representative of exposure to radiation in this protocol that can be verifyed by the small variance of the results. Consequently, a larger sample, that could present a greater dispersion depending on physical completion is out of procedure control. Dose control can and must be performed according to the protocol and in the proposed time.

Table 1 – Data

	Hight (cm)	Weight (kg)	MA (average)	kV	Total time (min)	DAP_m (cGy.cm^2)	DAP (cGy.cm^2)	DAP rate (cGy.cm^2/min)	DAP rate normalized (cGy.cm^2/min)
CMF	1.48	42	1.0	65	7.1	3061	3385	477	4096
SIF	1.65	60	1.6	70	7.5	4777	5282	704	4327
MLO	1.49	59	1.0	64	7.7	4107	4541	590	4442
JM	1.60	63	1.2	65	6.7	4125	4561	680	3865
AFS	1.60	60	1.6	70	7.8	4257	4707	603	4500
PFMC	1.65	54	1.1	65	5.9	2694	2979	505	3404
CDP	1.55	52	1.1	60	6.8	2941	3252	478	3923
St.dev.							881.5		387

In table 2 above, the descriptive statistics is discussed and allows the evaluation of the influence of the different variables in DAP values. Age, sex and physical complexion, represented by hight and weight are determining factors in density variations and consequently in final DAP. These parameters, inherent to the patient, do not change, nevertheless its observation will help the interpretation of the DAP found for each individual. The location of a determined DAP in one or other end of the gaussian distribution can point out towards a better or worse performance of the applied methodology or radiological equipment. When patient who were expected to be located in the lower part of the curve appear in the upper part, it can be an indicative of careless examination, lack of examinator expertise or deficient equipment. Another important factor to be considered is collimation. As the measurement is done after the collimator, to colimate a field, whenever possible, reduces exposure area and consequently the DAP.

The DAP obtained in our study can be related to other studies of dose-area of digestive system [7,8]. Our results are distributed in the lower dose level obtained up to date in radiological procedures of this system. The examination time is the parameter that can be easily manipulated to reduce DAP together with an optimized technique. For this reason, we define exposure by an examination per unit

time (minutes). This exposure was obtained for each examination dividing total DAP by the time required for that specific examination. Examination time is clearly dependent on the protocol and depends on the examinator's expertise and the degree of difficulty presented to perform the examination. However, it is here that the efforts to reduce DAP must be directed. This reduction can be achieved improving the examinator's performance, specially through the elaboration of protocols which clearly define the sequence of events to be observed. However, to reduce DAP, the examination quality can not be degraded.

The DAP rates served as a basis to obtain a mean value of what exposure during the evaluation of swallowing. We believe that it is the best parameter to represent exposure. This resource allows the reduction of several variables interfeering in the generarion of DAPs. If we compare standard deviation which covers 68% of mean dispersion, we can see that it from about 21% of total exposure to around 16% in exposure per minute, showing less disperssion in the average when considering exposure/minute.

Table 2 – Descriptive Statistics

	Age (y)	Hight (m)	Weight (kg)	KV	mA	Total time (min)	DAP_m (cGy.cm^2)	DAP (cGy.cm^2)	DAP rate (cGy.cm^2/min)
Average	53,57	1,57	55,71	65,57	1,23	7,07	3709	4101	577
Standard error	7,79	0,03	2,7	1,32	0,1	0,25	301	333	35
Standard deviation	20,61	0,07	7,13	3,51	0,26	0,67	797	881	94
Minimum	21	1,48	42	60	1	5,9	2694	2979	477
Maximum	72	1,65	63	70	1,6	7,8	4777	5282	704
Sum	375	11,01	390	459	8,6	49,5	25962	28709	4038
Counts	7	7	7	7	7	7	7	7	7

5. Conclusion

Typical value of DAP obtained during the videofluoroscopic analysis of swallowing with analysis of its three phases is 4101 +/- 881 cGy.cm^2 and the typical DAP rate was 577 +/- 94 cGy.cm^2/min for individuals 1,57 cm height, 56 kg weight, examined with protocols which can be performed in around 7 minutes. The values defined here as typical refer to the used protocol. To our knowledge, the mean DAP rate is a good parameter to estimate radiation exposure due to videofluoroscopic study of swallowing.

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RADIATION DOSES IN INTERVENTIONAL NEURORADIOLOGY

C.Theodorakou[1], P. Butler[2], J.A.Horrocks[2]
[1]Queen Mary and Westfield College, University of London, [2]Bart's and the London NHS Trust
FAX: +442076018294,E-MAILS:c.theodorakou@mds.qmw.ac.uk, j.a.horrocks@mds.qmw.ac.uk

ABSTRACT

Patient radiation doses during interventional radiology (IR) procedures may reach the thresholds for radiation-induced skin and eye lens injuries. This study investigates the radiation doses received by patients undergoing cerebral embolization. Measurements were conducted using thermoluminescent dosimeters. Radiotherapy verification films were used in order to visualise the radiation field. For each procedure the fluoroscopic and digital dose-area product, the fluoroscopic time, the total number of acquired images and entrance-skin dose calculated by the angiographic unit were recorded. In this paper, the skin, eye and thyroid glands doses on a sample of patients are presented. From a preliminary study of 13 patients having undergone cerebral embolization, it was deduced that six of them have received a dose above 1 Gy. Detailed dose data from patients undergoing IR procedures will be collected in the future with the aim of developing a model to allow estimation of the dose prior to the procedure as well as to look at techniques of dose reduction.

INTRODUCTION

In 1994 the Food and Drug Administration (FDA) [1] reported a number of severe radiation-induced skin injuries to patients resulting from interventional radiology (IR) procedures. Since then numerous reports have been published on patient and staff radiation doses in IR procedures [2,3,4].

Cerebral embolization (CE) is a neuroradiological procedure and it is considered to be a high dose IR procedure. It is used for treatment of life-threatening diseases such as aneurysms and/or arteriovenous malformations (AVMs). Alternative treatments are surgery and radiosurgery.

Embolization results in the occlusion of aneurysms and/or AVMs from the blood supply. The efficacy of the procedure is monitored by injection of contrast media in the vessels in conjunction with fluoroscopy and digital subtraction angiography (DSA). Materials that are used for the occlusion of the vessels are metal coils (platinum) in the case of aneurysms and chemical agents (superglue) in the case of AVMs. The metal coil is supplied in a cartridge which allows it to be fed into the catheter and then into position in the area of interest. Superglue has a liquid form and it solidifies as soon as it comes in contact with blood and it reaches the area of interest via a catheter. In most of the cases, the AVM embolization is likely to be repeated in a short period of time and it is followed by radiosurgery at which the dose to the target volume (AVM) may reach levels as high as 25 Gy. Thus, the cumulative dose resulting from embolization and radiosurgery may reach high levels.

Many authors have reported doses in CE varying from few hundreds of mGy up to few Gy [2,3,4]. This study investigates the entrance-skin doses (ESD), the dose-area product (DAP) and organ doses to thirteen patients undergoing CE and the radiation doses to the physician performing the CE. Also, the dose distribution over the patient's skin area has been obtained by means of thermoluminescent dosimeters (TLDs) and it is compared with that obtained from films placed at the irradiated area. The relationship of the dose with some technical parameters such as fluoroscopy time, number of acquired images and with the ESD which is calculated by the unit is investigated.

METHODS AND MATERIALS

Measurements were made on a Siemens biplane X-ray system consisting of a lateral (LAT) and a posterior-anterior (PA) Megalix X-ray tube and a Polydoros IS-Ax2 (Neurostar) pulse generator. Tube settings are controlled by the automated exposure control (AEC). The X-ray unit is equipped with a DAP-meter which provides the user with the cumulative DAP for each plane and for each mode (fluoroscopy-DSA) separately. The ESD and the ESD rate are calculated by the unit at a focus skin distance (FSD) of 55 cm giving an estimation of the ESD during the procedure in each plane. It also provides the user with useful technical parameters such as tube voltage, tube current and exposure time, magnification, frames/sec, number of acquired images for each DSA run. During the fluoroscopy mode the ESD and the ESD rate as well as the tube voltage, mA, pulses/sec and the DAP are provided. Three different protocols for DSA mode can be used when CE is performed. The user

has the option to change the settings of the program and the most frequently changed parameters are the frame rate, scene duration and pulses/sec (fluoroscopy). In the following table (I) the parameters for the three different protocols are shown.

TABLE I. DSA protocols

Protocols	kVp	ms[1]	Scene(sec)[2]	dose[3]	Frame rate	Pulses/sec
AngioDSA Carotids	73	160	80	4.8	2	7.5
Angio DSA AVM Glue	70	125	20	4.8	3	7.5
Angio DSA Vertebral	70	64	40	4.8	2	7.5

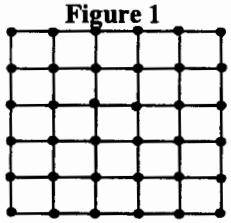
[1]maximum pulse width in milliseconds

[2]maximum duration of a scene in seconds

[3]input dose per frame in μGy, measured at the following nominal conditions: 70kV, 2.5 mm Copper filter and 17cm Image Intensifier

Lithium fluoride TLDs (TLD-100) were used to measure the ESD for the PA and for the LAT plane. The TLDs were arranged in a grid form as shown in figure 1 to measure the dose distribution. The TLDs were placed on two exposed films. One of the two films was placed on the back side of the patient's head to measure the dose from the PA plane and the second one on the right side of the patient's head in order to measure the dose from the lateral plane. The grid was square with dimensions (15x15)cm^2 and every three cm for both vertical and horizontal dimension (bullets in the figure) a TLD was placed, giving 36 TLDs for each plane. The dose to the eyes and to the thyroid glands of the patient and the doses to the physician's eye were measured with TLD-100H which are suitable for measuring low doses due to their high sensitivity.

Figure 1



For doses above 1 Gy, correction factors have been applied to TLD-100 doses in order to account for supralinearity.

Kodak X-OMAT V radiotherapy verification film has been used to visualise the radiation field for two patients and for both planes.

Dose rates have been measured using a tissue equivalent phantom (15x15x15) cm^3 for both fluoroscopy and DSA. Different field sizes, pulses/sec, frames/sec have been used.

RESULTS AND DISCUSSION

In figures 2 and 3 the isodose curves obtained from the TLD grids for PA plane and LAT plane for respectively are superimposed onto the images taken from the films. Figures 2 and 3 correspond to two different patients. Starting from the edges of the grid the first isodose curve is that of the lowest dose range. The dose scales shown in the figures are in mGy.

From figure 2 it may be seen that an area of (8x7) cm^2 receives a dose above 400mGy and from figure 3 an area of (6x6)cm^2 receives a dose above 1750mGy. By not using TLDs arranged in a grid form the irradiated area cannot be estimated and from those two examples it may be seen that a large area of the patient's head has received the highest dose. In both figures the x-ray tube has been moved throughout the procedure. Due to the movement of the X-ray tube during the procedure there is a risk of placing the TLDs outside the field size or outside the area of the highest dose unless a large TLD grid is used. Although the grids are (15x15) cm^2, it may be seen that they are not large enough to cover the whole radiation field since the isodose curves for the low doses are interrupted.

Figure 2. Patient A

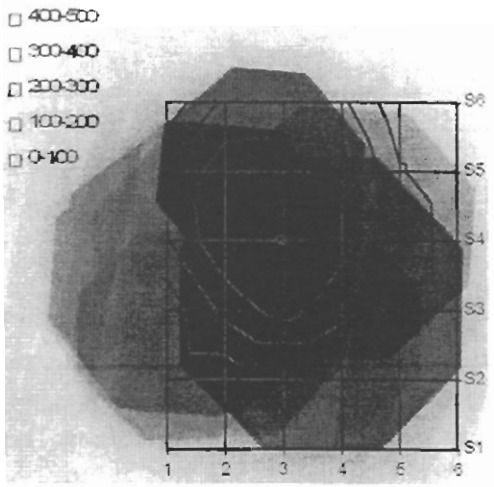
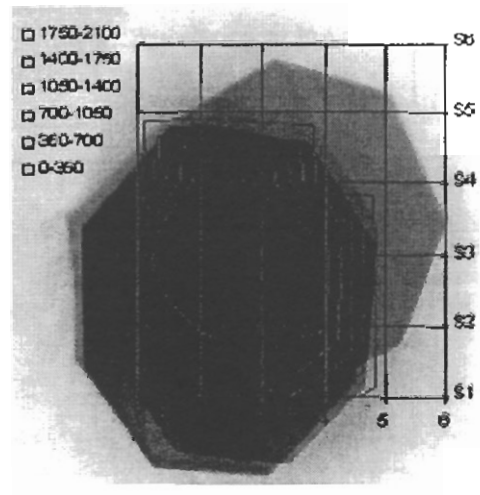


Figure 3. Patient B



In table II the results for both PA and LAT plane for the thirteen patients are shown.

Table II. Patients' results

Patient	Fluoroscopy Time (min)		Number of images		DAP ($Gycm^2$)		ESD_{DAP}[1] (Gy)		ESD_{TLD}[2] (Gy)	
	PA	LAT	PA	LAT	PA	LAT	PA	LAT	PA	LAT
1	4.9	22.0	73	156	52.7	61.9	0.52	0.69	0.24	0.59
2	4.6	11.0	127	316	49.5	106.7	0.53	2.00	1.20	1.44
3	8.9	2.0	52	28	30.5	6.1	0.64	0.15	0.26	0.09
4	26.3	8.0	123	118	62.1	22.9	1.48	0.61	0.90	0.38
5	1.9	18.0	90	272	72.6	76.7	0.79	2.20	0.40	1.40
6	2.5	22.0	55	725	38.3	365.2	0.27	4.44	2.44	3.2
7	9.9	16.0	229	425	92.9	127.0	2.12	2.86	1.14	1.78
8	3.9	4.0	139	159	55.1	34.6	1.09	0.96	0.63	0.63
9	1.8	31.0	59	227	25.2	129.6	0.23	1.63	0.88	1.21
10	2.0	22.0	54	87	15.1	24.6	0.37	0.63	0.18	0.52
11	6.5	14.3	216	344	52.1	43.2	0.68	0.12	0.40	0.55
12	0.9	17.2	58	137	14.1	14.8	0.21	0.32	0.10	0.18
13	2.9	10.9	767	975	218.6	231.0	5.01	2.63	2.61	1.94

[1] ESD_{DAP}: the ESD calculated by the x-ray unit at 55cm FSD

[2] ESD_{TLD}: the maximum TLD dose

It may be seen from the ESD_{TLD} that for the PA plane 4 patients have received a dose above 1 Gy and 2 of these have exceeded the threshold of 2 Gy for transient erythema [5] while for the LAT plane 6 patients have exceeded 1 Gy and one has exceeded the threshold of 3 Gy for temporary epilation [5]. Comparing the ESD_{DAP} and the ESD_{TLD} for both PA and LAT plane it may be seen that the ESD in most of the cases is higher than the ESD TLD. Thus, the ESD calculated by the x-ray unit tends to overestimate the actual dose since the actual FSD is always higher than 55cm typically between (70-80) cm and since the tube is moving during the procedure spreading the dose over the patient's head.

In table III the dose for the eyes and thyroid glands of the patient, as well as the doctor's left eye dose who performs the CE, are shown. It may be seen that the patient's right eye and right thyroid gland receives a higher dose than the left eye does and this is because the lateral x-ray tube is always on the right side of the patient's head. The eye doses are high in some patients but are below the threshold for formation of detectable opacities[6]. The doctor's eye receives a low dose and only in three cases the dose reaches the 3/10 of the annual dose limit (i.e classified worker) if one case per day (250 each year) with such a dose is performed.

TABLE III. Organ doses

Patient	Right eye dose (mGy)	Left eye dose (mGy)	Right thyroid dose (mGy)	Left thyroid dose (mGy)	Doctor's eye dose (mGy)
1	38.1	5.2	50.5	8.0	0.069
2	16.1	13.1	21.3	7.5	0.120
3	3.2	3.3	2.4	2.3	0.038
4	16.1	13.1	21.3	7.5	0.078
5	16.1	13.1	21.3	7.5	0.078
6	71.8	10.9	36.2	9.2	0.471
7	64.1	22.1	11.3	4.9	0.218
8	8.5	5.5	6.8	4.0	0.018
9	13.7	6.6	16.4	2.2	0.218
10	14.1	5.2	5.2	3.1	0.061
11	44.0	30.0	6.7	2.6	0.110
12	12.7	5.1	180.4	7.2	0.018
13	69.2	27.5	36.1	18.4	-

In figure 4 the relationship between the doctor's eye dose, the total DAP and the LAT DAP is shown. It may be seen that the doctor's eye dose is correlated better with the LAT DAP than with the total DAP since the LAT X-ray tube is always on the left side of the doctor. It may be seen that as the LAT DAP increases the doctor's eye dose increases linearly.

Figure 4

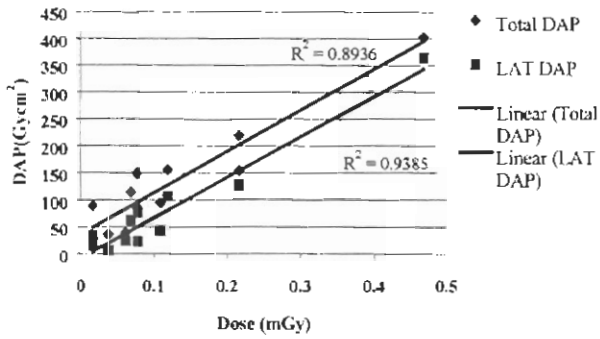
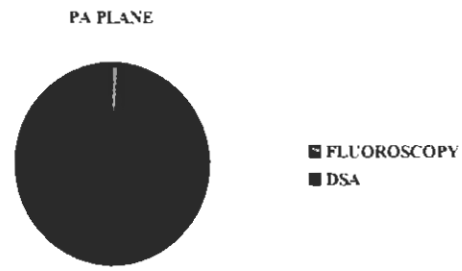


Figure 5



In figure 5 the contribution of DSA and fluoroscopy mode to the total DAP is shown for PA plane for patient 13. It may be seen that the main contribution comes from the DSA mode and not from the fluoroscopy mode. Thus, the use of DSA mode should be limited to the minimum.

From quality assurance measurements it was deduced that the ESD/sec for fluoroscopy mode is within a range of (0.029-0.2) mGy/sec which is equivalent to (1.76-11.9) mGy/min for different technical parameters while for the DSA mode the ESD/sec is in a range of (1.6-6.62) mGy/sec for the same parameters as in fluoroscopy. The ESD/frame for the DSA mode may vary from (0.73-2.65) mGy/frame. Comparing the dose rates for fluoroscopy and DSA it may be seen that the doses from DSA are much higher than that of fluoroscopy. Thus, by limiting the images obtained during a procedure the ESD may be highly reduced.

CONCLUSIONS

In this paper a new method to obtain dose distribution over the patient's skin area for CE procedures has been introduced. This method gives accurate and reliable results of the ESD by combining a TLD grid for measuring the ESD and films for visualising the field size. The results show that a relatively large skin area may receive a dose that can exceed the thresholds for skin injuries. The patient's eye and thyroid glands may receive a relatively high dose but it is below the threshold for causing any radiation-induced injuries. It has been found that there is a good correlation between the doctor's eye dose and the DAP from the LAT plane. It also has been found that the contribution of the DSA mode

to the total DAP is much higher than that from the fluoroscopy mode. Quality assurance results showed that the ESD rate is much higher for the DSA mode than that for the fluoroscopy mode. Thus, the number of images obtained during a procedure should be kept to the minimum. Us eof distance and shielding may also reduce staff doses.

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Radiation Dose during Angiographic Procedures

By [1]Christian Lavoie, P.Eng. and [2]Pasteur Rasuli, FRCP, FRCP(C).

[1]Radiation Protection Bureau, Health Canada, Ottawa, Ontario, Canada and [2]Department of Radiology, Ottawa Hospital, General Campus, Ottawa, Ontario, Canada.

Abstract

The use of angiographic procedures is becoming more prevalent as new techniques and equipment are developed. There have been concerns in the scientific community about the level of radiation doses received by patients, and indirectly by staff, during some of these radiological procedures. The purpose of this study was to assess the level of radiation dose from angiographic procedures to patient at the Ottawa Hospital, General Campus. Radiation dose measurements, using Thermo-Luminescent Dosimeters (TLDs), were performed on more than 100 patients on various procedures. The results show that while the patient dose from the great majority of angiographic procedures is less than 2 Gy, a significant number of procedures, especially interventional procedures may have doses greater than 2 Gy and may lead to deterministic effects.

Introduction

In the last few years, the number, the type and complexity of interventional radiological procedures has dramatically increased. These changes were driven by improvements in equipment design, the need for improved patient prognoses and the necessity for more cost effective treatments. With the increased complexity of these procedures, the irradiation time has also increased, giving rise to concern about patient doses. There have been a few reports of deterministic effects from angiographic procedures, especially interventional procedures. For instances, Carstens et al have reported a case of radiation dermatitis after embolization [1], Freedman et al reported radiation burns during a transjugular intrahepatic portosystemic shunt (TIPS) procedure [2], Huda et al reported cases of temporary epilation after an neurological procedure [3], and Shope reported a few cases of radiation induced skin injuries from interventional procedures [4].

Following the reported cases of radiation damage from interventional procedures, the United States Food and Drug Administration had issued a bulletin to health care professional on the potential for radiation injuries from angiographic procedures [5]. This bulletin requests that the absorbed dose to the irradiated areas, likely to approach the threshold for radiation injury, be estimated for angiographic procedures, including interventional procedures. The area of interest when performing these evaluations for angiographic procedures is the skin area closest to the entrance X-ray beam since it will receive the largest amount of radiation.

Equipment and Method

All procedures were done by the same team of radiologists using an Omnicon L Digital Subtraction Angiography (DSA) unit (Picker, Cleveland OH), utilizing 15 pulse/s

fluoroscopy. The entrance doses were measured by placing several equally spaced packets of three thermo-luminescent dosimeters (TLDs) on the table under the patient's pelvis to cover the area exposed to radiation during the procedure. Three TLDs were used per packet to provide confidence for each measurement point. The TLDs used were TLD-100 (LiF) (Harshaw, Cleveland, OH). TLD-100 (LiF) has been shown to be appropriate for the measurements of both skin entrance and organ doses in diagnostic radiology [6]. Each TLD measures approximately 3 x 3 x 1 mm^3. The separation between the packets used was 10 cm at first and was subsequently decreased to 3 cm. This change in the packet separation was made to increase the number of measurement points to confirm the radiation pattern of entrance dose. The TLDs were calibrated for the energies used during the procedures and were processed at Health Canada laboratories on a Harshaw Nuclear Systems Model 2000D TLD reader (Harshaw, Cleveland, OH). Technical data, such as the tube voltage, current, fluoroscopy time, the number of DSA images and the tube position were recorded for each procedure.

Results

The skin entrance doses and pertinent information for angiographic procedures are presented in Table 1. The values presented are the average for all patients undergoing the specific procedure. The numbers in parentheses show the range of values measured for each category.

Table 1. Results of the radiation dose measurement for diagnostic angiographic procedures

Procedure	# of proc.	Patient weights (kg)	Irradiation time (min.)	# images	Dose (mGy)
Aorta/Iliac Arteries					
Translumbar aortogram	3	99 (70-136)	3.5 (2.3-5.2)	88 (76-104)	162 (45-299)
Iliac artery angioplasty & stenting	3	71 (68-84)	20.5 (3.8-43.1)	88 (43-190)	1,028 (161-2,560)
Carotid Artery					
Carotid artery angiogram	1	64	3.3	97	80
Carotid artery angioplasty & stenting	1	74	27.3	93	188
Embolization					
Embolization of liver tumours	8	78.5 (48-117)	20.2 (12.7-43.5)	144 (56-473)	2,062 (137-9,329)
Uterine Artery Embolization	28	73 (53-120)	29.2 (13.3-54.1)	124 (66-241)	1,289 (383-3,363)

Procedure	# of proc.	Patient weights (kg)	Irradiation time (min.)	# images	Dose (mGy)
Abdomen					
Inferior Vena Cava filter placement	2	66 (64-68)	3.0 (2.9-3.1)	25 (22-27)	44 (41-47)
Abdominal angiogram	3	79 (50-114)	6.8 (4.8-8.1)	243 (163-311)	935 (138-2,450)

One of the major problems in assessing the patient dose is that the range of doses for a specific procedure can be quite considerable. Table 2 shows the individual patient skin entrance dose for embolization of liver tumours. The entrance skin dose values presented are the maximum measured doses for each patient.

Table 2. Results of the radiation dose measurement for embolization of liver tumours

Patient	Age/sex	Weight (kg)	Irradiation	# images	Dose (mGy)
17	47 / M	84	13.1	69	1,032
22	56 / M	97	20.2	162	999
30	71 / F	50	23.2	95	222
35	59 / M	86	18.1	114	573
49	71 / F	48	18.0	108	137
51	68 / M	82	43.5	473	9,329
61	64 / F	117	12.7	74	3,273
63	40 / M	64	13.1	56	930
Average		*78.5*	*20.2*	*144*	*2,062*

Discussion

The measurement of patient doses is not an easy task. If properly handled, TLDs can provide an accurate value of skin doses. Unfortunately, TLDs are complicated to use and have limited usage in a clinical setting. Another method of measurement is the use of a detector to measure the dose-area product. The major drawback of the use of dose-area product measurement during angiographic procedures is that it is often difficult to relate the result to the skin dose or to a specific organ dose. This is especially true with angiographic procedures where patients are being irradiated at different angles and skin surface locations for various irradiation times.

In general, patient doses are greater in interventional procedures than in diagnostic angiographic procedures. Not all interventional procedures generate large skin doses. For

example, the skin dose produced during the placement of an inferior vena cava filter is small. One of the most difficult problems in assessing the risk from an angiographic procedure is the large variability of skin doses for different patients. For each procedure, it is important to know the range of skin doses that can be attained since this range can be very wide. For example, the embolization of liver tumours, as demonstrated in Table 2, the range of skin doses is from 137 mGy to 9,329 mGy. Two of the eight patients received skin doses greater than the threshold level of 2 Gy. Other procedures show the same characteristics; for iliac angioplasty and stenting, the range of doses is from 161 mGy to 2,560 mGy, for uterine artery embolization, the range is from 383 mGy to 3,363 mGy, and for abdominal angiogram, the range is from 138 mGy to 2,450 mGy. The most important factors responsible for such large variations of skin doses are the size of the patient, the expertise of the operator, and the difficulty in performing the procedure.

Skin doses can be greater than 2 Gy for many interventional procedures. A complete assessment of the range of skin doses should be done to evaluate the risk of deterministic effects for specific procedures.

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SHIELDING FOR RADIATION SCATTERED DOSE DISTRIBUTION TO THE OUTSIDE FIELDS IN PATIENTS TREATED WITH HIGH ENERGY RADIOTHERAPY BEAMS

Sung Sil Chu, Ph.D
Department of radiation Oncology, Yonsei cancer center, Yonsei University
Seoul Korea
E-mail : schu@yumc.yonsei.ac.kr
Fax : 82-2-312-9033

-ABSTRACT-

Scattered dose of therapeutic high energy radiation beams are contributed significan t unwanted dose to the patient. Measurement of radiation scattered dose outside fields and critical organs, like fetus position and testicle region, from chest or pelvic irradiation by large field of high energy radiation beam was performed using an ionization chamber and film dosimetry.

The scattered doses outside field were measured 5 - 10% of maximum doses in fields and exponentially decrease from field margins. The scattered photon dose received the uterus from thorax field irradiation was measured about 1mGy/Gy of photon treatment dose

Shielding construction to reduce this scattered dose was investigated using lead sheet and blocks About 6cm lead block shield reduced the scatter photon dose under 10mGy for 60Gy on abdomen field and reduced almost electron contamination.

INTRODUCTION

High energy photon beams from medical linear accelerators produce large scattered radiation by various components of the treatment head, collimator and walls or objects in the treatment room including the patient. These scattered radiation do not provide therapeutic dose and are considered a hazard from the radiation safety perspective. The scattered photon dose received the fetus from thorax field irradiation was measured about 1mGy/Gy of photon treatment dose and typical therapeutic doses of photon radiation lie in the range 40 -70Gy. Thus, without additional shielding, the scattered photon dose received by the fetus might be several hundred mGy. Under conditions of occupational radiation exposure of pregnant women, the NCRP advises that the fetus be regarded as a separate entity distinct from the woman bearing it and that the total dose equivalent limit for the fetus be 5 mSv and no greater than 0.5 mSv in any given month. Similarly the ICRP recommends a dose equivalent limit of 2 mSv once the pregnancy is known. These advisory bodies emphasize that medical exposures are excluded from these occupational exposure dose limits. In addressing medical exposures of benefit to the mother, ICRP take the position that irradiation of the pregnant woman is to be avoided . However it does recognize that there may be exception circumstances in the treatment of a life threatening malignancy of the mother in which therapeutic irradiation is the method of treatment that carries the lowest detrimental risk to the patient and fetus. In such cases it is emphasized by the ICRP that treatment should be planned in a way that minimizes the dose to the fetus by use of all relevant measures including shielding.

There are no internationally recognized guidelines for limiting the dose to the fetus during radiation treatment of the mother for malignancy. However it is known that a dose of 500mGy may cause abortion at any stage of pregnancy and that radiation detriment to the fetus includes risk of mental retardation with a possible threshold in the dose response relationship around 100 mGy for the gestational period of maximum vulnerability

Hammer Jacobson made the controversial recommendation that an abortion be performed whenever an embryo has received a dose above 100mGy during the first 6 weeks following

conception to avoid the risk of producing an anomalous child. Irradiation of a fetus also carries the increased risk of childhood cancer and fatal cancer and fatal cancer later in life . Risk estimates for childhood cancer induction vary but may be as high as 10^{-3} per mSv to the fetus.

The ICRP principle of as low as reasonably achievable (ALARA) was recommended for protection of occupation upon the linear no-threshold dose response hypothesis for cancer induction. We suggest this ALARA principle be applied to the fetus in therapeutic treatment of the mother. Applications of the principle will in many instances reduce the total dose equivalent to the fetus below dose thresholds for nonstochastic radiation effects. Thus effective shielding of the fetus must be introduced when ever possible. In the specific instance considered in this article of a therapeutic high energy photon beam treatment of the mother shielding should be designed to reduce the scattered photon to the normal organs.

Radiation dose outside a photon treatment filed is mostly due to scattered photons.

This scattered dose is a function of the distance from the beam edge, treatment geometry, primary photon energy, and depth in the patient.

The need for effective shielding of the fetus is reinforced when one considers many pregnant women are treated with external beam radiation therapy every year and then shielding designed to reduce the scattered photon dose to normal organs have to considered.

MATERIALS and METHODS

Irradiation was performed at a gantry angle of 0 degree in phantom using high energy photon beams produced by a Varian 2100C/D medical linear accelerator (Varian Oncology Systems, Palo Alto, CA) located at the Yonsei Cancer Center. The composite phantom used was comprised pf a commercially available anthropomorphic Rando phantom (Phantom Laboratory Inc., Salem, YN) and a rectangular solid polystyrene phantom of dimensions 30cm x 30cm x 20cm. the anthropomorphic Rando phantom represents an average man made from tissue equivalent materials that is transected into transverse slices of 2.5cm thickness. When assembled the 36 slices, numbered 0-35, Provide a head and torso with skeleton, lungs, and air passages. Slices 20-28 correspond to the abdomen and were removed and replaced by the polystyrene phantom.

Photon dose was measured using a Capintec PR-06C ionization chamber coupled to a Capintec 192 electrometer (Capintec Inc., Ramsey, NJ) and this system had a calibration factor traceable to a standards laboratory and the photon scattered doses were measured by inserting the appropriate dosimeter in the milled a space located in one of the slavs of the polystyrene phantom.

In case of fetus , the dosimeter was placed at a depth of 10cm in this phantom at 100cm source to axis distance and located centrally 15cm from the inferior edge of the 30cm x 30cm x-ray beam irradiating the Rando phantom chest wall. A fraction of a typical patient treatment dose was delivered during scattered dose measurement.

Of note is that a depth of 10 cm has been previously accepted as the standard depth of a fetus. In our geometric setup the measurement location chosen as representative of the position of the fetus corresponds approximately to an anatomical location that is 10 cm below the umbilicus of the mother, According to the AAPM task group 36 report the mother's umbilicus will be the height of the fundus at 20 -22 weeks gestation. Obviously, the fetus occupies a volume that increases with the period of gestation and the depth of the midline of the fetus will also vary with its position the size of the mother, and other factors.

A wooden bridge of size 40 cm x 40 cm and a clear space of about 21 cm was fabricated and placed on top of the rectangular polystyrene phantom representing the abdomen of the patient . The idea was to simulate the bridge being as close as possible to the patient's body while ensuring the weighty of the bridge and shield rested on the legs of the bridge . Shielding material comprised of 30 cm x30cm lead sheets of total thickness 6cm was placed on the top of the wooden bridge that covered the abdomen.

The scattered photon with and without shielding were measured at the representative position of the fetus. The scattered photon dose was usually made for a 10 Gy primary photon beam treatment, however to obtain good statistics

RESULTS

Scattered photon doses of critical organs from various region by 10MV photon beam was measured and presented in table 1.

The scattered photon dose for uterus and testicle can be reduced under 10 mSv when the lead shield was used while the tumor region was irradiation by high energy photon beam and presented in table 2.

The results indicate that it is possible to improve shielding to reduce scattered photon and side at the position of a fetus when a pregnant women is treated with a high energy photon beam.

The AAPM task group report 36 concentrated on shielding of the fetus from scattered photons and recommended that the lead shielding be draped over the edge of the bridge to provide extra shielding of the fetus against collimator scatter . This report also stated that it is prudent to treat with photon beams generated by electrons less than 10 MeV if this modality is adequate to treat the tumor.

Table 1. Scattered photon dose measured at critical organs from 10MV x-ray beam irradiating various regions

unit : mGy / Gy F: in field

Region / Organs	Thorax 12 x12 cm	Abdomen 14 x14 cm	Pelvis 14 x14 cm
Brain	1.8	0.2	0.1
Lens	2.2	0.3	0.2
Thyroid	48.3	1.9	0.8
Lung	F	20.2	1.5
Pancreas	4.8	F	3.7
Kidney	2.5	F	39.8
Uterus	0.9	6.2	F
Testicle	0.7	4.2	58.2

Table 2. Requirement lead thickness to be reduce under 10mGy for 60Gy irradiated on field with 10MV x-ray

unit: cm F: in field

Regio / Organ	Thorax	Abdomen	Pelvis
Uterus	4.5	7.0	F
Testicular	1.2	2.0	6.5

INVESTIGATION OF RADIATION SKIN DOSE IN INTERVENTIONAL CARDIOLOGY

Caroline M. Webster*, Delia Hayes+, Julie Horrocks*
St Bartholomew's Hospital*, London, City University, London+.
Telefax: +44-20-7601-8042

Background - The study investigated the radiation skin doses for interventional patients in cardiology; two procedures which have the highest radiation dose are Radiofrequency Catheter Ablation (RFCA) and Percutaneous Transluminal Coronary Angioplasty (PTCA).
Methods and Results - 56 patients were randomly selected and investigated; 23 patients in the RFCA group and 33 in the PTCA group. Skin and effective dose were calculated from Dose Area Product (DAP). Thermoluminescent Dosimetry was the second method of dose measurement used. Patients were followed-up for a three month period to check for possible skin reactions resulting from the radiation dose during the procedure.
Radiation skin doses in 14 patients were calculated to be more than 1 Gy, including three patients who received more than 2 Gy, the threshold dose for deterministic effects of radiation. 7 patients (12.5%) reported skin reactions as a result of the radiation received to their backs during the procedure. Mean DAP and estimated effective doses were 105 Gycm^2 and 22.5 mSv for RFCA, and 32 Gycm^2 and 6.2 mSv for PTCA procedures respectively.
Conclusion - Complex procedures in Interventional Cardiology can exceed the threshold level for deterministic effects in the skin.

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1. Introduction. Patients undergoing Percutaneous Transluminal Coronary Angioplasty (PTCA) and Radiofrequency Catheter Ablation (RFCA) may receive considerable doses of X-radiation during the procedure. These two procedures are both complex and lengthy to achieve the desired result; both treat cardiological medical conditions. Unlike PTCA most RFCA procedures involve the investigative test for diagnosis followed by the treatment.

1.1 The aims of the study were:

(a) to evaluate the magnitude and range of radiation skin doses received by patients during PTCA and RFCA procedures,

(b) to find if there were any deterministic effects of radiation manifested by the patient such as skin reddening (erythema) with a follow-up for a three month period.

1.2 Background. Several incidents of radiation induced skin problems have been reported in the USA as a result of high dose examinations (Shope, 1996)[1]. Shope stated that 26 injuries had been reported to the Food and Drug Administration (FDA) between 1992 and 1995; 12 of the patients underwent RFCA procedures and 4 received PTCA examinations. The FDA issued a health warning in 1994, that patients undergoing interventional procedures, could suffer from late radiation skin injury and that it would not be sufficient for clinicians to check patients before they were discharged from hospital (FDA, 1994)[2]. The FDA recognised that a threshold dose of 2 Gy would cause deterministic effects of radiation but recommended that a safety margin of 1 Gy should be observed. The advent of digital equipment with microprocessor controlled X-ray generators allow higher outputs and X-ray tubes with better cooling capabilities have enabled longer fluoroscopy times and uninterrupted acquisitions of images (Philips, 1995)[3]. A paper written by Park et al, (1996)[4] studied 500 RFCA patients with 5.6% of patients exceeding threshold doses for signs of early transient erythema.

2. Methods. Symptomatic patients were enrolled into PTCA and RFCA groups, monitored for radiation skin dose and followed up for possible deterministic effects of radiation. The investigation took place over 4.5 months between 24th September 1998 and 5th February 1999. 56 patients were studied, 23 patients in the RFCA group and 33 patients in the PTCA group. Patients of both sexes aged between 18 and 75 years were randomised into the study.

2.1 Radiation skin dose was estimated by two methods; via dose-area product meter (DAP meter) and radiation field area measurement and via Thermoluminescent Dosimetry (TLD). The DAP meter was

already installed as an integral part of the equipment. The DAP method gives an average value and does not take account of the distribution of the skin dose due to movements of the x-ray tube. The TLD method allowed point measurements. During the procedure projection, field size , focus skin distance, fluoroscopy time, DAP, kV and mA per 5 minutes RFCA fluoroscopy time and PTCA acquisition.

2.2 TLDs were placed directly on the patient's back to measure entrance surface dose (ESD) including backscatter. TLDs were placed in the following places: bilaterally midway between the spine and the lateral chest wall at the level of the lower end of the scapula in the region of the ninth thoracic vertebra (T9), one placed over the spine, one placed bilaterally on the lateral chest wall at the same level and one placed half way between the lower costal margin and the axilla on both sides of the patient giving a total of 7 TLDs per patient in the RFCA patients. A further two TLDs were placed in the PTCA group at the level of the lower costal margin.

2.3 The patients' backs were checked by a nurse for any skin condition prior to the patient leaving hospital within 24 hours of the procedure and by the patients' husband, wife, partner or friend on six dates over a three month period. A form was provided to assist in providing information of any skin condition that may have occurred at that time. The patient was phoned by the researcher after three months to enquire if any skin problems had occurred.

2.4 The skin dose for each projection was calculated by dividing the DAP by the field size at the patient's skin. Field sizes were estimated from an acquisition taken from rulers placed on the table top in identical projections that the equipment was in when the original acquisition was taken; the same table height and source image distance was used. The estimated skin dose from DAP was multiplied by the backscatter factor. A backscatter correction was used so that results could be compared to TLD measurements which included backscatter. However this method does not take the movement of the tube within a projection into account and therefore would tend to overestimate skin dose in a given projection.

2.5 Skin dose for each of the three main projections of the C-arm; left and right anterior oblique (LAO & RAO) and postero anterior (PA), were summated and compared.

2.6 Effective dose was calculated by multiplying the DAP by a conversion factor taken from NRPB-R262[5]. The factors depend on projection, kV and filtration.

3. Results and Discussion.

Table 1. RFCA & PTCA DAP, Fluoroscopy Time and Images

RFCA	DAP ($Gycm^2$)	FLUORO (minutes)	IMAGES	PTCA	DAP ($Gycm^2$)	FLUORO (minutes)	IMAGES (number)
MIN	14	7	0	MIN	8	5	236
MAX	341	117	1806	MAX	76	54	1854
MEAN	105	37	144	MEAN	32	12	733
ST DEV	85	27	78	ST DEV	18	9	392

Table 1 shows the minimum, maximum, mean and standard deviation of both groups studied.

Table 2. Comparison of RFCA & PTCA skin doses from DAP/ field size in LAO, RAO and PA projections

RFCA SKIN DOSE (mGy)	LAO (mGy)	RAO (mGy)	PA (mGy)	PTCA SKIN DOSE (mGy)	LAO (mGy)	RAO (mGy)	PA (mGy)
MIN	54	89	100	MIN	42	6	4
MAX	2422	1939	791	MAX	1470	1018	306
MEAN	777	403	284	MEAN	409	258	70
ST DEV	648	445	223	ST DEV	366	268	87

3.1 Skin dose calculated from DAP was recorded for each patient and compared to the maximum TLD reading for each patient.

The RFCA mean for skin dose from DAP = 777 mGy and mean for TLD dose = 531 mGy. A correlation but not significant could be made between the two sets of measurements. (Correlation = 0.76261 p = 0.08 ns).
The PTCA mean for skin dose from DAP = 522 mGy and mean for TLD dose = 135 mGy. No significant correlation could be found comparing the two doses. (Correlation = 0.15 p = ns).
There was a wider difference between the two measurements in the PTCA group as it could not be predicted which projections would be used prior to the procedure and many more views were generally taken than in the RFCA group.

Table 3 Characteristics and doses of patients with skin reactions

No	Exam	Age	Sex	Fluoro time (minutes)	Equipment DAP ($Gycm^2$)	TLD Max Dose (mGy)	Skin Dose (mGy) from DAP	Effective Dose (mSv) from DAP
1	RFCA	66	F	18.9	38.9	147.8	264	5.16
2*	RFCA	63	M	50.3	288.2	1346.59	1880	47.0
3*	RFCA	58	M	117.3	195.6	236.0	1386	25.2
4	PTCA	59	M	6.6	15.5	12.52	187	1.7
5*	PTCA	55	M	53.5	103.8	237.4	1516	13.1
6	PTCA	72	F	8.9	22.4	316.48	289	3.3
7	PTCA	45	M	15.8	30.4	18.29	394	3.4

* denotes patients receiving a skin dose of more than 1 Gy.

Table 3 summarises the seven patients suffering from skin reactions indicating fluoroscopy time, DAP, maximum TLD dose, skin and effective doses. Most of the patients experienced itching prior to redness appearing in the subscapular region on their backs and the time of onset varied between 24 hours and twelve weeks. None of the estimated doses for these 7 patients exceeded 2 Gy.

3.2 Threshold doses. 9 of 23 RFCA patients received a total skin dose calculated from DAP of more than 1 Gy. Three of these patients received more than 2 Gy but reported no reaction. 5 patients received skin doses in excess of 1 Gy when the C-arm was angled to the LAO. 2 of the 9 patients received skin doses in excess of 1 Gy when the angulation of the C-arm was in the RAO projection and one of these patients received almost a deterministic level of 1939 mGy. 2 of the 9 patients reported skin injury.

5 PTCA patients received a total skin dose measured from DAP in excess of 1 Gy. Two of these patients received more than 1 Gy to the right side of the back in the direction of the X-ray tube in the LAO angulation. One patient reported a skin reaction.

3.3 Effective dose. Total body effective dose E was calculated from the DAP using conversion factors from NRPB-R262[5].

Table 4 Effective dose from the two procedures.

Procedure	Mean DAP ($Gycm^2$)	Mean E ± SD	Min E (mSv)	Max E (mSv)
RFCA	105	22.5 ± 20	2.8	79.6
PTCA	32	6.2 ± 4.0	1.2	16.8

3.4 The risk factor coefficient for cancer for the adult working population = 0.037 per Sv or 1 in 27,027 per mSv. Younger patients who are exposed to radiation have a greater risk of fatal malignancy than older patients. Lindsay et al, (1992)[6] stated that there is also a higher risk of fatal malignancy in females for increasing lengths of fluoroscopy time. The likelihood of cancer increases with increased radiation doses but not the severity Wagner et al, (1994)[7].

If patients returned with a late skin injury following a procedure with prolonged fluoroscopy time, Nahass (1995)[8] indicated that they should be diagnosed as having radiodermatitis and that they should be followed-up at regular intervals as this condition could later develop into a carcinoma.

4. Actions taken at the time of the procedure and future recommendations were made:
(a) More explanation given to patients as to the amount of radiation they may be receiving. The researcher noticed on consenting patients for the procedures that many patients were unaware of any X-radiation involved.
(b) Patients should be informed of the potential radiation risks involved with RFCA or PTCA procedures.
(c) Patients should be checked regularly for skin reactions for deterministic effects of radiation if a certain dose has been exceeded and asked to report if any should arise.
(d) Collimation should be used wherever possible to reduce field size to observe only the area in question.
(e) Ensure that the table height is at least 60 cms from the tube focus to reduce ESD.
(f) Magnification for RFCA procedures should be used as little as possible.
(g) The angulation of the C-arm should be changed to prevent over exposure in one area remembering that the LAO position produces the most radiation dose. The lateral projection should not be liberally used as the focus to skin distance is minimal.
(h) Use appropriate equipment to deliver the lowest overall exposure dose required for the procedures.
(i) Protocols should be observed and updated regularly with time limits set for lengthy fluoroscopy procedures.

5. Conclusion. It can be seen from the results that very high radiation skin doses were received by several patients in the RFCA and PTCA groups of patients. Seven of these patients have reported skin injury and three of these patients received doses more than 1 Gy. However the remaining four received estimated doses of less than 400 mGy.
Unlike other studies, the researcher followed the patients for a three month period and the skin reactions would have been unnoticed if the follow-up had not taken place.

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A STUDY ON THE ANNUAL EQUIVALENT DOSES RECEIVED BY CARDIOLOGISTS IN A UK HOSPITAL

Ruby Y. L. Fong, Elaine Ryan, Sara Alonso-Arrizabalaga
Clinical Physics Group, St Bartholomew's Hospital, London, United Kingdom.
Fax: +00144-20-76018294. E-mail: r.y.l.fong@mds.qmw.ac.uk

Abstract

A dose assessment study was carried out to determine the likely annual equivalent doses received by various parts of a cardiologist's body. High sensitivity GR-200 thermoluminescent dosemeters were attached to cardiologists' foreheads, little fingers, wrists, elbows, knees and ankles. Three common cardiology procedures were investigated, namely, percutaneous transluminal coronary angioplasty (PTCA), permanent pacemaker insertion (PPM) and left heart catheterisation (LHC). Dose monitoring was done on a case-by-case basis. Data on ten cases of each procedure were gathered. The projected annual equivalent doses were computed by averaging the ten doses measured at each site for each examination type and finding out from the cardiologists how many cases of PTCA, PPM and LHC they do in a year. Results in this study show that for the lens of the eye, the projected annual equivalent dose is below 10 mSv and for the other body parts, it is below 100 mSv per year. The study demonstrated that the methodology used can help to optimise radiation protection in diagnostic radiology.

1. Introduction

For workers who are occupationally exposed to ionising radiations, article 9 of Council Directive 96/29 Euratom [1] states an annual equivalent dose limit of 150 mSv for the lens of the eye and 500 mSv for hands, forearms, feet and ankles. United Kingdom has adopted these values in the Ionising Radiations Regulations 1999 [2]. Paragraph 1(c) of Schedule 4 of Ionising Radiations Regulations 1999 states, "the limit on equivalent dose for the hands, forearms, feet and ankles shall be 500 mSv in a calendar year". For the first time in UK legislation, specific parts of the limbs are subject to a dose limit, hence there is a need to make some dose assessment to these body parts. In diagnostic radiology, the group of workers that is most likely to receive the highest doses are people who are involved in interventional work. Cardiologists are one example.

A study was carried out to (i) assess scattered doses received by different parts of a cardiologist's body, (ii) estimate the likely annual equivalent doses that the various body parts would receive and (iii) establish if additional protective measures are needed.

The dose received by different parts of the cardiologist's body depends on many factors, such as the examination procedure, the patient and complexity of the case, the skill of the cardiologist, the x-ray image intensifier system, the protective equipment used and the position of the cardiologist in relation to the x-ray tube and patient. Due to this interplay of contributing factors and for practical reasons, dose assessment was made per individual case using small, high sensitivity thermoluminescent dosemeters (TLD) that can be attached on or close to the body parts under study. Previous researchers [3] have studied exposure to operating staff in cardiology using thermoluminescence dosimetry but only five cases of cardiac catheterization were investigated. The current study investigated three common cardiology procedures and data from many more cases were collected.

2. Materials and Methods

The study was conducted in a well-established cardiology department of a large teaching hospital. Seven cardiologists were involved, comprising one consultant and six specialist registrars in various years of their training. Three common cardiological procedures were selected for this study: percutaneous transluminal coronary angioplasty (PTCA), permanent pacemaker insertion (PPM) and left heart catheterisation (LHC). Data on ten cases of each of these examinations were collected. Dose monitoring was done on a case-by-case basis. The examinations were carried out in three cardiac laboratories equipped with C-arm x-ray image intensifier units that are less than 5 years old (table 1). Each unit has Diamentor transmission ionisation chamber (Diamentor, PTW, Freiburg, Germany) attached to the head of the x-ray tube.

Table 1. Specification of the x-ray equipment in the three cardiac laboratories

	Laboratory 1	Laboratory 2	Laboratory 3
Manufacturer/ Model	Philips Integris V3000	Siemens Coroskop Classic	Philips Integris H3000
Generator	Optimus CP	Polydoros IS/C	Optimus M2000
Field sizes (cm)	38, 31, 25, 20, 17	23, 17, 13	23, 18, 13
Copper pre-filtration	None	Fluoroscopy and Acquisition*	Fluoroscopy

*No copper filter in acquisition mode if patient size is greater than 25 cm.

Individually calibrated LiF: Cu, Mg, P dosemeters were used to monitor doses at various sites of the cardiologist's body. They were GR-200 chip dosemeters, also called TLD-100H chips (3mm x 3mm x 1mm) from Harshaw Bicron/NE-Technology (BICRON-NE, Solon, OH, USA). These TLDs have high sensitivity and are able to detect doses down to 1μSv above background. They are commonly known as Chinese TLDs. The TLDs were sealed in small black plastic sachets and attached to the forehead, the fifth digit of each hand and the left and right wrists, elbows, knees and ankles. The TLD sachets were taped to the body part using micropore tape except for the forehead where a headband was used and the wrists where wrist bands were used. The TLD at the forehead was aimed at monitoring dose to the eye. The finger TLDs were taped at the distal end of the finger but not at the fingertip so that the dexterity and comfort of the cardiologist were not affected. Two unexposed TLDs were used as control dosemeters. At the end of each examination, all TLDs were removed and read out in a Toledo 654 reader (D. A. Pitman Ltd.). They were annealed in an oven at 240° for 15 minutes followed by rapid cooling to room temperature before re-use.

In addition to the GR-200 dosemeters worn for the purpose of this study, the cardiologists also wore their monthly dosemeters comprising a body film badge, a collar film badge, a headband containing a TLD-100 dosemeter and a wrist band containing a TLD-100 dosemeter. They all wore lead aprons which had 0.5mm lead (Pb) at the front and 0.35mm Pb at the back, a 0.5 mm Pb thyroid shield and no Pb glasses. During PTCA and LH catheterisation procedures, they used a Brompton screen for protection. The screen has a cut-out in the Pb glass and has Pb drapes at the bottom. No protective screen was used for pacemaker insertion procedures.

The projected annual equivalent doses were computed by averaging the ten doses measured at each site for each examination type and finding out from the cardiologists how many cases of PTCA, PPM and LHC they do in a year. These three examinations together comprise the majority of their workload. In order to be conservative, data from a cardiologist who had the highest caseload were used.

3. Results and Discussion

The results are presented in figures 1 and 2.

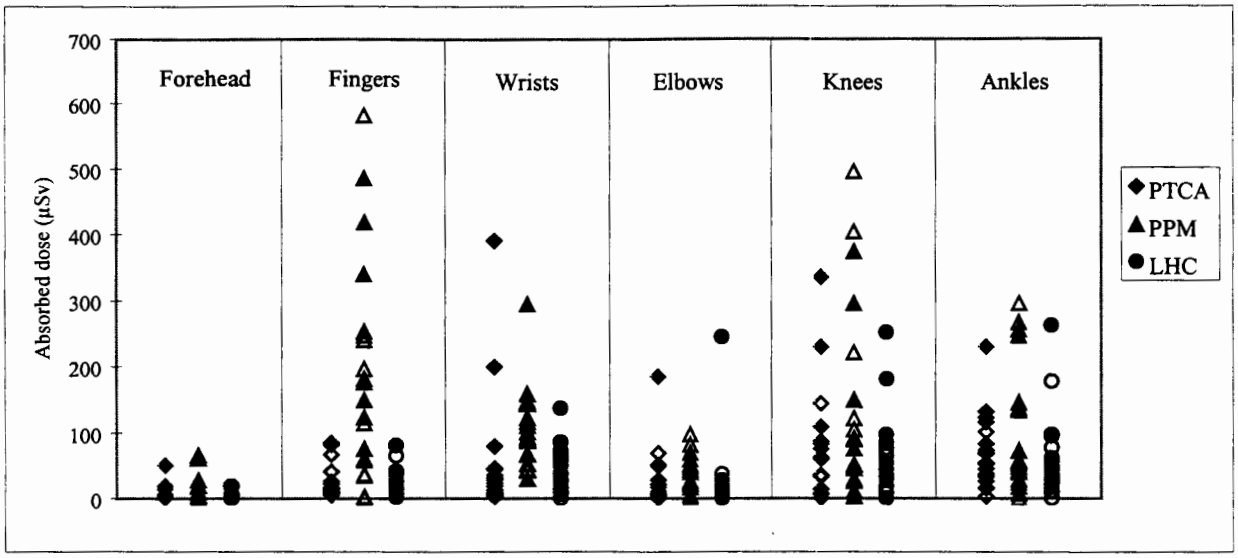

Figure 1. Distribution of individual doses measured in the study. Solid markers are doses measured on the left body part and open markers are doses measured on the right body part.

Figure 1 shows all the individual doses measured in the study. For PTCA which is marked by diamond markers, the highest doses are found in the wrists and knees. The left wrist and left knee get a higher dose than the right side. The left is marked by solid diamonds. During PTCA, the cardiologist stands on the right side of the patient and it is the left side of the cardiologist that is closer to the x-ray tube, hence the higher dose. For PPM, the fingers and knees get the highest doses. Many of these doses are also much higher than those received during PTCA and LHC. This is because the cardiologists do not use any protective screen during PPM. In PPM, it is the right side of the cardiologist that gets the higher dose, marked by open triangles. This is because during PPM, the cardiologist stands on the left side of the patient and it is the right side of the cardiologist that is closer to the tube, hence the right side tends to get the higher doses. For LHC, the knees and ankles get the highest doses. Like PTCA, the left side gets a higher dose than the right side. The cardiologist stands on the right side of the patient and it is the left side of the cardiologist that is closer to the tube, hence the higher doses marked by the solid circles. In general, doses received during LHC are lower than those received during PTCA which is a more complicated procedure.

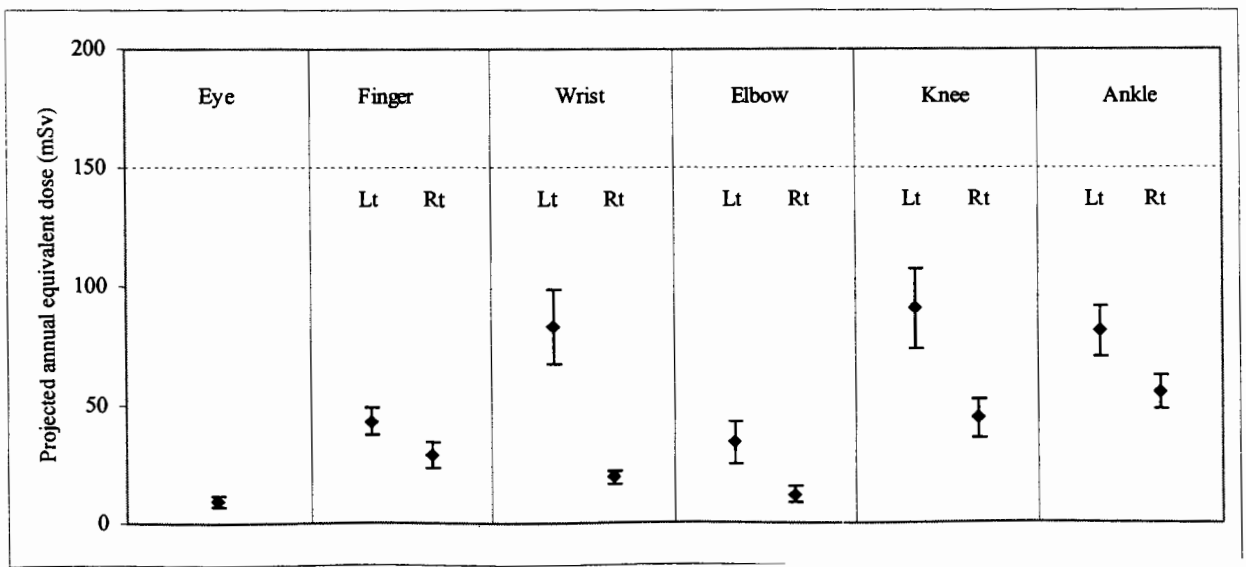

Figure 2. Projected annual equivalent doses for a senior cardiology specialist registrar

Figure 2 shows the projected annual doses and standard error. It also marks the 150 mSv level which is the three-tenths UK annual equivalent dose limit for the various body parts and the full annual dose limit for the lens of the eye. All doses are well below the 150 mSv line. Projected annual equivalent dose to the lens of the eye is below 10mSv and the spread is small. For the other body parts, the projected annual equivalent dose is less than 100 mSv, even taking the spread in dose into account. In each case, the left hand side gets more dose than the right hand side because except for PPMs, it is the left side of the cardiologist's body that is closer to the tube. Left wrist, left knee and left ankle get the highest doses.

4. Conclusions

The use of high sensitivity GR-200 thermoluminescent dosemeters had enabled individual doses at various sites of a cardiologist's body to be measured on a case-by-case basis. Three common cardiology procedures were investigated, namely, PTCA, PPM and LHC. Three conclusions can be drawn from this study.

(1) Overall, doses on the left side of a cardiologist's body are higher than doses on the right. This is due to the fact that for PTCA and LHC procedures, the cardiologist stands on the right side of the patient and it is the left side of the cardiologist's body that is nearer to the x-ray tube.
(2) Results from this study show that the projected annual equivalent doses are well within three-tenths of any UK annual dose limit. Therefore there is no justification for designating cardiologists in the establishment concerned as classified workers on the basis of their equivalent doses. Routine personal monitoring shows that cardiologists' body doses are also well below the three-tenths limit.
(3) Dose monitoring at the additional sites is not routinely required under current circumstances.

From this study, two recommendations are proposed. Firstly from the point of view of radiation protection, routine monitoring of wrist doses should be done on the left wrist. Secondly, the addition of lead curtains to beds in angiography laboratories should be considered. This will greatly reduce doses to knees and ankles. On-going training in radiation protection is necessary in helping radiation workers to keep their doses as low as reasonably achievable.

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PATIENT AND STAFF DOSE DURING HYSTEROSALPINGOGRAPHY

BULS N and OSTEAUX M
Free University Hospital Brussels (AZ-VUB)
Department of Radiology and Medical Imaging
Laarbeeklaan 101, B-1090 Brussels, Belgium
Nico.Buls@az.vub.ac.be

Abstract

Hysterosalpingography (HSG) is a useful and widely employed technique which uses X-ray fluoroscopy to investigate the female genital tract. Fluoroscopy is assessed by a gynaecologist, a physician who is not always trained to work with ionising radiation. Dose-area product measurements in a group of 34 patients allowed an estimation of the median effective dose (0,83 mSv) and the median dose to the ovaries (1,63 mGy) of the patient per procedure. The dose to the staff was estimated using thermoluminescent dosimetry. The following median entrance surface doses were estimated per procedure: 0,22 mGy to the lens of the eye, 0,15 mGy to the neck at thyroid level and 0,19 mGy to the back of the hand. The annual eye dose limit could be exceeded if the gynaecologist is a member of the public.

1. Introduction

Hysterosalpingography (HSG) with water-soluble contrast media is a useful and widely employed method of investigating the female genital tract. The most common indication to perform an HSG is infertility. During an HSG, X-ray fluoroscopy is carried out by a gynaecologist to visualise the genital tract (uterus and Fallopian tubes). Since most patients (age between 20-40) desire pregnancy and the X-rays are targeted at the gonadal region, optimisation in terms of dose reduction and image quality is essential. A gynaecologist is a physician who is generally speaking not trained and used to work with ionising radiation as a radiologist and therefore not always familiar of the harmful effects to himself and his patient. Often he is not an occupational exposed worker but a member of the public. This clinical study is undertaken to estimate the effective dose and organ doses to the patient with respect to articles 4 and 9 the Euratom 97/43 directive [1] which imposes the European member states the promotion of the establishment and use of diagnostic reference levels. The doses to the eye, neck and hands of the staff (gynaecologist) were also estimated by using thermoluminescent dosimetry.
Several international papers have already been published regarding the patient dose in HSG [2-6], but no recent papers, to our knowledge, could be found regarding the dose to the staff.

2. Material and Methods

A total of 34 patients were evaluated on a over-couch General Electric Prestilix 1600 DRS radiographic unit. The input air kerma rate for the smallest field size (12.5 cm) in high dose rate selection measured on top of the image intensifier with a 15 cm^3 ionisation chamber and 2 mm additional copper filtration is 0.68 $\mu Gy.s^{-1}$. Digital acquisition is used during the examinations.
The dose area product (DAP) as a measure of radiation dose was determined for each radiographic and fluoroscopic exposure to each patient. Accordingly, the kilovoltage and view/projection for each single exposure were documented. The effective dose and doses to

the ovaries and uterus were estimated using the recorded DAP value in combination with effective dose conversion factors derived from Monte Carlo computer calculations for a female mathematical anthropomorphic phantom [7]. These factors are expressed in function of beam quality, applied kilovoltage and anatomical projection.
For the staff dosimetry, entrance surface doses (ESD) were measured by using thermoluminescent dosimeters TLD-100H (LiF: Mg, Cu, P) at different positions on the body of the gynaecologist. Three TLD chips were attached to the skin between the eyes, three to the skin of the neck at the level of the thyroid and three to the skin of the back of the hands for each examination. The ESD at one position (eye, thyroid or hand) was calculated as the average of the three readings. The TLD's were calibrated in air at 96 kVp (= energy used during ERCP) on the same X-ray unit. They were processed with a Harshaw-Bicron 5500 TLD reader and annealed in a PTW-TLDO oven. The gynaecologist wears a wrap around apron with 0,25 mm lead equivalence as personal protection.

3. Results and discussion

3.1. Dose to the patient

An overview of the patient exposure data per HSG procedure in terms of dose area product (DAP), fluoroscopy screening time, ovarian dose, uterus dose and effective dose is presented in table 1. 80 % of the dose to the patient is due to the contribution of fluoroscopy. Since the data presents not a normal distribution, the 1st quartile, median, 3rd quartile and maximum values are provided besides the mean.

Table 1 Patient exposure data evaluated for 34 examinations.

Exposure indicator	Hysterosalpingography (34 studies evaluated)				
	Mean	1st quartile	Median	3rd quartile	Maximum
Dose Area Product (Gy cm²)	5,62	3,54	4,30	6,38	23,2
Fluoroscopy screening time (s)	58	34	43	66	210
Ovarian dose (mGy)	2,70	1,36	1,63	2,82	15,5
Uterus dose (mGy)	4,06	1,81	2,15	4,32	27,8
Effective dose (mGy)	1,39	0,70	0,83	1,44	8,53

From the data in table 1 can be seen that the exposure to the patient shows a large variation. This can easily be understood considering the influence of the patient size on the tube load and the variation in the assessed screening time according to the conduct of the procedure and the patient condition. The effective dose of the HSG patient is comparable to the dose resulting from other conventional radiological examinations. Table 2 compares our data to this from other studies previously published in literature.

Table 2 Comparison of HSG dosimetric data published in literature.

Study	Sample size	Fluoroscopy screening time (s)	DAP (Gy.cm²)	Ovarian dose (mGy)	Effective dose (mSv)
This study	34	43	4,30	1,6	0,83
[2]	21[b]	15		3,1	
	24	12	0,22	0,5	
[4][a]	40	40		2,8	
[6][a]	16[b]		4,42		
	16		2,07		
[5][a]	35			4,5	1,95

[3]	41	7,13	4,6	3,10

[a] mean values
[b] analogue unit

All the values presented are median values recorded on digital units unless stated different. The data shows a large variation due to the difference in radiographic equipment, applied clinical technique and statistical analysis.

2.2. Dose to the staff

Table 3 shows an overview of the entrance surface doses to the forehead, neck and hand of the gynaecologist. A comparison is made to staff doses from other interventional radiological (IR) procedures previously published in literature. Due to the lack of HSG staff dose data in literature, no comparison could be made for this procedure. The data shows that staff doses in HSG are rather low compared to those from more complex IR procedures. In HSG, the staff is located at a very short distance to the area of exposure but the beamload and fluoroscopy screening times are low compared to more complex IR procedures where screening times are often between several minutes up to a half hour.

Table 3 Entrance Surface Dose (ESD) per HSG procedure for the eye, neck and hand of the staff, compared to other dosimetric data previously published in literature.

Study	Procedure	Sample size		ESD (mGy) per procedure		
				Eye	Thyroid	Hand
Present	HSG	34	Median	0,22	0,15	0,19
			3rd quart.	0,26	0,19	0,25
			Maximum	0,28	0,21	0,29
[8]	Cardiac IR	5	Maximum	0,15	0,34	0,65
[9]	Cardiac IR		Median	0,24	0,10	0,30
[10]	Percutaneous renal surgery	8	Median	0,19		0,23
[11]	Various IR	30	Mean			1,5

4. Conclusions

This study investigated the patient and staff doses during hysterosalpingography (HSG) The third quartile values of the ovarian dose and the effective dose for a group of 34 patients were 2,82 mGy and 1,44 mSv respectively. The measurements show that the dose-area product (DAP) is an easy tool to guard the patient dose during the examination. This is strongly advised since the gonadal region is exposed and all patients are young women who desire pregnancy.

Considering an average of 85 annually performed HSG examinations and the data (third quartile values) presented in table 3, the gynaecologist would receive an annual ESD of 22 mGy at eye level, 16 mGy at thyroid level and 21 mGy to the skin of the hand. This is, in general, lower than doses to staff-members who perform more complex IR procedures (angiography and cardiology) but the gynaecologist is often a member of the public who is not trained to work with ionising radiation. Moreover, the annual dose limit of 15 mSv to the lens of the eye could be exceeded. From the view of patient protection, it is clear that gynaecologists who perform HSG should be properly trained to use ionising radiation and especially in limiting the fluoroscopy screening time. He should also be a member of the occupational exposed workers.

It is advised that HSG should be included in future clinical multi-center patient and staff dose surveys at national and international level.

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RADIATION PROTECTION OF PATIENTS IN DIAGNOSTIC RADIOLOGY IN ESTONIA

Irina Filippova
Estonian Radiation Protection Centre
Kopli 76
10416 Tallinn
Estonia
Tel. + 372 6603331
Fax + 372 6603352
e-mail: irinaf@kopli.envir.ee

Abstract

The medical use of ionizing radiation started at the beginning of the century. It has always been considered necessery , as well for diagnostic applications where exposure to the patient is the price to pay in order to obtain useful images, as for therapy where the patient is exposed on purpose, in order to kill malignant cells. It is nowadays the major man-made contribution to the population dose . Even with the Developments of substitutive imaging or treatment techniques , there is still an increasing demand and many organizations are joining their efforts to try to keep the dose to the patient " as low as reasonably achievable ".
This is particularly the case for the International Commission on Radiological Protection (ICRP) which recommended in publication 26 to follow three main principles: justification, optimisation and limitation. Limitation , however, does not apply to patients since the individuals exposed are expected to benefit from this exposure, but justification and optimization are relevant.

1. Regulatory Authority

The national legislation (Radiation Protection Act) nominates a national Regulatory Authority which is given responsibility for regulating any practices involving radiation sources.
Estonian Radiation Protection Centre was established in January 1996. The general functions and responsibilities of Estonian Radiation Protection Centre are following:

- development of regulations, guides and codes
- assessment of applications for permission to conduct practices that entail or could entail exposure to radiation
- authorization of such practices and of the sources associated with them
- conduct of periodic inspections to verify compliance with license conditions
- enforcement of any necessary actions to ensure compliance with the regulations and standards
- keeping records of all sources of ionizing radiation
- keeping records of all radiation doses received by radiation workers and make estimates of doses received by the public
- preparations of plans and procedures for dealing with emergency situations

- advice to other national institutions, users of ionizing radiation and the public on radiation protection and related matters.

2. Legislation

In common with other developing countries, Estonia try to implement all legislative acts in compliance with the Euratom Directive 97/43 of 1997 dealing with the " Basic Standards for the Health Protection of the General Public and Workers against the Dangers of Ionizing Radiation".

2.1. Radiation Protection Act

Radiation Protection Act in Estonia was issued in 23 of April 1997.
Chapter 2 , § 5 :
" A license for activity involving radiation is required for:
1) construction, operation and decommissioning of nuclear facilities
2) handling of nuclear substances or materials or materials containing nuclear substances
3) addition of radioactive substance at production and manufacturing of pharmaceuticals and consumer goods
4) administering of radioactive substance to humans and animals for diagnostic, therapeutic and scientific purposes
5) use of an X-ray apparatus, an accelerator and an irradiator containing radioactive substance in production , medicine and scientific research

A license for activity involving radiation may be issued if:
1) the licensee for activity involving radiation has a staff of the required professional qualifications;
2) the site for activity , and other conditions guarantee observance of safety requirements".

Chapter 3, § 21 :

"(1) The subject of medical exposure are:
1) the patient at diagnostics and treatment of an ailment;
2) the person nursing the radiation-treated patient if nursing is not his (her) professional occupation and he (she) is aware of the radiation treatment of patient;
3) any person voluntarily having agreed to participate in biological research."

2.2. Regulations of Minister of Social Affairs

The requirements for use of radiation for treatment and diagnostics of ailments was established by ordinance of the Minister of Social Affairs.
The regulation is known as the "The Requirements for Use of Radiation for Therapeutic Purposes and Diagnostics and the Requirements for Radiation Protection of Patients".

Chapter 1. Common requirements.
According this chapter :

- the benefits of the medical procedure must be greater than the detriment it causes;
- phisicians, who give examination or treatment and those who refer patients to it must in every case make sure the exposure to radiation is justified, they both are responsible for this exposure;
- before examination a physician should inform the patient about diagnostic or treatment dose and radiation risks;
- the radiological procedures can to refer only physician, who is sertified in Estonia;
- radiation exposure of test subjects in biological and medical is justified only for very special reasons. It requires a positive opinion from an Radiation Protection Centre;
- in the each user's organization should be established the Quality Assurance system and Quality Assurance Manual;
- before reffering a patient for radiological examination physician have to review results of previous clinical and radiological examinations.

Chapter 2. Requirements to radiological and radiation protection staff.

Chapter 3. Requirements to radiological equipment.
In this chapter:
- difinition " radiological equipment ";
- radiological equipment has to correspond IEC standarts
- in the each user's organization should be established QC programme
- list of quality requirements for X-ray equipment , processing and films.

Chapter 4. Requirements for radiation protection of patients and staff.
In this chapter:
- individual protective shieldings for patients and staff
- working places monitoring
- individual monitoring

2.3. Regulations of Minister of Environment

1. Statute of the National Dose Register of Radiation Workers; Procedure for Certifying Radiation Workers and for Issuing Certificates.

- radiological staff has to be examinated by Commission of Qualified Experts, which was established by Minister of Social Affairs

2. Requirements to rooms and protective shielding in radiological departments.

3. Positives and negatives in radiation protection of patients.

3.1. Positives during 1997-2000 :

- QA system started in Estonia, Qa requirements was included to Estonian legislation
- Authorization system is according IAEA recommendations
- QC requirements was included to Estonian legislation and during 1997-2000 was tested 80% of radiological equipment

- Requirements to radiological and radiation protection staff were included to legislation
- New programme of rezidentship for radiologists? new generation of radiologists
- Special requirements to mammografy
- Profilactic chest examinations only by radiografy
- Developing process only by developing processors (not manually)
- Very good co-operation between Radiation Protection Centre and Radiological Society

3.2. Negatives in radiation protection of patients:

- List of " accepted practicies " in radiology not approved yet
- Maximum doses (activities) of radioactive materials which should be administrated to patients are not established yet
- Maximum doses which should be received by patients in diagnostic radiology are not established yet
- Control of patient doses is not established yet
- Clinical audit (internal and external) in hospitals is not established yet
- QC requirements for dental radiografy, nuclear medicine and radiotherapy are not included to national legislation.

3. Plans for 2001-2002 (in co-operation with Finnish STUK)

- Developing the legislation for radiation protection in medical radiology (guides for QA, inspections, patient doses, optimization).
- Preparing the measuring and controll system for radiation protection in medical radiology.
- Training the staff for the new radiation protection tasks required in Medical Directive97/43 Euratom.

RADIATION DURING PREGNANCY

Dr Keith Faulkner
Quality Assurance Reference Centre
Newcastle General Hospital, Westgate Road
Newcastle upon Tyne. NE4 6BE, England

Prof J F Malone
Dean of Medicine
Trinity College. Dublin, Ireland

Dr R H Corbett
Radiology Department
Hairmyers Hospital. Scotland

Dr P Craven
Barrister at Law
Dublin, Ireland

Dr E K Osei
Medical Physics Department
Princess Margaret Hospital
Toronto, Canada

K Faulkner – Fax No: +44 191 219 5034; email keith.Faulkner@northy.nhs.uk

RADIATION DURING PREGNANCY

K Faulkner, J F Malone, R H Corbett, P Craven, E K Osei

ABSTRACT

The risks of radiation during pregnancy are well established. There is a risk of somatic effects, genetic effects occurring in subsequent generations and mental retardation if the fetus is irradiated in the critical 8-15 week period when organogenesis occurs. It is imperative that the unintended irradiation of the fetus is avoided. Whilst fetal risks have been appreciated for some time, the International Commission on Radiological Protection has never issued practical guidance. However, many national bodies have developed such guidance. In many centres the 10-day and 28-day rules have been variously applied. The purpose of this paper is to review various sources of advice and to highlight three practical implementation issues. These are:

1. Referral could mean more than one examination is performed.
2. The application of the concept of justification to elective procedures.
3. Practical implementation issues.

1. Introduction

The risks of radiation during pregnancy are well established. The main risks are the possibility of inducing cancer (mainly leukaemia), genetic effects occurring in subsequent generations (as the fetus may be considered as a potential parent), and mental retardation, if the fetus is irradiated during the critical 8-15 week period when organogenesis occurs [1]. It is as a consequence of these potential effects of ionising radiation that operational rules are applied for the diagnostic exposures of women who are or may be pregnant, so that these risks are minimised or are avoided. Over a number of years various advice on avoiding the unintended irradiation of the fetus during pregnancy has been issued by the National Radiological Protection Board (NRPB). This has resulted in what are known as the 10-day and the 28-day rules [2]. As a result of advice from the NRPB [2] the 28-day rule replaced the earlier 10-day rule. At the time it was felt that the risks of radiation to the fetus in the initial period following conception were so low as not to warrant the rescheduling of the mother's examination. This decision arose from a reappraisal of the risks during the first weeks post conception and compares those risks with those of the mother not having the examination. Fundamentally, the basis for the advice on avoiding radiology during pregnancy is a judgement on the risks of performing an examination compared with those of not performing the examination. It is interesting to note that neither the International Commission on Radiological Protection or the International Atomic Energy Agency has issued advice on any rule applying to medical exposure of women who are or may be pregnant. The purpose of this paper is to review the work of international organisations in this area and highlight three practical aspects associated with the implementation of these rules.

1) Referral for a radiological opinion could mean more than one examination is performed.
2) The application of the concept of justification to elective procedures.
3) The implications for practical implementation within a radiology department.

2. National and International Advice

Recently two documents have been published which influence the advice on radiation during pregnancy. First is the Medical Exposures Directive of the Commission of the European Communities [3], which places statutory duties on member states. It represents a legal obligation rather than advice on good practice. Article ten of the Directive covers special protection during pregnancy and breast-feeding. This article requires those responsible (i.e. the doctor prescribing the examination and the practitioner performing it) to ask whether a female of child bearing age is or maybe pregnant. If pregnancy cannot be excluded, special attention shall be given to the 'justification' of the procedure. The article requires that the procedures performed on pregnant women are optimised and that the exposure of both the expectant mother and unborn child are considered. In this context the risk/benefit consideration for radiological examinations of women who are pregnant or who may be pregnant is quite demanding and complicated. The risk involves a consideration of the effects of the examination on both the patient and the unborn child. Included in the assessment is the effect of postponing the examination on the mother. The mother mainly derives the benefit of the examination and the embryo/fetus may only benefit indirectly.

The second document is the joint guidance from the National Radiological Protection Board, College of Radiographers and Royal College of Radiologists on exposure to ionising radiation during pregnancy [1]. The objective of the joint advice is to prevent the unnecessary exposure of the fetus during radiological procedures in pregnancy. The advice suggests that when a female of reproductive age is to have an examination in which the pelvis is likely to be irradiated by the main beam emitted by the X-ray set, or during nuclear medicine investigations, she should be asked if she is, or might be pregnant. If there is no possibility of pregnancy then the examination may proceed. If the patient is definitely or probably pregnant then the justification for the examination must be reviewed. In these circumstances, if a procedure is undertaken it is essential that the examination be optimised so that the fetal dose is minimised, consistent with the diagnostic objectives of the examination. If pregnancy cannot be excluded and the radiation dose involved with the examination is considered to be low then the joint advice is to proceed with the examination, provided that the period is not overdue. On the other hand, for 'high dose' procedures, which are considered to be examinations resulting in fetal doses of some tens of mGy, it is suggested that one of the following two courses of action should be adopted.

1. Apply the 10-day rule, in which females of childbearing age are booked for a radiological examination in the first 10 days following the onset of menstruation.

or

2. Re-book patients who attend for such examinations and are identified to be in the second half of their cycle and in whom pregnancy cannot be excluded.

3. Practical Implications

There are a number of issues that arise from applying this advice in a practical situation in the context of the operational procedures of a radiological department. Firstly this depends on the definition of a high dose procedure, as a few tens of mGy is an imprecise end point for practical purposes. It could be interpreted usually as applying to all examinations where the fetal dose could be 20 mGy or more. The joint guidance ignores the issue that women are referred for a radiological opinion. In many instances the radiologist may decide to perform a series of radiological investigations to achieve a diagnosis. Consequently, this could involve the woman having a number of radiological examinations that individually would result in doses below 20 mGy but cumulatively could mean that the fetus receives a dose in excess of 20 mGy. Whilst most departments would be aware that more than one examination may be performed and would be aware that the cumulative dose would be over 20 mGy, some may not recognise that underlying issue. Applying the advice of the NRPB, COR and RCR would not preclude this eventuality. For example, a woman referred for an investigation for lower back pain could have a conventional radiographic examination of the lumbar spine, and intravenous pyelogram followed by a computerised tomography scan of the lumbar spine. Independently, these examinations would each have fetal doses below the 20-mGy value, but collectively the fetal dose would be above this level. This hypothetical example is illustrative of two further issues. Firstly, lower back pain is not considered an emergency or needing urgent investigation. Secondly, conservative treatment, without the need for radiological examinations is usually advocated.

Thus when a request for a radiological opinion is received for lower back pain, or other conditions that could precipitate a series of conventional radiographs of the lower abdomen, then it is recommended that the department develop an operational policy to deal with this situation. It is suggested that the fetal dose is estimated to discover whether the cumulative fetal dose from these examinations is above 20 mGy. It is important to stress the need to estimate the dose to the individual woman, as there is scientific evidence that suggests that women who have x-rays who subsequently discover that they are pregnant would receive a fetal dose higher than that suggested by using the average from a large-scale survey.

In elective investigations, the situation of the embryo/fetus with regard to radiation risks must be respected. Elective in this context means an examination that could be performed straight away or deferred for a period of time without adversely affecting the mother. In many respects, this situation is similar to that of the occupational exposure of a woman who is known to be pregnant as the latter is in effect an elective exposure. For occupational exposures of staff, the fetus is considered to be a member of the public [4]. By implication if one considers occupational exposures to be elective then advice should be consistent in relation to fetal exposure. However, the dose threshold for elective examinations (i.e. a few tens of mGy) is much larger than the dose limit for occupational exposures, which in most circumstances would be regarded as elective exposures. For an elective medical exposure, the benefit of the exposure to the mother and hence the child must be taken into account. In particular, for elective procedures the concept of justification should be adapted to take into account that it may be possible to reschedule the examination and avoid the fetal radiation risk entirely.

Secondly the Medical Exposures Directive is written in terms of the unborn child. In a court of law this could be interpreted as including both the pre- and post-implantation phases of pregnancy. The advice on the development of the 10 and 28-day rules should be viewed in the context. Application of both rules must obviously be adjusted to take account of individual variations of the duration of the menstrual cycle. The impact of changes in the menstrual cycle on the 10 and 28-day rules is explained clearly in the NRPB document [1]. If the woman had a shorter cycle than the normal 28 days, fertilisation could occur before 10 days. For example, a lady with a cycle of 21 days, there would be a possibility of fertilisation occurring at any time after 7 days of the menstrual cycle. Consequently the application of a 10-day rule without considering the menstrual cycle of the individual concerned could result in the unintended irradiation of the unborn child. This is particularly relevant as many departments use a form that records the date of the last menstrual period and not whether the patient has been asked if she is pregnant.

Applying the 28-day rule also has difficulties. The purpose of asking female patients of childbearing age the date of their last menstrual period is to establish whether the patient is pregnant. This is an inappropriate question if it is the only one that is posed as it has an implicit assumption that the patient has a 28-day menstrual cycle. Thus in a practical situation, it is a waste of time, as is recording the date of the last menstrual period on the request form. Asking the question 'Have you missed a period?' or 'Are you or could you be pregnant?' are to be preferred. For women who state that they have missed a period it is necessary to establish whether they could be pregnant, because not all women in this group will be pregnant. Developing an operational procedure to ask a series of diplomatic and appropriate questions in the light of the above is beset with difficulties.

A fundamental question in formulating advice on irradiation during pregnancy is upon what level of risk should the guidance be based. Implicit in the joint advice is that at 20 mGy the risk is considered not to require the rescheduling of radiological examinations. It is stated in the joint guidance [1] that this level equated to a probability of inducing fatal cancer to age 15 of 1 in 1,650. This compares with a fatal cancer risk to age 15 in the general population of 1 in 1,300. Thus extrapolating from joint advice, 25 mGy doubles the fatal cancer risk to age 15.

The choice of a few tens of Gy must be the subject on informed debate and not appear to be a somewhat arbitrary figure. In addition, there is a risk of hereditary effects from fetal irradiation, which at a fetal dose 20 mGy equates to a risk of 1 in 52,000 (extrapolating from reference 1). This is somewhat less than the natural risk of hereditary disease at birth in the human population of 6%, which depends on what is considered to constitute heritable disease. Moreover, there is the unknown risk of the loss of an embryo prior to implantation. One may suspect that many members of the general public would choose, with strictly elective procedures, not to undergo these risks and reschedule their appointments to a time when they are definitely not pregnant.

In addition, most operational procedures for radiological examination of women of childbearing potential will have to be developed at a local level. There is an opportunity for there to be confusion over who has day to day operational responsibility. Is it the referring physician/surgeon, the radiologist identifying the procedures to be performed or the radiographer performing them? This issue has clear medico legal consequences and should be addressed in the implements of the Medical Exposures Directive [3].

In summary, there are a number of practical issues surrounding the implementation of the joint advice in the context of the Medical Exposures Directive of the European Union. These issues have a much wider relevance. We wish to raise these issues in order to stimulate a scientific debate on a basis for the formulation of this advice and how this should be transposed into practical guidelines.

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Radiation Risk Evaluation and Reference Doses in Interventional Radiology

K Faulkner, E Vano, R Padovani, J Zoetelief

Abstract

In interventional radiology, there are two potential hazards to the patient. These are somatic risks and, for certain procedures, deterministic injuries. The task of radiation protection in interventional radiology is to minimise somatic risks and avoid deterministic injuries. Radiation protection tools and protocols must be developed to achieve these two objectives. Reference doses have been proposed as a method of identifying high dose centres and equipment. The role of reference doses in interventional radiology will be discussed. There are two approaches to reference doses in interventional radiology. These are the measurement of patient entrance skin dose or skin dose rate, or image intensifier input dose rate. Alternatively, dose area product or effective dose to the patient may be monitored. These two main approaches have their advantages and disadvantages.

1. Introduction

The International Commission on Radiological Protection first introduced the concept of reference doses in Publication 60 [1]. The use of reference doses has been expanded in Report 73 [2]. In paragraph 100 '*the commission now recommends the use of diagnostic reference levels for patients. These levels which are a form of investigation level apply to an easily measured quantity, usually the absorbed dose in air or in a tissue equivalent material at the surface of a simple standard phantom or representative patient*'. ICRP introduced the concept of reference doses as a means of identifying centres, equipment or procedures that consistently exceeded the appropriate reference dose level. If these reference dose levels were exceeded, then it was intended that there would be a local review of practice and procedures within the centre and that optimisation studies would be concentrated on high dose equipment as a consequence.

Reference levels were intended to apply to medical exposures and not to occupational or public exposures and are therefore entirely different in nature from dose limits and dose constraints. In practice, reference doses may be regarded as an optimisation tool for the reduction of patient doses in radiology. It was intended by ICRP that the reference dose levels would be selected by professional medical bodies and reviewed as they regarded reference doses as an evolving concept that would continually drive down radiation dose levels to patients.

2 Interventional Radiology

Interventional radiology procedures almost invariably involve the use of fluoroscopy using image intensification. There has been a number of reports of deterministic injuries occurring in patients undergoing certain types of interventional radiology procedures that have long fluoroscopy times. Thus, the purpose of applying reference doses in interventional radiology is to minimise the risk of somatic effects and to avoid the occurrence of deterministic injuries for certain types of procedure.

Deterministic injuries in interventional radiology can occur as a result of a combination of factors. The main contributing factor found in an analysis of previous incidences was found to be the use of high dose rate equipment [3]. Another factor was the lack of training and education of the practitioner performing interventional procedures. Moreover the type of protocol used to perform an interventional procedure will have a dramatic influence on the absorbed dose received by patients during that particular procedure.

As the potential for deterministic injuries in interventional radiology could be the result of many different underlying reasons, it is necessary to develop a sophisticated approach to the application of reference doses in interventional radiology procedures. For example, simplistic approaches based upon the measurement of equipment based parameters such as image intensifier input dose rate or entrance dose rate at the patients skin will serve to only identify those centres where the equipment is either incorrectly set up and at the high dose end of the spectrum of equipment used. This approach will not pick up deterministic injuries that occur as a consequence of poor clinical protocols. The alternative approach of establishing reference doses on the basis of patient dose measurements involving either dose area product or effective dose has the advantage of being able to assess whether the clinical examination protocol has contributed to the occurrence of deterministic injuries, but it is difficult to establish whether this is alone the cause on the basis of a single measurement. This paper will describe the two approaches to assessing reference doses in interventional radiology and present a set of reference doses for both equipment related and patient related dose quantities. Furthermore, the advantages and disadvantages of these approaches will be compared and contrasted.

3. Approaches to Establishing Reference Doses

The problem with the use of fluoroscopy equipment for interventional radiology is that the procedures are almost invariably performed under a variety of forms of automated control. As a consequence, the technique factors continually vary during the examination that makes the calculation of patient doses extremely difficult for interventional radiology. Consequently, for this type of examination it is common practice to measure either the dose area product or air-kerma area product by using a large area ionisation chamber attached to the output port of the x-ray tube. The ionisation chamber intercepts the entire radiation beam and the reading is a combination of the area of the patient irradiated and the absorbed dose across the beam. The quantity dose area product has the advantage of being independent of the plane of measurement away from the source of the x-rays. It is possible to convert a dose area product or air-kerma area product reading to the quantities energy imparted and effective dose. This involves the simulation of the procedure and the measurement of radiation dose in a phantom using thermoluminescent dosimeters. Alternatively, radiation transport calculations can be made in mathematical models. Conversion factors are examination specific and depend, for example, upon the area of the patient irradiated and the projection directions used.

Many international bodies and regulatory authorities have specified reference dose in terms of the maximum entrance dose rate at the patient's surface during fluoroscopy. However, none of the regulatory bodies have specified a measurement protocol to assess this quantity. In addition, there is no established international consensus upon the reference value that should be applied as may be deduced from Table I [4]. An alternative quantity, which can be used and easily measured, as part of a quality control programme for fluoroscopy equipment is a measurement of dose rate or air-kerma rate at the image intensifier, input surface. This measurement is usually performed as part of a protocol for the assessment of image quality. A 1 or 1.5 mm copper filter is placed at the x-ray tube housing and an ionisation chamber is placed as close as possible to the input surface of the image intensifier. Measurements are performed at typical technique factors selected by the automatic control system.

Table I – References Dose Rates Recommended by National and International Bodies

Organisation	Fluoroscopy Mode	Dose-rate (mGy/min)
IAEA	Normal	25
IAEA	High level	100
UK	Any	100+
FDA	Normal	50
AAPM	Normal	65

+should not exceed 50 mGy/min.

4. Results

Table II presents a series of reference doses for a number of interventional procedures [5]. These reference doses have been deduced from a large-scale patient dose survey in the North of England performed in a number of x-ray departments in hospitals. The reference dose value is taken to be the 75th percentile of the dose distribution.

Table II – Reference Values for Interventional Procedures. Size Corrected Dose-Area Product ($Gy.cm^2$)

Examination	Reference Value
ERCP	19.39
Angiogram	24.26
Venogram	3.61
Hysterosalpingogram	4.12
Angioplasty	16.92
T-tube cholangiogram	9.70

5. Discussion

Measurement of image intensifier input dose rate is relatively easily made. It will be performed as part of a quality control programme for fluoroscopy equipment. It will identify equipment which has been poorly set up or calibrated or where the performance of the image intensifier has deteriorated over a period of time. It will not, however, be appropriate to use this to assess all centres where deterministic injuries may occur, as the injuries could be the result of use of inappropriate patient protocols.

An alternative approach, that of measuring the patient entrance surface dose rate which may be performed using phantoms, has the advantage that it will measure a quantity from which it is possible to deduce the maximum entrance dose from a knowledge of the total elapsed fluoroscopy time. This requires centres to record examination details such as total fluoroscopy time and number of acquired images. Its disadvantage is that it will overestimate maximum skin entrance dose unless an examination specific reduction factor is applied to take into account the fact that the irradiated area changes throughout interventional procedures. It will, however, detect equipment that is poorly calibrated or set up but once again it's main failing lies with the lack of its sensitivity to assessing problems with patient protocols.

The assessment of dose area product or effective dose using a dose area product meter has the advantage of producing a quantity that is closely related to the somatic risk of the procedure. For this reason, it is recommended for use, as it will give an indication of those centres where the somatic risks are going to be the greatest. Unfortunately, its relationship to maximum skin entrance dose is somewhat tenuous. For example, examinations that have a high dose area product will not necessarily result in a high risk of deterministic injuries to the patient because the irradiated area may change during the examination. It is therefore recommended that a combined approach to the application of reference doses in interventional radiology be adopted. This would involve the measurement of phantom related dose quantities such as image intensifier, input dose rate or maximum skin entrance dose rate at the surface of a patient equivalent phantom, as well as the assessment of effective dose using dose-area for procedures actually performed on patients.

One problem with the use of effective dose measured on patients could be the difficulty of measuring the quantity on a group of patients whose size and build correspond to that of reference man or woman. Interventional radiology is a type of procedure that is performed on relatively sick patients who may not have the same size and composition as reference man. As a result, it may be difficult to determine the reference dose for a group of patients whose size corresponds to that of reference man. In these circumstances it is probably best to perform the series of measurements on all patients who attend the clinic for a specific interventional procedure and apply a height and weight conversion factor to allow for any deviation in size and composition from that of reference man [6]. This technique was first proposed by Linskoug [6] and has been further developed by Chapple et al [7]. It

RADIATION RISK EVALUATION AND REFERENCE DOSES IN INTERVENTIONAL RADIOLOGY

K Faulkner
Quality Assurance Reference Centre
Newcastle General Hospital, Westgate Road
Newcastle upon Tyne, NE4 6BE, England

E Vano
Department of Radiology, Faculty of Medicine
Complutense University, Avda. Seneda 2
Madrid 28040, Spain

R Padovani
Azienda Ospedaliera S. Maria Della Misericordia
Istituto di Fisica Sanitaria, P. Le S. Maria Della Misericordia, 15
Udine I-33100, Italy

J Zoetelief
Delft University of Technology
Interfaculty Reactor Institute/Radiation Technology/Medical Physics
Mekelweg 15, 2629 JB
Delft, The Netherlands

Keith Faulkner – Fax No: +44 191 219 5034; email: keith.Faulkner@northy.nhs.uk

enables reference doses to be obtained from large-scale patient dose surveys by correcting each individual dose quantity into that which it would have been if the individual corresponded to the size and composition of reference man. Thus, there will be a greater statistical certainty are put on the dose quantity derived in this manner.

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AN APPROACH TO LOCAL DIAGNOSTIC REFERENCE LEVELS (DRL's) IN THE CONTEXT OF NATIONAL AND INTERNATIONAL DRL's

AT Rogers, Medical Physics Department, Nottingham City Hospital NHS Trust, Nottingham, U.K.

In recent years there has been a greater focus on the management of patient doses. This effort has been driven by the realisation of both the increasing magnitude of patient doses and their variation both intra- and inter-nationally. Legislators and guidance-issuing bodies have developed the idea of 'Diagnostic Reference Levels' (DRL's). In particular, the European Union, in their Council Directive 97/43/Euratom, required Member States to develop DRL's. The UK Government, when consolidating this EU Directive into UK legislation, extended the concept of DRL's from a national to an employer level. However, the methodologies used for development of national and international DRL's do not translate to a local level and hence a new approach is required. This paper describes one particular approach made by a UK hospital to introduce 'Local DRL's' in such a manner as to aid the optimisation process. This approach utilises a dose index, based on the local patient population, which is monitored for trends. Any trend in patient dose triggers an investigation linked to the clinical audit system within the Clinical Radiology Department. It is the audit cycle that ensures a continuing move towards an optimised situation. Additional triggers may be employed such as large patient dose variations.

1. Introduction

In recent years there has been a greater focus on the management of patient doses. This effort has been driven by the realisation of both the increasing magnitude of patient doses [1,2] and their variation both intra- and inter-nationally [3,4]. Legislating and guidance issuing bodies have been active in this area and have developed the idea of 'Diagnostic Reference Levels (DRL's) [5-8]. In the context of the international and national situation the idea of DRL's is reasonably understandable. However, a recent EU directive [5] has led, in the UK, to the introduction of legislation [9] introducing the concept of Local DRL's. The concept has been legislated for without clear guidance to local hospital staff of how it would operate at that level. This paper describes an attempt to bridge the gap of international and national DRL's being set by national authorities and the concept of Local DRL's.

2. International & National Diagnostic Reference Levels

Many bodies have been active in the area of DRL's, including the IAEA [6], European Union [5,8] and various national bodies [eg 7]. When the origin of these DRL's are investigated one discovers similarities in that often a large survey of individual institutions within the geographical boundaries of the authority issuing the DRL's. At each institution mean patient doses for a range of common examinations are determined. These institution mean doses are gathered together into a distribution of means and then an arbitrary level within the distribution is taken as the DRL. This level is typically the 75th percentile. The philosophy of this approach is to provide the 25% of institutions with mean doses above the DRL to work towards dose reduction in that particular examination. The DRL on its own, however, is no incentive to the other 75% of institutions that achieved mean doses below the DRL.

3. Local DRL's in the UK

Following the EU Council Directive 97/43/Euratom, the UK Government introduced the concept of Local DRL's in legislation promulgated in May 2000 [9]. The definition of DRL's in the UK legislation is, 'dose levels in radiodiagnostic practices ..... for typical examinations for groups of standard-sized patients or standard phantoms for broadly defined types of equipment'. This definition of DRL's is similar to that described in the EU Medical Exposures Directive. However, in the UK legislation, it is the local employer, not national authorities that must establish such DRL's. Furthermore, the employer 'must undertake appropriate reviews whenever DRL's are consistently exceeded and ensure that corrective action is taken...' From the employer's perspective they can either implement DRL's using existing national or international guidance or else formulate their own approach. In adopting the former approach of using existing DRL's, the probability is that local dose levels will be lower than published DRL's which suffer from being at the higher end of practice when the relevant survey was undertaken. Therefore there is no downward pressure being exerted by the concept of Local DRL's on locally delivered patient doses. The problem of developing a local approach is that no consensus exists in the UK as to the methodology needed to develop Local DRL's, despite it being a legal requirement. At a local level, the dose distribution in question is one of individual patient doses and is mainly due to patient size variations rather than a distribution of institution mean doses which is the origin of national and international DRL's.

4. The Nottingham Approach

The driving force behind the tool of DRL's, whether they be international, national or local, is the concept of optimisation. Therefore, in Nottingham, we looked for ways to link our existing patient dosimetry efforts to a system of quality improvement. Furthermore we required a system that triggered an investigation if 'DRL's are consistently exceeded.' We were aided in this aim by the development at Nottingham of a networked, dose-area product based, patient dose logging system which enables the collection of large numbers of patient doses (> 2000 examination doses per month) [10]. However, the methodology developed does not depend on this patient dose collection system and so is transferable to other institutions.

At Nottingham City Hospital the median dose by examination type is collected from our dose data each month. In our case we can be sure that our median dose reflects the dose to our average patient due to the large number of patient doses measured. Other centres, however, by judicial selection of patients, could achieve the same end. This dose index is then plotted on a control chart that essentially plots the index's time course. During the steady state ie when no changes to practice or equipment occurred, it is possible to calculate a meaningful average median monthly dose. This average median dose (taken over a period of six months in Nottingham) was deemed to be our Local DRL. It was also our target dose in that it was the expected median dose from our local patient population. Any deviations in median dose indicated a sub-optimal radiographic process compared to our baseline practice.

The link to optimisation is achieved by the triggering of a dose and image quality investigation whenever certain criteria are met. These triggers are locally set to reflect local optimisation strategies. In Nottingham our triggers are currently either a downward or upward trend in monthly median dose or else a large standard deviation in the monthly median dose distribution. The number of concurrent investigations and the speed of their completion are entirely resource limited. Resource limitations notwithstanding, the comparison of monthly median dose levels with our Local DRL's linked to an image quality/dose investigation when

triggered by preset criteria defines our route from the imposed concept of Local DRL's to that of optimisation. For each examination that is investigated, the outcome ought to be optimised practice within the constraints of current equipment, current good practice guidance and local radiologist preference. Such investigations can also highlight the need for equipment replacement and produce useful arguments for capital expenditure. Each investigation, if properly disseminated within the organisation, can act as a powerful training resource and often leads to a more harmonised approach, reducing staff-dependent dose variations.

In summary therefore, the methodology described above links the concept of Local DRL's (a legal requirement in the UK) with the process of optimisation. It is the process of optimisation that is the important end point. As stated by the International Commission on Radiological Protection [11], 'The optimisation of protection is the most powerful of the components of the system of radiological protection. It should pervade all stages of the use of radiation in medicine, from the design of premises, equipment, and procedures through to day-to-day applications.' This methodology also fits with the recently proposed National Radiological Protection Board (UK) concept of 'achievable dose' [12]. An achievable dose is one obtained by applying best practice to the radiographic process in terms of, for example, radiographic factors, views required and sensitivity of detector. The outcome of our dose monitoring – audit cycle process, if all best practice guidance is implemented, would be a local achievable dose. This methodology is not the only way to implement Local DRL's but, in Nottingham, we have found it to be a useful mechanism for a planned move towards an optimised practice.

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IODINE VISIBILITY IN CORONARY ANGIOGRAPHY USING COPPER FILTRATION

AT Rogers & ME Holloway, Medical Physics Department, Nottingham City Hospital NHS Trust, Nottingham, U.K.

AT Rogers - email arogers@ncht.org.uk
fax +44 115 962 7784

With constantly developing technology and emerging clinical applications, the field of interventional radiology is rapidly expanding. This is bringing enormous benefits to patients in terms of less invasive procedures. However, interventional radiology often involves prolonged fluoroscopy and cine runs which potentially leads to high staff and patient doses. One approach to dose reduction and improved iodine contrast visibility is the use of added copper filtration in conjunction with high heat capacity x-ray tubes which enable the x-ray spectrum to be matched to the k-edge of iodine whilst reducing dose. This paper presents results characterising the iodine imaging performance of a modern vascular x-ray imaging system. The results indicate that skin dose savings of 75% are possible with acceptable iodine contrast loss and that, for iodine sensitive patients, reductions of iodine concentration of about 25% may be achievable.

1. Introduction

With constantly developing technology and emerging clinical applications, the field of interventional radiology is rapidly expanding. This is bringing enormous benefits to patients in terms of less invasive procedures. However, interventional radiology often involves prolonged fluoroscopy and cine runs which potentially leads to high staff and patient doses. Indicative of this growing awareness of safety and protection needs in interventional radiology was the interest shown in the recent workshop on efficacy and safety in interventional radiology [1]. One common approach to patient dose reduction has been the use of additional beam filtration. This is well documented in the fields of paediatric and fluoroscopic imaging [2,3]. Recent technical developments in tube technology have allowed higher copper added filtration to be utilised along with an mA-kVp curve which maintains the beam spectrum at a kVp advantageous to imaging iodine which is used as a contrast medium in angiography. Last year, Nottingham City Hospital installed a new cardiac catheterisation laboratory with the features mentioned above and this paper describes our attempts to characterise its performance in terms of iodine visibility and dose as the extra filtration is applied.

2. Method

The installation was a Philips Integris H5000F C-arm imaging system with an x-ray tube that could run continuously at 30mA enabling high levels of copper filtration to be employed. The x-ray tube has three filter 'modes' for fluoroscopy. Mode 1 has no added filtration (HVL ~3.2 mm Al @ 80 kVp), Mode 2 has added filtration of 1.5 mm Al + 0.1 mm Cu (HVL ~5.3 mm Al @ 80 kVp) and Mode 3 has added filtration of 1.5 mm Al + 0.4 mm Cu (HVL ~ 7.4 mm Al @ 80 kVp). Entrance skin doses were measured using a calibrated ionisation chamber and include backscatter.

Images were obtained of three different sized plastic tubes (1.0 mm, 1.5 mm & 2.5 mm diameter) laid across a 10 cm PMMA phantom. For each Mode of fluoroscopy images were

obtained at four iodine concentrations (370 mg/ml, 320 mg/ml, 200 mg/ml & 100 mg/ml I_2) representing concentrations used clinically (370 mg/ml & 320 mg/ml I_2) and less concentrated contrast media. Fluoroscopic images were captured in the unit's 'photofile' and transferred to a PC workstation for analysis. All imaging was performed using the 23cm field size.

Contrast was defined as the difference in signal level between the maximum iodine signal in the vessel (averaged over four profiles) and the background flat-field signal from the 10 cm PMMA phantom which was obtained from a region-of-interest within the central portion of the image.

3. Results

The measured entrance skin doserates, with backscatter, are given in Table 1 along with the filter details for each Mode of fluoroscopy.

Table 1: Entrance skin doserates, with backscatter, for a 10 cm PMMA phantom

FLUOROSCOPY MODE	ADDED FILTER	SKIN DOSERATE (mGy/min)
Mode 1	no added filter	18.1
Mode 2	1.5mm Al + 0.1mm Cu	8.1
Mode 3	1.5mm Al + 0.4mm Cu	4.4

Figures 1 & 2 show how the contrast varies with varying the amount of filtration and the iodine concentration. The contrast values are in arbitrary units and the standard deviation of the contrast values ranges from 5-10%. This level of standard deviation is due to the averaging technique employed across the four profiles of each vessel. Results are only presented for the 2.5mm vessel diameter as the smaller vessels indicated similar trends.

Figure 1: Contrast as a function of added filtration for a 2.5mm vessel imaged on a 10cm PMMA phantom

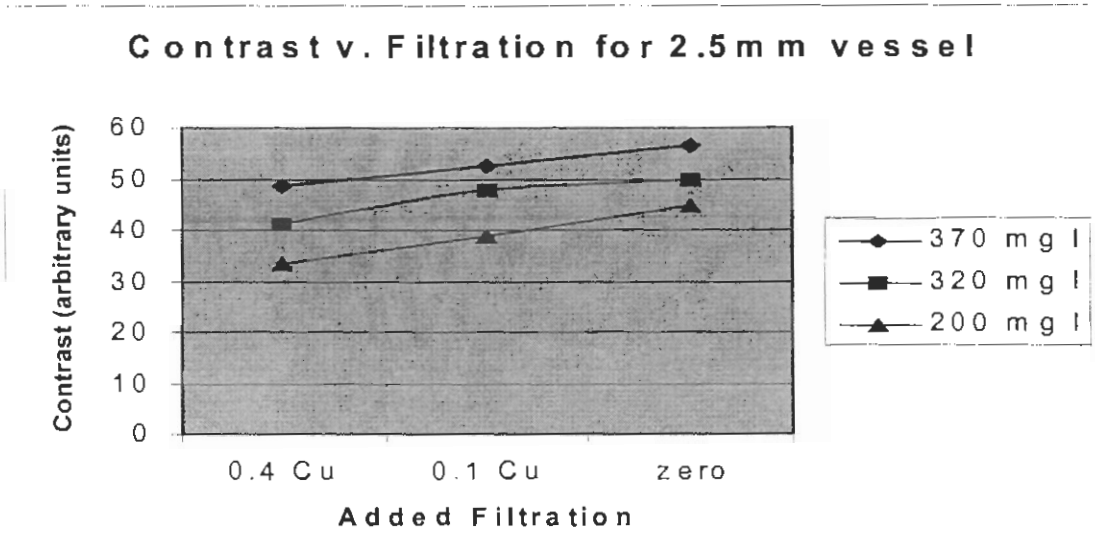
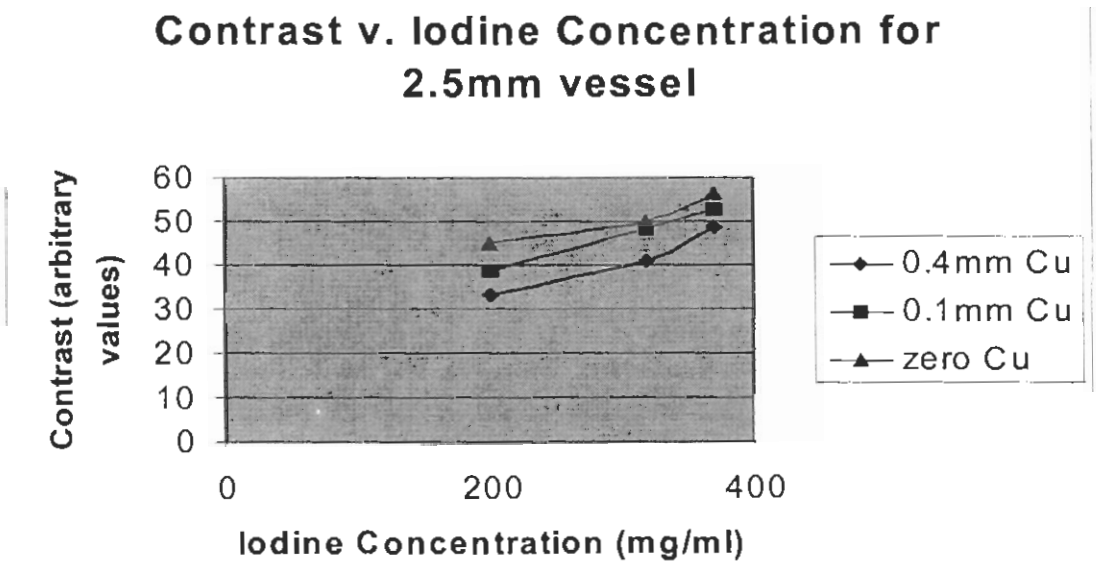


Figure 2: Contrast as a function of iodine concentration (mg/ml I_2) for a 2.5mm vessel imaged on a 10cm PMMA phantom



4. Discussion

The results obtained must be seen in the context of a first characterisation of the iodine imaging capability of our new cardiac catheterisation x-ray unit. We have not, as yet, ascertained a threshold value for iodine contrast in terms of clinical acceptability and our arbitrary units. However, it is clear that real differences are achieved by the use of added copper filtration where, clinically, the loss of iodine contrast seems acceptable and results in a skin dose saving of approximately 75%. This is especially important for the more complex angioplasty with stenting examinations where examination skin doses can approach several gray. It is also worth noting that, in the case of no added filter, similar levels of iodine contrast would be achieved, to that of the largest copper filter, with 25% less iodine concentration. This has implications for situations where patient reactions to iodine are important. It is our intention, given our results so far, to work with the manufacturer and the cardiologists to further optimise the iodine imaging performance of the x-ray unit.

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IAEA-CN-85-79

MANUAL CROSSCHECK OF COMPUTED DOSE TIMES

FOR

MOTORISED WEDGED FIELDS

John Porte M.Sc.

Queen Elizabeth Hospital
Barbados

Fax: 246-429-5374
E-Mail: celport@sunbeach.net

Abstract. If a mass of tissue equivalent material is exposed in turn to wedged and open radiation fields of the same size, for equal times, it is incorrect to assume that the resultant isodose pattern will be effectively that of a wedge having half the angle of the wedged field. Computer programs have been written to address the problem of creating an intermediate wedge field, commonly known as a motorised wedge. The total exposure time is apportioned between the open and wedged fields, to produce a beam modification equivalent to that of a wedged field of a given wedge angle.

Manual cross check of open field dose calculations follows the usual pattern: -product of relative exposure rate, exposure rate of standard applicator/field, BSF/TAR/%DD gives the output in dose per unit time. Dividing the daily-prescribed dose by this result gives the exposure time. For a wedged field, inclusion of the wedge factor should produce a correct result. Manual planning essentially then, requires the mapping of isodose curves, using accurate depth dose curves supplied, to arrive at a dose maximum normalised to 100% of the prescribed dose, then applying the same calculation methods to arrive at the dose times.

With the advent of computer planning, the curves supplied are only relative and cannot be used for accurate isodose mapping. In the absence of curve mapping, calculations alone can produce acceptable accuracy with open fields and in some cases where identical opposing full-wedged fields are used. However, appreciable discrepancies are seen with non-identical fields and there is no simple way to manually check dose times when motorised wedges are employed. This paper then is an attempt to devise such a method that will give approximately +/- 7% deviation. The last statement presumes that the computed dose times are absolutely correct that is with a +/- 2% error that is accepted for machine output exposure rates.

Motorised wedges are routinely used in the tangential fields for treatment of post mastectomy patients. Having created a symmetrical chest wall shape of average size and separation, that would require a full 45degree wedge, the data is entered and the dose times determined for a given prescribed dose. The 6w X 15 cm wedge field used is generated on the computer at the most accurate calculation matrix. A pair of such fields is then used on the test

outline for mapping of the isodoses, arriving at the normalisation dose and subsequent calculation of dose times in the usual manner, with the inclusion of the given transmission factor for the wedge. Calculation of the dose time by the manual method shows agreement to within +/- 3%.

The most logical approach from here was to make a semilog plot of percentage transmission vs. wedge angle, connecting the two points 100% for the open field and 48.5% for the full wedge, plot A of Fig 1. This transmission factor was determined practically, by dosemeter measurements in the open and wedged beams. The above exercise was then repeated, this time using an outline appropriate for a half wedge, 22.5 degrees. The corresponding transmission value was taken from the curve and used in the calculation as before. The manually calculated dose time was 2.24 minutes whereas the computed dose time was 2.2 minutes. There is no way of determining how the time is apportioned between the wedge and the open fields. This is precisely what the computer does and we are forced to accept it.

An asymmetric shape was now drawn which was typical of the average breast outline and using the same 6w x 15 wedge, 25 and 30 degree wedges were found to be appropriate. The calculation times, manual 2.45 minutes, computed 2.21 minutes. This represents an eleven percent error, which is outside the accepted range. The source of error is apparently the value of the transmission factor used, since the prescribed dose and the field sizes are unchanged. A closer look at the generated fields revealed that the central axis depth doses appeared greater than expected, supporting the reason for not using them in isodose mapping. In order to approach this problem from first principles, an open 6 x 15 field was generated and the central axis depth doses compared with those from tables. Another open 6 x 15 field was constructed from depth dose tables,[1]from which a family of curves of percentage depth dose against field size for fourteen different depths was constructed, and from which depth dose values for 6 x 15 field at the corresponding depths, were taken. A curve of percentage depth dose against depth for the 6 x 15 field of equivalent square 8.5 cm was made, and from which values could be taken for 90% to 35 % in increments of ten. These values were then used to draw isodose curves for a 6 x 15 open field. The comparison with the computer-generated field shows that the percentage depth doses of the computed field are

approximately 7% greater. If the open field for the 15 x 20 dimension is deduced in a similar manner, the factor is of the same order, being 6.4%. Since the computer is programmed to use the 15 w x 20 wedge for all breast plan cases, wedge curves of this dimension for 15, 22.5, 30, and 37.5 degrees were generated, each set of curves being normalised 0.5 cm below the surface and 1.0 cm in from the thin end of the wedge. The corresponding open field curves generated were normalised at the same point as the wedged curves.

The open field is superimposed on the wedged fields in turn and a transmission factor for each wedge is determined by using the ratios of the isodose values on the central axis, at equal displacements on both sides and for four successive depths. The mean values of the transmission factors were found to be in excess of those deduced from the graph used for half wedge factor value. The transmission factors were adjusted by the factor in the previous paragraph, 0.936 and then plotted on the semilog curve as Plot B adjacent to Plot A, the line for the measured transmission and the 100% point. The best straight line through the points was drawn and a third line, Plot C was constructed by taking the mean between these two lines. This mean line was then used to determine transmission factors for other wedge combinations and acceptable agreement in the dose times was seen for a 25deg / 30deg wedge combination used on the asymmetric outline which is more often the general case. An attempt was made at constructing the equivalent symmetrical outline for which 27.5-degree wedges were used and again acceptable agreement was realised. Unfortunately the results for the full wedge and the 22.5 degree wedge showed a greater deviation than when the lower curve was used.

The prescribed dose in all cases was 4000 Cgy in 15 fractions of 267 Cgy at 100% for a chosen dose point. The table below shows the results for dose times using transmission factors based on plots A and C compared with the computed dose times. This method, though crude, gives a measure of satisfaction to the physicist who would otherwise be forced to blindly accept the computed calculations.

WEDGE COMBINATIONS	DOSE TIMES FOR METHOD		
	PLOT A	COMPUTED	PLOT C
Full 45.0°	3.178	3.13	2.94
Half 22.5 °	2.24	2.20	2.07
Symmetric 25 °	2.374	2.23	2.22
Asymmetric 25/30 °	2.45	2.23	2.232

Table 1

[1] Cohen, M., Jones, D.A.E. and Greene, D. Central Axis Depth Dose Data for Use in Radiotherapy Supplement Number 11 British Journal of Radiology, British Institute of Radiology, London 1978. p. 59 Table 6.3. PERCENTAGE DEPTH DOSES: 80 cm SSD for Cobalt 60 gamma rays.

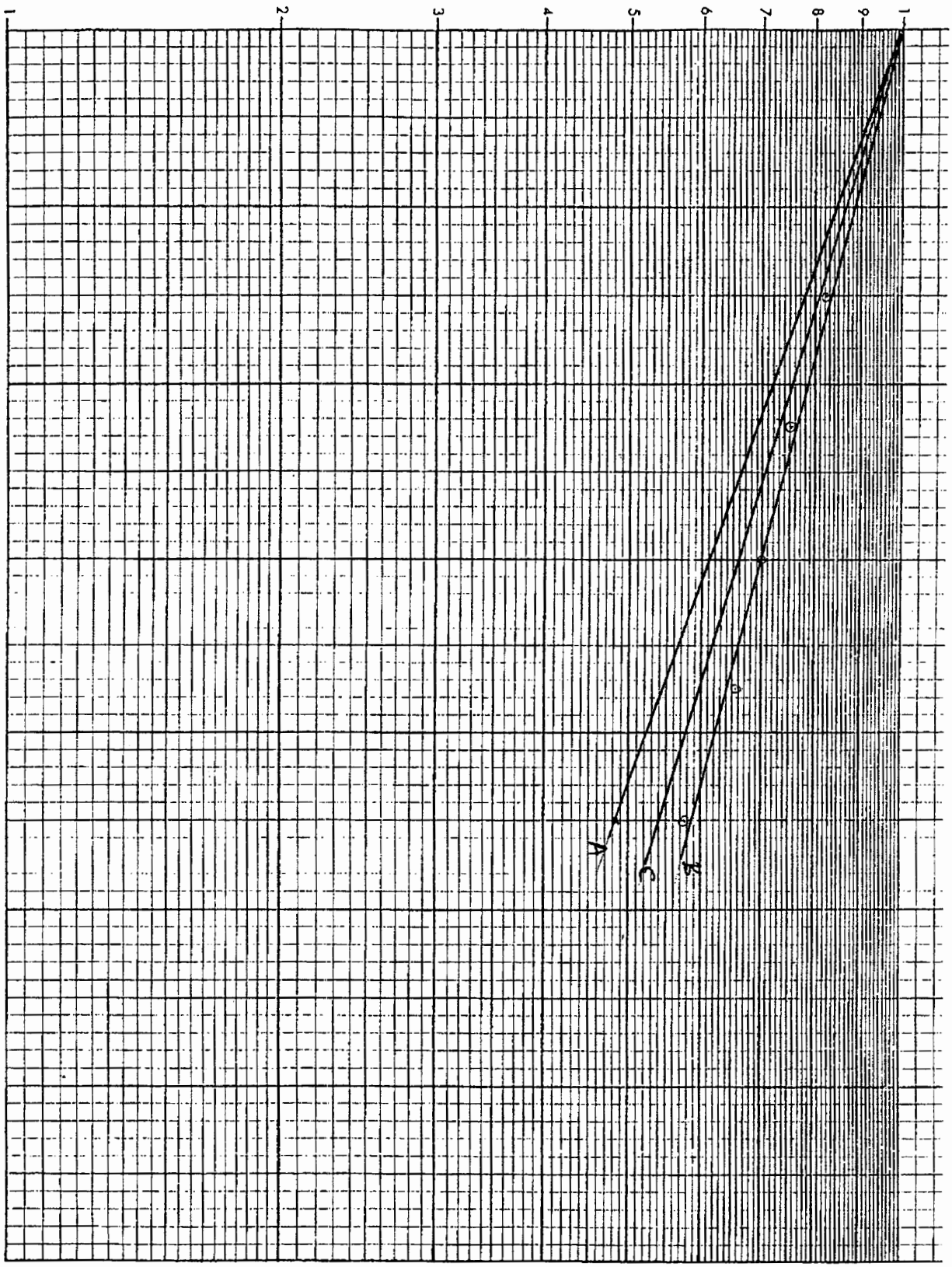

FIG 1

RADIOLOGICAL PROTECTION IN INTERVENTIONAL CARDIOLOGY IN CHILE

Ramírez A (1), Vañó E (2), Leyton FA (1), Oyarzún C (3), Gamarra J (3), Farias E (1), Silva AM (1), Ortiz P (4)

(1) Hospital Clínico de la Universidad de Chile. Santiago. Chile. <aramirezn@entelchile.net>

(2) Hospital Universitario San Carlos. Universidad Complutense. Madrid. España

(3) Comisión Chilena de Energía Nuclear. . Santiago. Chile.

(4) International Atomic Energy Agency. Vienna. Austria

Abstract

In September 2000, an expert mission was assigned to Chile, under the regional project named "International BBS in Medical Practices Radiation Protection and Quality Assurance In Interventional Radiology" (ARCAL XLIX). The objectives of the mission were to evaluate the level of radiation protection (RP) and safety in interventional cardiology (IC) installations.

A team of local cardiologists, medical physicists and technologists was created for this purpose and during one week, several cardiology laboratories were evaluated and some basic quality controls (QC) were carried out. A basic pilot training course in radiation protection was imparted at the Hospital of the University of Chile in Santiago de Chile and some of the key objectives for a future national quality assurance programme were presented during the national congress of IC. In addition, a national survey on radiation protection aspects was circulated and its results evaluated. These activities enabled the local team to become familiar with the methodology of assessment of the level of protection and the organization of a programme, which was illustrated with the examples of similar European programmes.

As result of these actions, several proposals were made to both the local authorities and the IAEA. The most important were: a) to initiate a basic QC programme, b) to organize a training in RP for cardiologists in order to formalize their accreditation, c) to improve personal occupational dosimetry, d) to initiate a programme of patient dosimetry, e) to optimize the technical and clinical protocols, f) to create a national registry of incidents with skin injuries.

1. Introduction

In Chile there are 48 specialists in interventioal cardiology (IC) training in renowed European and North American centers. They perform nearly 1,500 therapeutic and 6,000 diagnostic procedures in a year. Facilities and procedures for cardiac electro-physiology are not included in these figures. For comparison, in Spain (data from 1999), there are 110 hemo-dynamic rooms (in 83 hospitals) where 575 therapeutic procedures (22% of the total) per million of population are performed and 2,070 diagnostic procedures per million of population (78% of the total) [1]. These numbers are 50 % of the procedures in other European countries, such as Austria, Switzerland and Germany [2].

Considering the rate of development in Chile, it can be assumed that in a medium term it will reach the current levels of Spain.

There is no specific programme for training cardiologists in radiation protection. There are, however, protective elements in most of the facilities, such as couch- supported articulated shielded screens and personal shielded garment (aprons and thyroid shielding). Personal monitoring does not seem to be used systematically and the dosemeter reading are made by institutions not dependent on the "Comisión Chilena de Energía Nuclear" and with unknowed quality control and no systematic participation in intercomparative round .

Personal exposure monitoring is done using one single dosimeter which may be insufficient for IC. [3].

With regard to the RP of patients, there is neither a general culture and awareness of cardiologist nor of suppliers of x-ray equipment. The current organization of the IC is structured around the Chilean Society of Cardiology and Cardiovascular Surgery. The interest by its members in achieving a qualitative and quantitative change towards a culture of patient protection and towards implementation of a QA programme in a short time, provides ideal conditions for moving in this direction.

2. Material and methods

In September 2000, an expert mission was assigned to Chile, under the regional project named "International BBS in Medical Practices Radiation Protection and Quality Assurance In Interventional Radiology" (ARCAL XLIX). The objectives of the mission were to evaluate the level of RP and safety in IC . In addition a basic training action in RP and a pilot QA programme should be initiated.

A team of local cardiologists, medical physicists and technologists was created for this purpose and during one week, several cardiology laboratories were evaluated and some basic QC were carried out. A basic pilot training course in RP was imparted at the Hospital of the University in Santiago de Chile and some of the key objectives for a future national quality assurance programme were presented during the national congress of IC. In addition, a national trial on RP aspects was circulated and its results evaluated.

Previous contact with the local delegations of the main industry supplying X ray systems in Chile (Philips, General Electric, Siemens and Toshiba) was established in order to obtain support for these evaluations.

The basic QC carried out, during the mission, in several installations was a reduced version of the European DIMOND (Digital Imaging: Measures for Optimizing Radiological Information Content and Dose) protocol [4] .. In addition, the maximum patient entrance dose rate and the image quality obtained with a test object (TOR 18-FG, from the Leeds University) was measured. In the cardiology lab of the Hospital Clinico of the University of Chile, some patient doses were measured with a transmission chamber together with skin dose evaluation using slow radiotherapy films [5].

A basic pilot training course in RP was imparted at the Hospital of the Chile University in Santiago and during the National Congress of IC held in Antofagasta.

A national survey on radiation protection and collateral aspects was prepared similar to one used in Spain by the Spanish Section of IC to be answered by the medical specialists in Chile.

3. Results

Survey

A survey on RP aspects was made on a personal and anonymous basis. It was distributed to 16 of the 19 existing centers in the country and reply was obtained from 13 of them. Of the 46 professionals involved in IC 39 responded, which gives the survey a valuable indicator of the activity at national level. 56% of those polled consider that their knowledge of RP are adequate for their professional activitiy, however 97% considers appropriate to perform continuous training in radiation protection as well as in QC in order to optimize the use of their equipment.

Equipment

Equipment in Chile is uneven. Three of units are of a design of the 1977, 1979 and 1986 all of them had to be adapted for IC. 71% of the equipment used in Chile includes digital image acquisition. 53% of those polled in the survey consider that their facilities are adequate and 38% consider that they should be renewed as RP is concerned. Half of those polled feel acquainted with the features and capabilities of their equipment, while the other half mean to have incomplete knowledge of the use of the equipment; 80% would like to have more detailed information on the capabilities of the equipment.

Occupational dose assessment

Dose monitoring is available to 67 % of the interventional cardiologists but only 61% of those polled use it on a regular basis and 33% lack dosimetric control. In none of the centers are TLD dosimeters available. 54% of the cardiologists are aware of their occupational dose values and pay attention to them and 33% are not aware of them. However, 92% indicate that no professional advice is available on radiological protection; this advice is wanted by 90% of those polled and all participants in the survey consider that effort and investments should be made to improve the level of protection to the professionals involved in IC. The average team for an IC unit in Chile consists of four interventionists, two to three nurses, one to two technologist, two to four nursing assistants. There is only one center with a medical physicist. 92% of those polled declare to have quality control and maintenance for the equipment, and 48% of them indicate that this is performed on scheduled basis. 61% report to be aware of the results of maintenance activities.

Patient dose assessment

All participants in the survey consider that patient dose assessment is of prime importance and 97% agree to participate in comparative studies with other countries, although when interrogated about a possibly excessive exposure, 84% declare that this never occurred and 90% state that never know about of any skin injuries related to the area of incidence of the radiation beam on patients who underwent IC procedure.

4. Conclussions

1- Interventional cardiology in Chile is well organized and a programme of QC and RP could be easily implemented. Cardiologists performing interventional procedures show a great interest in radiation protection and demand a training programme in order to achieve the necessary knowledge to adequately protect their patients and to obtain an accreditation in radiation protection from the Chilean health authority.

2- A pilot training course in radiation protection has been designed for interventional cardiologists (20-30 hours following the European approach on protection in medical exposure).

3- Occupational protection conditions are in general adequate but personal monitoring should be improved by recommending the use of two TLD dosimeters by professionals with a significant workload in IC.

4- Equipment assessed is in good condition in general although there is not yet a culture of radiation protection of patient, which mst be implemented in a near future.

5- It is advisable to initiate a programme of patient dose monitoring, to optimize the technical and clinical protocols and to initiate a national registry of incidents with skin injuries.

5. Acknowledgments

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INDONESIA EXPERIENCE ON IAEA-CRP* OF RADIATION PROTECTION IN DIAGNOSTIC RADIOLOGY

Nasukha
Clinical Dosimetry Group, R & D Center for Radiation Safety and Nuclear Biomedicine, National Nuclear Energy Agency of Indonesia (Batan),
P.O Box 7043 JKSKL Jakarta 12070 Indonesia
Fax : 62.21.7657950
Email : aljabar2@hotmail.com

ABSTRACT

IAEA-CRP on Radiation Doses in Diagnostic Radiology and Methods for Dose Reduction has been participated by some Asian and East European countries. Indonesia is one of participants that followed the IAEA program. This paper is not disscuss of CRP-results since it will be published on TECDOC soon. But the work on evaluation of examination frequencies, film reject rate analysis, patient dose measurements, image quality before and after Quality Control (QC) and QC itself gave some experiences to investigator to be explored and presented. Experiences could be in form of problems, how to solve problems and some suggestions. Started from no QC up to complicated QC to be face on conventional radiography to CT-scan and fluoroscopy units. These valuable experiences of Indonesia are proven exercise of IAEA-CRP as a good start for next CRP or national projects in diagnostic radiology.

INTRODUCTION

The Indonesia as a developing country with population of more than 200 million people have many problems on radiology diagnostic services. It is not only facilities, but also human resources to serve of about 100 million people if approximately 50 percent of population occupy this health service. The number of x-ray diagnostic machines nationally is only about 1197 units that spread to the whole country which have of about 5000 islands. Quality of services is very important one to success the aim of diagnoses.

Two well known International agencies that concern radiological health care all over the world are World Health Organization (WHO) and International Atomic Energy Agency (IAEA). WHO activities on radiological health care for Member states assist in developing a policy of services through publication, experts adviser and training for increase knowledge and skill human resources[(1)]. On the other hand, IAEA seek to accelerate and enlarge the contribution of atomic energy to peace, health and prosperity through the world[(2)]. Indonesia as a Member of both WHO and IAEA, is always participated their activities.

The International Commission on Radiological Protection (ICRP) published recommendation concerning the radiation protection in diagnostic radiology is an ideal concept that it is not a simply practical implementation. Optimization needs more efforts to success radiation protection in diagnostic radiology that is more attention on daily practices.

A Coordinated Research Program (CRP) on assessment of radiation doses in diagnostic radiology and studying methods for reduction was firstly started in IAEA Member States in cooperation with the Commission of the European Communities (CEC)[(3)]. A second CRP-IAEA that Indonesia is one of the nine Asian country regionally participated on Radiation Doses in Diagnostic Radiology and Methods for Dose Reduction Project. There were two phases to

* IAEA-CRP is International Atomic Energy Agency-Coordinated Research Project

complete the project, which were Conventional radiography for the first phase and Flouroscopy and CT-scan for the second.

The Technical Assistance (TA) has been planned to develop quality assurance program on medical application of ionizing radiation nationally, especially in diagnostic radiology. A scenario has planned on 1993 to develop a quality assurance program as required for radiodiagnostic examination in Indonesia for some hospitals. The action plan of the idea was performed through technical cooperation of International Atomic Energy Agency (IAEA). The National Workshop on Quality Assurance and Radiation Protection in Diagnostic Radiology was dedicated to radiologist, radiographers and medical phycisists on 1994. The workshop was organized by our institution joint with Radiologist's society and one of the hospitals that participated on the project. Introducing and understanding of radiation protection optimization in diagnostic radiology has been given on lectures by some international experts. Practical sessions were also organized on the last day of five day's workshop.

BASIC UNDERSTANDING OF THE PROJECT

It is necessary to participants of the CRP's to understand the main objective of project, especially for investigators. Fundamental basis of radiation protection in diagnostic radiology on The International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Sources (BSS) needs more elaborations. Optimization of radiation protection by means a quality assurance program and dose reduction methods is also necessary to elaborate practically for them. Thinking separately of dose reduction to patients without inherently improvement of image quality is not satisfactory for optimization in protection radiation. However, this is not simple to be implemented on daily practices.

SELECTION OF HOSPITALS

The project should participate one major hospital and three satellite hospitals. Before choosing hospitals that participated the project, investigators should have data for number of patients, type of examination - projection and facilities those hospitals. Unless the project will not complete as the schedule time.

- **Number of patients and type of examinations**

Eight x-ray projections that selected on the project were chest PA and lateral, LS-AP, LSJ (L5-S1) lateral, pelvis AP, skull Pa and lateral. Problems arrive from number of patients. Each hospital has own number of patients, as an example the major hospital recorded daily minimum and maximum patients for chest PA respectively were 34 and 71 patients. While the satellite hospital, 10 and 30 patients for daily minimum and maximum patients respectively. It was seen that the daily maximum number of patients at satellite hospital to be the daily minimum number of patients of the major hospital. This number affects to percentage of reject film statistically. Next experience was founded when evaluation to be done for limited (less) - not many patients (examination) such as skull PA on the satellite hospital and LS lateral for the other satellite hospital.

The above problems were not only for film reject analysis, but also for patient dosemetry measurements. To complete 10 patients of weight 65 ± 10 kg to 8 type examination may be require more than scheduled time. So that, some satellite hospitals could not complete and continued for patient dose measurements, moreover it will be automatically a evaluation of image quality problem.

It seem that the number of patients and type of examination (8 x-ray projections) for he first phase of IAEA-CRP could not perfectly be completed on the schedule time as it was planned before. Three satellite hospitals were targeted to participate and complete the IAEA-CRP, two hospitals were dropped. It was just because of limited the number of patients for some type

examinations. Solution could be done by choosing satellite hospitals on the other city to get enough number of patients of some type examinations, like Bandung, Semarang or Surabaya cities. However, the other problems will occur from transportation and coordination when the action plan to be implementation.

Next experiences happened when second phase project started. Selection of hospitals on the first phase based on feasibility study of conventional radiography. The hospitals that participated on first phase, it would be possible to continue their participation on second phase. Actually, fluoroscopy units on the hospitals that participated on first phase were not as many as required. Alternative hospital should be participated to fulfil the second phase of project. Since difficulties on the target of patient weight on the first phase, so the second phase patient weight was lowered to be 60± 10 kg. Due to limited patients on CT chest examination and standard QC CT-phantom, Indonesia could not complete this part.

- **Facilities and equipment used**

Number of patient consideration when choosing hospitals is not enough without take account facilities - equipment used on hospitals. Minimum performance criteria of the facilities and equipment should be have to success the IAEA-CRP. Choosing facilities - equipment to be used for IAEA-CRP will affect to daily schedule hospitals if unusual facilities alter their functions, such as a x-ray unit used to LS examination than change of function to chest examinations.

Problems come out after the units were evaluated for QC. The condition of unit is less possible to get good image and low doses, such as not possible to reach high kVp and the stability of unit. This is happened at major hospital. By this experience, minimum requirement of facilities and equipment should be identified before IAEA-CRP to be done. These are not only performances of facilities and equipment, but also the possibility to increase image quality and to minimize doses.

TLD reader as a basic equipment of patient dose measurements could not work perfectly. Unfortunately, it could not be repaired soon. That was happened for 4 months. New reader was prepared to solve this problem. Meaning that on this IAEA-CRP, two TLD readers were used. Another experience according to TLD was loss TLD materials, since it were brought by patients. Two problems come out for dose patient measurement of fluoroscopy examination, one from limited of patient number then second from dosemeter. Patient dose measurement of fluoroscopy examinations is dependent on Dose Area Product (DAP) dosemeter.

CONCLUSION

IAEA-CRP need more efforts, such as understanding of concept as the whole, feasibility study of condition participants (number of patients, type of examinations, facilities and equipment used) that carry the project. Project like IAEA-CRP on Radiation Protection in Diagnostic Radiology practically is not simple to be implemented to whole hospitals nationally. This experience might be useful for institutions or organizations that offers grants. Support from government or such international organizations is very helpful to run quality control program.

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SWISS NATION-WIDE SURVEY ON RADIATION DOSES IN DIAGNOSTIC RADIOLOGY

A. Aroua*, J.-P. Vader**, B. Burnand** and J.-F. Valley*

* Institut de Radiophysique Appliquée, Lausanne
** Institut Universitaire de Médecine Sociale et Préventive, Lausanne

ABSTRACT

A nation-wide survey on radiation doses in diagnostic radiology was conducted in Switzerland in 1998-1999. More than 250 types of examinations were considered, covering conventional and interventional radiology, angiography, CT, mammography, osteodensitometry, conventional tomography and dental radiology. This survey aimed at establishing the collective radiological impact of radiodiagnostics on the Swiss population. The methodology of the survey is described. The examnination frequencies and integral dosimetric results associated with diagnostic radiology in Switzerland are presented.

INTRODUCTION

At the international level there is a great interest for establishing the radiation doses due to medical exposure. This is due to the fact that medical exposure is the highest source of artificial irradiation. During the last two decades many national surveys of the frequencies and doses associated with medical examinations have been reported in the litterature. A comparative work regarding these surveys is published regularly by UNSCEAR (1).

Switzerland has a long tradition in surveying the medical exposure that started in the late 50s (2-5); the present work being the continuation of the previous studies. The aim of this work is to determine the collective radiological impact of radiodiagnostics on the Swiss population, to gather enough data in order to issue recommendations aiming at patient dose reduction and to set a comprehensive framework for future studies.

MATERIAL AND METHODS

The methodology of the study is outlined in the diagram shown in figure 1. The frequential and dosimetric aspects were handled separately.

Concerning the dosimetric issue no measurements were performed. Rather, a standard technique was established for each type of examination (technical parameters, projections considered, number of films or CT slices, duration of fluoroscopy, etc.). After the validation of the technique, the dose indices (ESD, DAP) were modelled based on the conditions of the examination. The organ and tissue equivalent doses were then established using appropriate conversion factors. To this purpose, the programs ODS60 (6) and CTDOSE (7) were used for radiography/fluoroscopy and CT examinations respectively.

The second part of the study consisted in surveying the frequency of examinations in all the establishments who prescribe and perform radiological examinations in Switzerland: hospitals, practitioners and other institutions (school, penitentiary and military medicine, etc.). An information on the patient's age and gender and on the indication of the examination (affection of the patient, aim of the examination, sevrity of the case) was collected, whenever possible.

A convolution of the frequency and the dosimetric results was then performed, taking into account for each examination the patient's age and gender profiles, the film-screen sensitivity profiles and the corpulence profiles. For the age correction different models were used.

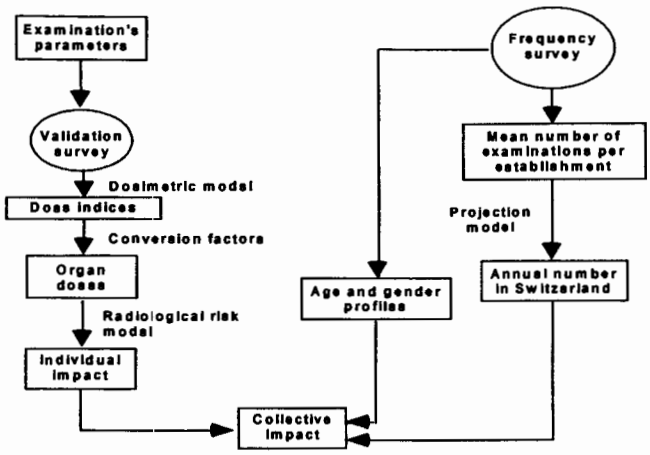

Figure 1. Methodology of the study

RESULTS

The survey revealed that the total annual number of examinations (all types together) in Switzerland is about 9.5 millions (1.34 per inhabitant) and that the collective dose is 7100 Sv, corresponding to a mean annual effective dose of 1.0 mSv per inhabitant.

Table 1 presents the distribution of the annual number of examinations and the collective dose with the different categories of examinations. In terms of the number of examinations, the radiography and dental radiology have the highest contributions to the total number (47% and 42% respectively). The other modalities represent together 11% of the total. In terms of dose, radiography, tomodensitometry and conventional fluoroscopy have the highest contribution to the collective dose (42%, 28% and 17% respectively). The other modalities represent 13% of the collective dose.

Table 1. Annual number of examinations and collective dose in mSv (rounded values) per category of examinations

Category	*Annual number*	*Fraction (%)*	*Collective dose*	*Fraction (%)*
Radiography	4'500'000	47	3'000'000	42.2
Dental radiology	4'000'000	42	70'000	1.0
Tomodensitometry	300'000	3.2	2'000'000	28.1
Mammography	200'000	2.1	40'000	0.6
Radiography and fluoroscopy : conventional	150'000	1.6	1'200'000	16.9
Radiography and fluoroscopy : angiography	70'000	0.7	500'000	7.0
Radiography and fluoroscopy : interventional	30'000	0.3	250'000	3.5
Osteodensitometry	30'000	0.3	40	0.0
Conventional tomography	10'000	0.1	50'000	0.7
Total	9'500'000	100	7'100'000	100

Table 2 presents the distribution of the annual number of examinations and the collective dose with the different categories of establishments. In terms of the annual number of examinations, the dentists are on top position with 42% of the total, followed by the hospitals with 31% and the general practitioners with 16%. The other categories contribute together for 11%. In terms of the collective dose, the hospitals alone contribute for about 73%. The general practitioners contribute for almost 10% and the radiologists for almost 7%. The contribution of the other categories all together is about 10%.

Table 2. Annual number of examinations and collective dose in mSv (rounded values) per category of establishments

Category	*Annual number*	*Fraction (%)*	*Collective dose*	*Fraction (%)*
General and internal medicine	1'500'000	15.8	670'000	9.4
Radiology	250'000	2.6	480'000	6.7
Small hospitals (< 500 beds)	2'000'000	21.1	3'300'000	46.2
Large hospitals (> 500 beds)	950'000	10.0	1'900'000	26.6
Dental medicine	4'000'000	42.1	70'000	1.0
Chiropractic	60'000	0.6	140'000	2.0
Others	700'000	7.4	580'000	8.1
Total	9'500'000	100	7'100'000	100

The distribution of the collective dose with the age of the patient is given in figure 2. The distribution peaks at age 65. If a correction for the age of the patient is performed according to an appropriate risk model we obtain a reduced mean annual effective dose of about 0.6 mSv per inhabitant.

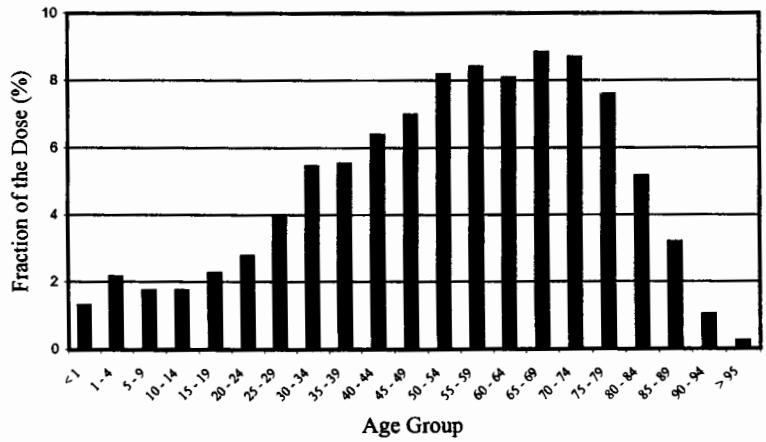

Figure 2. Distribution of the collective dose with the age of the patient

CONCLUSION

The present survey allowed the establishment of an accurate picture regarding the exposure of the Swiss population by diagnostic radiology. Both the frequencies and the doses associated with the different types of examinations were investigated. The results of the study will be used to elaborate recommendations in order to reduce the patient doses involved in diagnostic radiology.

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IMPLEMENTATION OF ICRP-60, BBS-115 AND THE PATIENT DIRECTIVES IN RADIATION SAFETY REGULATIONS OF TAEK

H.Burçin OKYAR, Mustafa VURAL

Turkish Atomic Energy Authority
Radiation Health and Safety Department
Licensing Division

The use of radiation sources offers a wide range of benefits throughout the world in medicine, research and industry. Precautions are, however, necessary in order to limit the exposure of persons to the radiation that is emitted. The International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources (BSS) were published as IAEA Safety Series No:115 in 1996 [1]. This publication marks the culmination of efforts that have continued over the past decades towards harmonization of radiation protection and safety standards internationally. The purpose of the Standards is to establish basic requirements for the protection against the risks associated with exposure to ionizing radiation and for the safety of radiation sources that may deliver such exposure. The Standards are based primarily on the recommendations of the ICRP which is a non-governmantal scientific organization to establish basic principles and recommendations for radiation protection; the most recent recommendations of the ICRP were issued in 1991 [2].

In 1997, the Council of the European Union published a new directive laying down the general principles of the radiation protection of individuals undergoing exposures to ionizing radiations related to medical exposures (Directive 97/43 Euratom) [4]. Directive 97/43 Euratom is a supplement on Directive 96/29 Euratom [3] on the basic safety standards for the protection of the health of workers and the general public against the dangers arising from ionizing radiations. The European Directives 96/29 - 97/43 Euratom and BSS-115 constitute a complete and coherent set of regulatory measures on radiation protection. In Turkey, the infrastructure exists to account for ionizing radiation sources by, for example, a system of licensing, legislative requirements on the user to keep appropriate records and perhaps to report to the TAEK on a periodic basis or, in the case of imported items (including re-export procedures) and customs clearance procedures.

The preamble to the Basic Safety Standards states that it is presumed in the Standards that Governments have an adequate national infrastructure in place in order to discharge their responsibilities for radiation protection and safety. In Turkey, the relevant national authority for regulating activities involving radioactive sources is the Turkish Atomic Energy Authority (TAEK). The structure of TAEK and its legislation will be introduced. Radiation Safety Regulation (Official Journal #: 20983) which was issued in 6 September 1991 was revised and issued in 24 March 2000 (Official Journal #: 23999).

Revised version of the Radiation Safety Regulation based on BSS-115 [1] and EC Directives [3-4] include definitions, exemptions, responsibilisation, dose limits (significant decrease in the limits follows the recommendations of ICRP-60 [2]), redefinition of controlled and supervised areas, import and re-export procedures of radioactive materials, redefinition of licensing procedures, limitations in import radiation generators used in medicine, quality control, guidance levels of dose, dose rate and activity for medical exposures (including diagnostic radiological prosedures,

diagnostic procedures in nuclear medicine), dose levels in interventions and guidelines for intervention levels and action levels in emergency exposure situations.

STRUCTURE

In Turkey, the authorization to determine the limits of responsibility for the principles and precautions and liability for protection against the hazardous effects of ionizing radiations have been given to Turkish Atomic Energy Authority with the Law numbered as 2690. It has been determined that governmental and private associations, organizations and persons who keep, use, import and export, tarnsport, store, make the commerce of radioactive materials and radiation generators must obtain license from the Authority in accordance with Radiation Safety Decree and Radiation Safety Regulation that have become effective in 1985 and 1991 respectively which have been prepared in accordance with, and with the order of this Law.

The requirements of license and permission have been described in the Decree and Regulation. In some other specific regulations that have been prepared in accordance with that Decree and Regulation, special conditions related to the area where the radiation sources are being used are stated. The radiotherapy regulation prepared in this connection has put into force in 1994. This regulation covers the provisions in compliance with Basic Safety Series 115 (BSS 115) criteria.The current legislation related with radiological safety of TAEK are shown below in figure 1.

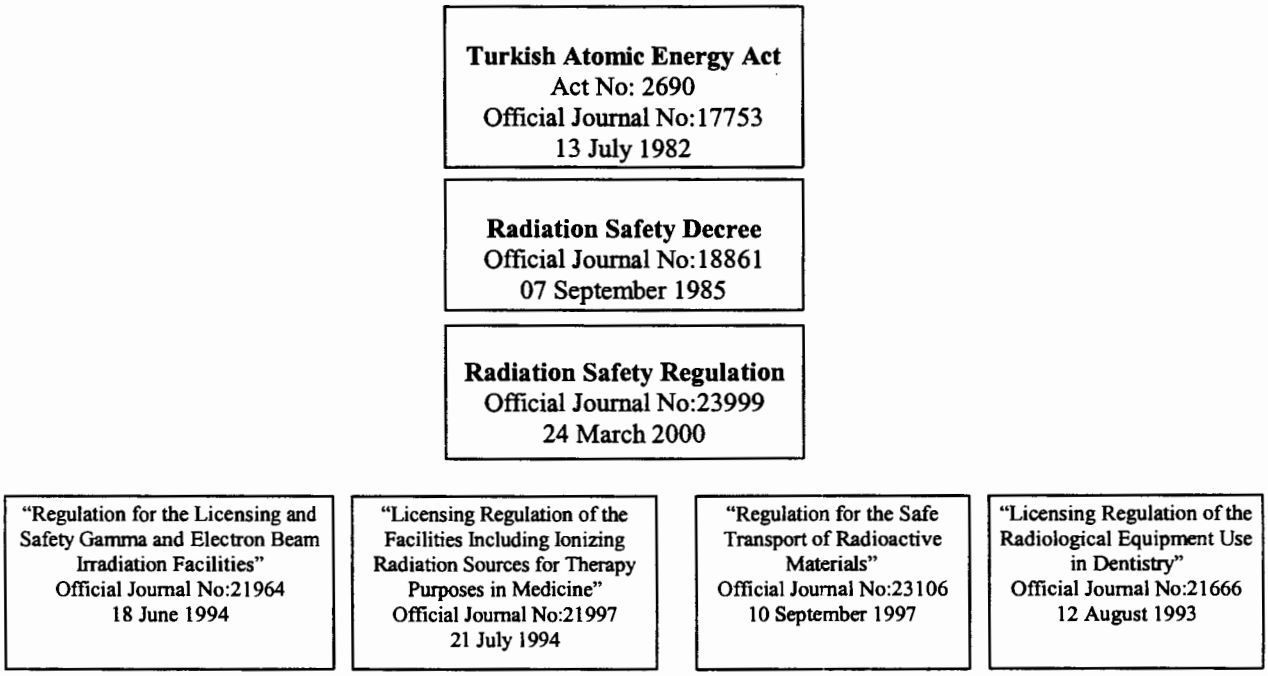
By the adoption of above mentioned recommendations, procedures followed in the import, export and licensing of sealed radiation sources in accordance with the application of the regulation have been given below.

a) For the realization of the import procedures, it is necessary that the importing company must obtain license from the Authority. For being granted with this license, it is necessary that the responsible persons and the supplier company must be stated, the compliance certificate of those equipment and sources to be imported to ISO, IEC or equivalent national standards, catalogues and other necessary documents related to the company must be submitted. The authorization certificate from the supplier company that this company can perform these are required and in order to obtain the license for the installation, exchange and maintenance and repair of the sources, the information about the tarining and experience of the people that will perform these and their medical reports are also requested.
b) The company that has obtained the license to perform such works is also obliged to apply and get permission for each importation process. The permission is being granted after submission of the proforma invoice of the supplier company, production certificate of the source, serial number of the source, the data including the serial number of the equipment and source head or the container and the name of the custom that importation will be made from.
c) The clearence of the source from the custom is only being made possible after the issuance of transportation permit" which is being prepared as a result of the radiation control of the TAEK experts in the customs. The transport permit is only being granted according to the provisions of "Regulation for the Safe Transport of Radioactive Materials". While this permit is being granted; serial number of the source, emergency case plan, license plate number of the vehicle, name of the driver, personal dosimeter number, the radiation measurement equipment that has to be present in the vehicle is being controlled and the route of the vehicle is being determined.
d) Source exchange procedures is being supervised by the experts after the source reaches its destination.
e) It is necessary that a "LICENSE" must be obtained for the facility where the equipment be put into operation according to the provisions of "Licensing Regulation of the Facilities including

Ionizing Radiation Sources for Therapy Purposes in Medicine". For being able to license such facilities; it is necessary that the building in which the source will be present must be granted with civil project approval from the radiation safety view, such facility must employ Radiotherapy Physicists and Radiation Protection Officer and must have all technical equipment that is required. "License" can only be granted to those facilities, after; necessary documents have been submitted the necessary conditions have been complied and quality compliance of the equipment have been approved by the authorized organizations after local measurements and investigations carried out by TAEK experts.

f) For the sending of the used sources to abroad, "Permit for sending abroad" must be obtained by the company licensed for such subject. This permit can only be granted after completion of the inspection at the point where the transportation will start from and following the grant of transportation permit.

Figure 1. CURRENT TURKISH ATOMIC ENERGY AUTHORITY LEGISLATION
related with radiological safety



In Turkey, a wide range of sources of ionising radiation are used in medicine, research and industry. These include X-ray equipment, sealed gauges containing radioactive materials which are used in industry and liquid radioactive materials used in medicine. While many uses of ionising radiation are clearly beneficial to society, there is an inherent risk associated with any such use.

The primary role TAEK is to ensure that these risks are kept to a minimum through its system of licensing and inspection. Turkish legislation prohibits the use of radioactive substances, irradiating apparatus and other sources of ionising radiation without an appropriate license.

LEGISLATION

In general, Turkish legislation governing the use of ionising radiation is derived from European Directives which in turn are based on the recommendations of the International Commission on Radiological Protection (ICRP). The ICRP was established in 1928 and its recommendations, while not mandatory, are highly influential internationally. In 1977 the ICRP published general recommendations on the conceptual framework of radiation protection, based on the following three key principles:

1. **Justification** - the process of showing that a particular use of ionising radiation produces sufficient benefit to the exposed individuals or society to offset the radiation detriment it causes;

2. **Optimisation** - the process of keeping all exposures as low as reasonably achievable, economic and social factors being taken into account; and

3. **Dose limitation** - the process of keeping the sum total of all relevant doses received whether by workers or members of the public within specified limits.

The publication of these general recommendations, commonly referred to as ICRP 26, led directly to the adoption by the European Community in 1980 of **Directive 80/836/Euratom** (subsequently amended by **Directive 84/467/Euratom**). This Directive laid down basic safety standards for the protection of the health of workers and the general public against the dangers arising from ionising radiation and is commonly known as the Basic Safety Standards (BSS) Directive.

The provisions of the 1980 BSS Directive were implemented into Turkish Law by the **Radiation Safety Decree published in 1985 and Radiation Safety Regulation published in 1991.**

These two statutory instruments provide the framework for the TAEK's licensing system and detail the general radiation protection requirements for all users of ionising radiation. Particular uses of ionising radiation which are covered by additional legislation include dental exposure, radiotherapy regulation and shipment of radioactive substances.

As a result of a continual process of reappraisal, ICRP recognized during the 1980's that the risks of exposure to ionising radiation were greater than had previously been thought. ICRP published new general recommendations in 1991, known as **ICRP 60** [2], which updated the standards in ICRP 26 and further developed the conceptual framework.

In particular, ICRP 60 distinguishes between practices (activities that increase human exposure) and intervention (actions taken to decrease human exposure in an actual situation). Practices cover the uses of ionising radiation already referred to such as medical uses etc. An example of intervention is the actions taken to reduce exposure in the aftermath of an accident. The principles which apply to practices, where the risk of exposure can be controlled, are different to those applying to intervention. In the latter case, a balance has to be struck between risks arising from the existing exposure situation and the risks involved in intervention measures taken to reduce that exposure.

In 1996 the European Commission followed up the changed standards in ICRP 60 by adopting a revised BSS directive (**Directive 96/29/Euratom**). In Turkey, the implementation of the BSS Directive to the legislation result in the following changes [3];

- Use of the new ICRP concept of practices and intervention,
- Explicit treatment of natural radiation sources,
- Explicit treatment of "intervention" which includes emergency preparedness.

The revised Radiation Safety Regulation to implement the BSS Directive was published in 2000. Under the EURATOM Treaty, the European Community is required to establish uniform safety standards for radiation protection. This is done by means of the Basic Safety Standards Directives which establish safety standards to protect the health of workers and the general public

against the dangers of ionising radiation. These directives form the basis for radiation protection legislation in all Member States.

The Directive does not apply to exposure to radon in homes, to naturally occurring radionuclides in the human body, to above ground exposure to radionuclides in the undisturbed earth's crust or to cosmic radiation at ground level. A feature of the Directive is the flexibility given to Member States in its implementation. This can be illustrated by a few examples. Firstly, while the Directive includes a list of practices which must be subject to prior authorization, Member States have been given freedom to extend this list. This means that, in Turkey, no major changes will need to be made to the current licensing system. Secondly, while the Directive lays down a limit on effective dose for exposed workers of 100 millisievert (mSv) over a period of 5 years, subject to a maximum dose of 50 mSv in any single year, Member States may decide on an annual limit. For members of the public, a dose limit of 1 mSv in one year is laid down. However, in special circumstances, a higher dose may be authorized in a single year, provided that the average over five consecutive years dose not exceed 1 mSv per year. This has already been given effect to in Turkish legislation, as annual dose limits of 20 mSv for workers and 1 millisievert (mSv) for members of the public were laid down in the revised Radiation Safety Regulation.

CONCLUSION

Finally, with regarded to work activities involving significant exposure to natural radiation sources, there is a good deal of flexibility but specific to be taken by Member States are laid down. These include the identification of work activities which may be of concern, estimation of exposure, implementation of countermeasures and, if required, the introduction of radiation protection procedures in workplaces.

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3. Council Directive 96/29 Euratom of 13 May 1996 lays down basic safety standards for the protection of the health of workers and the general public against the dangers arising from ionsing radiations

4. Council Directive 97/43 Euratom of 30 June 1997 on health protection against the dangers of ionizing radiation in relation to medical exposure.

THE INVESTIGATION OF BIOLOGICAL EFFECTS OF MEDICAL IMAGING SYSTEMS USING MICRONUCLEI ANALYSIS

Dr. Funda S. PALA[1*], Dr. Güler KÖKSAL[1], Prof. Dr. Özer PALA[2]

[1] Turkish Atomic Energy Authorithy Cekmece Nuclear Research and Training Center P.O Box. 1 Atatürk Airport, 34831-Istanbul/TURKIYE

[2] Thrace University, Medical Faculty director of Pediatrics Department Edirne /TURKIYE

ABSTRACT:

In recent years, using computed tomography (CT), ultrasonography (US), and magnetic resonance imaging (MRI) system for diagnostic purposes are increasing. In order to estimate their biological effects, the biological doses inducing these three imaging systems were investigated.

CT's are using finely collimated X-ray beam for scanning. On the other hand US and MRI systems are using non-ionizing radiations. To be able to compare the results using same criteria, biological dose assessments were performed using micronuclei analysis in peripheral blood lymphocytes.

In this study, 19 patients' micronuclei yields were determined before and after CT examinations. The biological doses induced CT was estimated as 0.19-0.22 Gy and 0.30-0.36 Gy respectively for the absences and the presence of the contrast medium during the scanning. The dose enhancement factor of contrast medium was calculated as 1.4-1.7.

The micronuclei yields of 19 children were compared before and after US examination. No significant increase was observed.

To understand the biological effect of MRI system, in-vitro study has been established. The static magnetic fields and its combine effects with radiofrequency were examined. There was no significant contribution of radiofrequency on micronuclei frequency. However, static magnetic fields induced slightly increase in the micronuclei yield depending on the duration of exposure.

* **e-mail:** palaf@nukleer.gov.tr , spala@atlas.net.tr
Fax: +90 212 548 22 30

INTRODUCTION

Nowadays various imaging systems are used at diagnostic Radiology. The conventional radiography is the most common used medical imaging system. In recent years, using of CT, US and MRI systems are increasing because of their advantages on imaging.

CT machines have a finely collimated X-ray beam is using for scanning across the plan of interest at various angles. Fan beam of X-radiation scans through 360 ° while on the opposite site of patient, detectors provide a digital read of amount of radiation and hence the degree to which it has attenuated. The CT examination takes much more time than conventional radiography, and uses extensive X-ray. In this respect, patients might be much more exposures by CT than conventional radiography. This assumption can only be explained by absorbed dose assessment of the patients.

US examination seems to be a safe diagnostic procedure that uses very-high frequency sound waves to produce an image of many of the internal structures of the body. Multiple studies have shown that these sound waves are harmless and may be used with complete safety even on pregnant women, where as CT or X-rays would be inappropriate. In some other cases either CT or US could be used to established a diagnosis but US examinations are typically quicker, harmless and less expensive. However, there are some studies showed that US were induced chromosomal aberrations such as Sister Chromatid Exchange [1,2]

MRI systems' images are obtained from the measurements of the energy absorbed and/or emitted by nuclei in the presence of a radiofrequency source and time varying and stable magnetic field. These systems are using generally regarded as more practical, and safer than radiography for both images and patients and able to achieve greater contrast. There are conflicting data from epidemiological studies [3,4] as to whether exposure to magnetic or electrical field causes an increase at the incidence of cancer.

In this study, biological doses were estimated with using micronuclei analysis technique. The easier and far less time consuming method of scoring micronucleus has been suggested as an alternative approach for quantifying chromosome damage. Micronucleus appears as a separate small nuclei in the cytoplasm in addition to the main nucleus in the cell. They originated either from acentric chromatin materials or whole chromosomes that were not included into daughter nuclei during mitotic divisions. The presence of micronuclei is the evidence of the appearance of chromatid/chromosome fragments or lagging chromosomes, or of effects on the mitotic spindle and the appearance of numerical chromosome aberrations [6]. For this reason, this method has become particularly suitable for the investigation and understanding of the mechanism of the effect of certain agents.

Diagnostic uses of ionizing radiation make large man-made contribution to the population dose. It is well known that X-rays induce chromosomal aberrations in the living cells. However the biological effects of non-ionizing radiation is not clear. The aim of this study were to investigate the biological effects of most common using three medical imaging System, CT, US, and MRI using micronuclei technique.

MATERIAL AND METHODS

a) Computed Tomography

The yields of micronuclei in peripheral blood lymphocytes were determined in19 patients' blood samples who had been examined by CT. None of the patients had been treated with chemotherapy or radiation therapy. Their ages was varying between 11 to 62 years. Blood samples were taken 1 hour before and 1 day after CT investigations. Hitachi W950 SR, CT machine were used which was on 140 mA, 120 kV X-rays. 5.000-10.000 binucleated cells were scored for each person.

b)Ultrasonography

Blood samples were taken from 19 children, 1 hour before and 1 day after US examination. General Electric RT2800 US machine, which has 30 mW/cm^2 intensity and was on 5 Hz radiofrequency were used. The duration of exposure was changing between 5 to 20 min. and the age of children were varying between 1-14 years.

c) Magnetic Resonance Imaging System

To evaluate the biological effect of MRI system, an In-vitro study was established. GE Magnetic Resonance Imaging System were used which was on 0.5 T static magnetic field and 21 MHz radio frequency.

The blood samples, which were taken from young healthy non-smoking female donor, were exposed to presence of static magnetic field and the presence of magnetic field and radio frequency for 0, 30, 60, 90, 120 and 150 mins.

All blood samples were cultured using technique, which was described in our Dose-response curve study [7].

400X light microscope magnification was used to scan the slides while 1000X magnification was used to identify micronuclei in binucleated cells. The following criteria that have been established by Contryman and Heddle [6] and Fenech and Morley [8] were used for identifying micronuclei. Only the cells with well-preserved cytoplasm were analyzed. The micronuclei did not exceed half of maximum diameter of main nuclei and were distinctly separates from main nuclei. Micronuclei's dyes have to be the same as or lighter than the main nucleus, not refractivity.

Dose estimations were done using Co-60 gamma rays dose response curve (dose rate: 45.73 R/min), which was established in our laboratory.

$Y= 1.143x10^{-3} +4.44x\ 10^{-3}D +1.16x10^{-2}\ D^2$ [7]

RESULTS AND DISCUSSION

a) Computed Tomography

To evaluate the biological effects of CT, 19 patients' micronuclei yields in peripheral blood lymphocytes were compared before and after CT examination. Results were given in Table 1.

Table 1. The comparison of 19 patients' micronuclei levels before and after CT examination

No	Age (years)	Sex	Body Part	Contrast media	$(MN/Cell)^1$	$(MN/Cell)^2$	Dose±SE (Gy)
T11	39	F	Brain	Yes	4/5000	5/5000	-
T13	27	M	Brain	Yes	11/5500	11/5058	-
T6	30	F	Brain	No	3/5000	4/5000	-
T15	40	F	Brain	No	-	3/5000	-
T18	29	F	Sinusoidal	No	5/5000	9/5000	0.11±0.07
T19	42	M	Neck	No	5/5000	8/3109	0.19±0.09
T3	60	F	Abdominal	Yes	5/5000	24/5000	0.36±0.06
T14	55	F	Abdominal	Yes	20/8000	59/8000	0.31±0.04
T8	40	M	Abdominal	No	10/10000	29/10000	0.22±0.04
T12	53	F	Abdominal	No	35/10000	69/10000	0.21±0.07
T2	21	F	Lungs	Yes	5/5000	20/5000	0.30±0.07
T1	11	M	Lungs	No	2/5000	14/5000	0.22±0.05
T4	58	M	Lumbar	Yes	10/10000	45/10000	0.34±0.05
T10	62	M	Lumbar	Yes	12/5000	37/5000	0.32±0.05
T5	50	F	Lumbar	No	14/10000	31/10000	0.19±0.03
T16	40	M	Liver	Yes	-	32/8000	0.32±0.06
T7	30	M	Liver	No	30/10000	62/10000	0.22±0.06
T9	30	F	Arm	No	3/5000	15/5000	0.22±0.05
T17	51	F	Arm	No	-	14/5058	0.22±0.05

$(MN/Cell)^1$: Micronuclei/Scored binucleated cells value of 1 hour before CT examination
$(MN/Cell)^2$:Micronuclei/Scored binucleated cells value of 1 day after CT examination
SE: Standard Errors

The biological doses were estimated by using Co-60 gamma rays dose response curve. Contribution of contrast medium on the estimated doses was taken into account. Dose estimation for the presence of contrast material during examination of the CT were found 0.30-0.36 Gy and dose estimation for absence of contrast material during examination of the CT were found 0.19-0.22 Gy by using Co-60 gamma ray's dose response curve.

These results were found similar with Weber et al's study [9]. Weber et al were also used Co-60 gamma rays dose response curve for dose estimation and they observed that 0.13-0.5 Gy for the biological dose estimation induced by extensive X-rays (including CT examinations)

Table 1 shows that biological doses of the head induced CT examination seems to be small. This result probably due to the exposure area is distant from the lymphocyte pools. During brain examinations, the examined area remains outside of the upper lymphocyte pools. Most part of lymphocytes are not exposed.

Using contrast medium increased the biological doses which is induced by CT examination. t-test were applied to estimate of that dose increment by the contribution of the presence of contrast medium during examination. The results showed that contrast medium significantly increased the doses. ($p<0.05$) Dose enhancement factor found between 1.4-1.7 is similar to Weber at al's [9] value between 1.5-2.0 .

Stephan et al [10] indicated that contrast medium itself showed no substantial action in producing aberrations. But contrast medium increased radiation induced aberration yield. This is obviously caused by the enhancement of radiation dose because of the photo effect of contrast medium.
Consequently an increased number of secondary electrons would transfer their energy to the lymphocytes adjacent to the contrast medium.

b) Ultrasonograpy
19 children's, blood samples were taken 1 hour before and 1 day after US examination. The results were given in Table 2.

Table 2. The comparison of micronuclei yields before and after US examination

No	Age	Sex	Duration (min)	$(MN/Cell)^1$	$(MN/Cell)^2$
U1	13	F	5	5/10000	5/10000
U4	3	F	5	3/10000	3/10000
U8	3	F	5	1/5000	1/5000
U12	10	M	5	6/10000	6/10000
U16	10	M	5	4/10000	4/10000
U2	13	F	10	4/8000	5/8000
U3	14	M	10	3/5000	4/6000
U6	7	M	10	2/5000	1/5000
U10	6	F	10	3/7500	3/7500
U13	8	F	10	2/5000	3/5000
U17	4	M	10	3/7500	2/7500
U5	5	M	15	3/10000	3/10000
U7	1	F	15	1/10000	1/10000
U11	9	M	15	3/7500	4/10000
U14	11	M	15	5/10000	5/10000
U18	6	F	15	3/8000	4/10000
U9	4	M	20	2/7000	3/10000
U19	10	F	20	2/5000	2/5000
U15	2	F	20	1/5000	1/5000

$(MN/Cell)^1$: Micronuclei/Scored binucleated cells value of 1 hour before US examination
$(MN/Cell)^2$:Micronuclei/Scored binucleated cells value of 1 day after US examination

There are conflicting data on induced chromosomal aberrations by US. The majority of papers are negative [11,12,13,14], however there are several positive reports [1,2]. Most of the studies, which were investigated the biological effect of US, were performed as in-vitro. Exposure conditions may affect the response.. Liebeskind et al. established two in-vitro studies they found either positive [2] or negative [14] results. For this reason in order to evaluate biological effects of diagnostic Ultrosonography, in-vivo study was preferred. Children were selected for this study because of the background micronuclei level is low. The effects of duration of exposure were also examined. Totally 145.500 binucleated cells were scored and 56 micronuclei were observed in blood samples which were taken 1 h before US examination while 154.000 binucleated cells were scored and 60 micronuclei were observed in blood

samples, which were taken 1 day after US examination. As seen on Table 2, no statistically increase on micronuclei frequency was found. Duration of exposure did not affect the micronuclei yield.

c)Magnetic Resonance Imaging System

Magnetic Resonance Imaging systems are using radiofrequency and magnetic field for imaging. In order to determine the biological effect of magnetic field and its combine effect with radiofrequency, an in-vitro study was established. The blood samples which were taken from young healthy non-smoking female donor were exposed to the presence of magnetic field and with or without radiofrequency. Results were given in Table 3.

Table 3. The evaluation of micronuclei induction capacity of Magnetic field and its combine effect with radiofrequency.

	Duration of Exposure (min)	Micronuclei/Cell	Dose (Gy) (%95 C.I.)
Control	-	2/5000	-
MF	30	3/5000	-
MF	60	3/5000	-
MF	90	4/5000	-
MF	120	6/5000	0.04 (0.00-0.21)
MF	150	8/5000	0.09(0.01-0.25)
MF+RF	30	3/5000	-
MF+RF	60	3/5000	-
MF+RF	90	5/5000	-
MF+RF	120	7/5000	0.05(0.00-0.23)
MF+RF	150	8/5000	0.09(0.01-0.25)

MF:Magnetic Field
RF:Radiofrequency

As seen on Table 3, magnetic field caused increasing on the micronuclei yields depending on duration of exposure. The micronuclei level for 150 min exposure time was observed as 4 times higher than control level. No significantly contributions were found from radiofrequency. Khalil and Qassem [15] exposed human lymphocyte cultures to a pulsing electromagnetic field (PEMF) for various durations (24, 48 and 72 h). They observed that exposure times (24 and 48 h) did not cause a significant delay in cell turnover (cell proliferation index) or an increase in the baseline frequency of sister-chromatid exchanges (SCE). However, cultures continuously exposed to PEMF for 72 h exhibited significant reduction of the cell proliferation index (CPI) and an elevation of SCE rate. This result supports our findings. Electromagnetic fields alter Ca^{++} levels in exposed cells [5]. Ca ions act an important role at DNA repair mechanism. a 60-min exposure of thymic lymphocytes at magnetic field inhibits calcium influx [16]. Calcium influx in the lymphocyte is an early event in signal transduction and calcium is an important second messenger for a wide variety of important cellular process such as RNA, DNA and protein synthesis; modulation of calcium signaling by electromagnetic fields has the potential to influence these cell functions. Yost et al [16] did not observe calcium alteration at resting cells . Because of the micronuclei analysis were performed at peripheral T lymphocytes which is at G_0 resting

phase, the effect of magnetic field on dividing cells may be much more than observed in our study.

Conclusion

Exposure to ionizing radiation has long been well recognized a risk factor for cancer development. Since ionizing radiation can induce mutation, and accurate way of measuring chromosomal aberration frequency could be a useful tool for evaluating cancer risk. The ages of CT is increasing day by day. Unnecessarily usage of this systems can be affect public's health adversely. Although the CT is the most important system for to provide a good quality image, it has to use more carefully.

No increase was observed at micronuclei frequency after US examination. However a slight increase at the micronuclei yields were observed in 120 min after exposure to magnetic field. It is not easy to say that there is a risk for public. On the other hand magnetic field alter Ca level at dividing cells. Therefore it could be effect the DNA repair mechanism. There is a continuously stable magnetic field at MRI room whether the system is working or not. This result indicated that MRI stuff would be under risk. To clarify the risk of MRI stuff , in-vivo studies are required.

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PATIENT DOSIMETRY IN INTRAVASCULAR RADIATION THERAPY

*S. Van de Putte MSc, **Y Taeymans, MD, PhD, *H. Thierens PhD
*Biomedical Physics Department, University Gent, Belgium, Proeftuinstraat 86, B-9000 Gent
sascha.vandeputte@rug.ac.be
** Department of Cardiology, University Hospital Gent, Belgium, De Pintelaan 185, B-9000 Gent
Belgium.

Percutaneous transluminal coronary angioplasty is a well-accepted method for nonsurgical myocardial revascularization. However the long-term success of this method is limited by the occurrence of restenosis. Endovascular brachytherapy has been put forward as means to avoid restenosis. Since this technique involves the placement of a radioactive source in a catheter in the patient's arteries, the possible radiation risk should be considered. In this paper the effective dose of the patient associated with the use of Iridium-192 for IRT treatment has been calculated using Monte Carlo techniques. To put the results into perspective the effective dose form the PTCA procedure was also calculated using the same techniques. Calculations were based on the measurement of DAP(Dose Area Product) for the procedure. We found a mean effective dose of 9 mSv for both the PTCA procedures as for the IRT treatment. Thus leading to the conclusion that, from the perspective of radiation burden, the elimination of one PTCA procedure through the use of IRT is a benefit for the patient.

1 Introduction:

Percutaneous transluminal coronary angioplasty is a well-accepted method for nonsurgical myocardial revascularization. However the long-term success of this method is limited by the occurrence of restenosis. Restenosis is seen in approximately 30 % of patients undergoing PTCA and usually occurs within 6 months after angioplasty. A number of pharmaceutical approaches have been tested to limit the rate of restenosis, none with sufficient success. Implantation of a stent can only reduce the rate of restenosis for a number of patients. Restenosis can be attributed to three components: recoil of the vessel, late remodelling of the vessel and intimal hyperplasia. The first two components are adequately remedied through the use of stents. The last component however, which is the growth of smooth muscle cells, fibroblasts and intercellular matrix into the lumen of the vessel as a reaction to the injury of the PTCA procedure, is not solved by stent placement. A promising approach is the use of ionising radiation. This can be applied in different ways : implantation of radioactive stents and catheters with gamma or beta sources. This paper focuses on the use of gamma sources, in particular Iridium-192. Data from the SCRIPPS, WRIST and GAMMA I trial suggest that this will be a useful technique to reduce restenosis. The main problem associated with the use of gamma radiation is the range of the photons, which might pose a problem towards staff dosimetry. A second point of interest is the extra dose the patient receives from this IRT treatment. In order to evaluate these risks the RABAS (Radiation Burden Assessment) study has been setup. In this study extensive dosimetry will be done for patients and staff in the treatment of patients with Iridium sources. This paper describes the partial results for the patient radiation burden.

2 Materials and Methods

2.1 Catheterisation room and treatment procedure

All patients were treated in the catheterisation room of the University Hospital Ghent, Belgium. The catheterisation room is a bi-plane room and consists of two Philips (Philips, Hamburg, Germany) cardiovascular X-ray units. A DAP meter is attached to the tube housing. These DAP meters are calibrated in situ using a Farmer NE2571 ionisation chamber and Kodak X-Omat V film. The calculation of the calibration factor was done according to the simplified method described by Shrimpton et al [1]. In this method the calibration factor is taken as the ratio between the actual DAP, calculated as the dose in the centre of the field multiplied with the field size as measured from the film, and the DAP reading. The usefulness of these devices in the calculation of X-ray doses has already been investigated by a number of authors [2-4]. To estimate the additional risk for both patient and staff an IRT-treated and a control group of patients will be studied. Only male patients

aged over 40 and satisfying severe inclusion criteria are considered in the study. Prior to the IRT-treatment, the patients in the treatment group are treated with normal PTCA procedures. When the cardiologist is satisfied with the success of the PTCA procedure, the IRT treatment is started. Using fluoroscopy and a dummy ribbon the length of the source is determined. Next the actual source is moved in to the treatment position by a radiation oncologist. At this time only the radiation oncologist is allowed in the room. During the actual treatment time, nobody is allowed in the catheterisation room. After the IRT treatment has ended the cardiologist makes the finals images to ascertain the initial success of the procedure. The patients in the control group are treated with normal PTCA procedures.

2.2 Patient dose study

To calculate patient dose a number of parameters are recorded during the procedures. These include DAP separately for every fluoroscopy and cine run. The position of the X-ray tubes, indicated as a set of two angles: rotation and skew. These angles as well as the tube parameters (tube potential, current, SID, II-field) are registered automatically for every cine run. The values for fluoroscopy are copied from the first cine run following a series of fluoroscopy. In the case of the IRT treated group the DAP and associated tube parameters are divided in two parts. A first part consists of all radiation before the IRT-source placement, the second is everything later on. In this way the additive X-ray patient dose associated with the IRT-treatment can be assessed.

Patient dosimetry is divided in three components. The first component is the entrance skin dose associated with the use of X-rays in interventional radiology. This part was measured with TLD's (LiF, Harshaw TLD-100 chips) attached to the body. A major problem associated with the use of TLD's ,as noted in a previous study [4], is the fact that is difficult to predict the location on the skin where the highest dose will be delivered. The only way to overcome this problem is through the use of an array of TLD chips. For this study 100 TLD's are used per patient. These TLD's are spaced over an array of 95 cm by 20 cm leading to an equal spacing of 5 cm in both the horizontal and vertical direction.

The second and third part are the organ and effective dose from the X-rays and 192-Iridium source respectively. As measurement of these components is difficult or impossible Monte Carlo calculations were done. The effective dose is then calculated using the tissue weighting factors given in ICRP60 [5]. The dose to the bone-marrow is calculated using the method of Rosenstein [6] to divide the energy deposited in the skeleton in two parts. Consequently kerma-to-dose conversion factors calculated by Kerr et al [7] were used to calculate the dose to the marrow. The dose to the bone surface is taken as the dose to the skeleton excluding the marrow.

2.3 Monte Carlo calculations

In the literature different sets of conversion factors relating DAP to effective dose are available. The factors used by most authors are those given in NRPB-R262 [3]. As tabulations are always limited, we preferred to use our own Monte Carlo calculations. The Monte Carlo code used was MCNP4b2 [8]. The kerma approximation with the following interactions were considered: Rayleigh scattering, Compton Scattering, photoelectric effect and pair production. The patient table is included in the model to compensate for additional attenuation. In the case of X-ray simulation, the source position is calculated from the X-ray tube angles and from the assumption that the iso-center of the bi-plane X-ray set-up is located at the heart for all incidences. For the calculations of IRT doses the source is takes as a curved line source in contact with the heart surface. The position was calculated to closely match the position of the lesion treated in the patient. The IRT sources used in this study (Cordis) have three possible lengths 23 mm, 39 mm and 55 mm. For calculation of the organ dose we used the mathematical phantom developed by Christy and Eckerman [9]. For the calculation of the X-ray dose the phantom has been adjusted for the above head position of the arms during the PTCA procedure. For every patient a Monte Carlo simulation has been done for every tube incidence and field-size used in the PTCA procedure.

2.4 Heart phantom and source position

We used the heart phantom as described in the mathematical phantom [9] which is the model described by Coffey [10]. The surface of the heart is represented by four quarter ellipsoids. Inside the heart a division is made between heart-wall and contents. The heart is described in an auxiliary coordinate system that is related to the phantom coordinate system by a rotation matrix. In this model the groove between atrium and ventricle can be approximated as the YZ-plane, similarly the division between the left and right side of the heart can be approximated as the XY-plane. The cardiovascular blood flow is supplied by two main coronary arteries, the Left and Right coronary artery. Both these arteries have their offspring in the aorta. The RCA (Right coronary artery) runs in the groove between the right atrium and ventricle. The Left coronary artery almost immediately divides into two branches the LAD (left anterior descending) which runs along the division between the left and right ventricle towards the tip of the heart, and the CX (circumflex) that runs along the groove between the left ventricle and atrium. All of these branches are divide in proximal, middle and distal parts.

3 Results and discussion

Table I gives some relevant dose determining parameters for the dose calculations. These include total treatment IRT-dwell time, source activity, source length and source position.

Table I : relevant dose determining parameters for IRT procedure

Patient	Dwell time (min)	Activity (MBq)	Source length (mm)	Source Position
A (1)	17.150	10748.5	39	Prox LAD
B (2)	17.150	10748.5	39	Prox CX
C (3)	18.088	6315.90	23	Prox LAD
D (4)	17.450	14737.1	55	Prox LAD
E (10)	15.106	12202.6	39	Prox RCA

Table II gives the dosimetric results for all patients. These include maximum skin dose , effective X-ray dose, effective X-ray dose after IRT treatment, effective dose from IRT treatment.

Table II: dosimetric results

Patient	Maximum skin dose (mGy)	Total Effective dose X-ray (mSv)	Effective dose X-ray after IRT (mSv)	Effective dose from IRT (mSv)	Effective dose per disintegration (mSv/dis)	Patient	Maximum skin dose (mGy)	Total Effective dose X-ray (mSv)
A	863	16.0	5.63	7.73	$6.99\ 10^{-13}$	F	241	3.07
B	501	7.13	1.30	9.55	$8.64\ 10^{-13}$	G	818	11.1
C	853	16.9	1.22	4.70	$7.11\ 10^{-13}$	H	753	11.9
D	442	7.73	1.14	10.4	$6.94\ 10^{-13}$	I	352	7.51
E	368	6.09	1.28	6.99	$6.33\ 10^{-13}$	J	473	7.43

3.1 Skin dose

The skin dose distribution associated with a coronary PTCA procedure is difficult to predict and depends entirely on the incidence the cardiologist will use to view a certain lesion. This is clear from figure 1 that shows the dose distribution obtained for the back of patient C. The left part of the figure shows the skin dose distribution the right part shows the same dose distribution but with the different TLD locations made clearer. The two hot spots are the result of two X-ray tube incidences (rotation –26 skew 13 and rotation 55 skew –20) that are responsible for respectively 30 % and 34 % of the total DAP, the rest is distributed evenly over a number of projections.

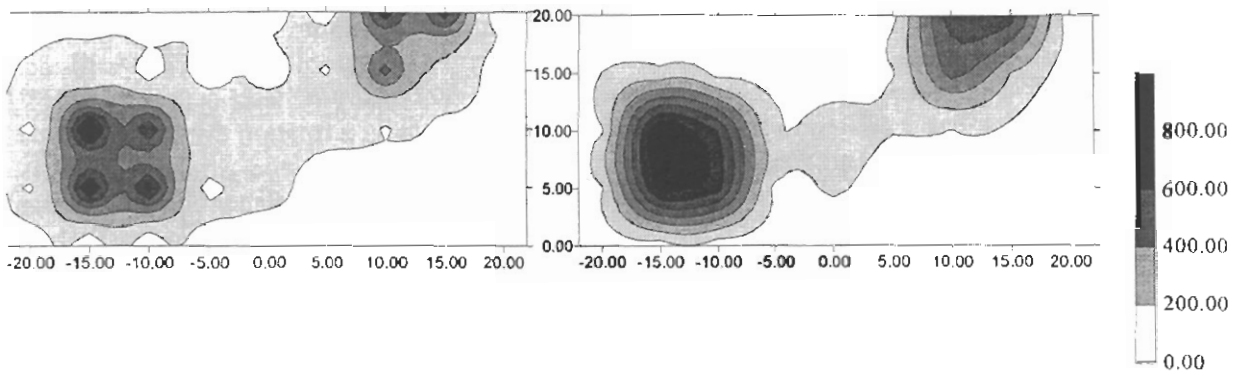

Figure 1: Skin dose distribution for patient C. The horizontal axis indicates the position on the back in cm , 0 is the centre and –20 is the right side. The color bar indicates the skin dose in mSv

3. 2 Effective dose

The higher dose found for patient A is due to stent placement. For patient C additional images before the PTCA procedure were needed to determine the exact location of the lesion. It is important to notice the dose after IRT-treatment in Table II, which has a mean value of 1.24 mSv excluding patient A, since a stent was placed after the IRT treatment. The effective dose from the Iridium source itself seems to depend strongly on the source length and hence the total activity. The dose for patient C for whom the longest source was used, is almost twice that of patient B for whom the shortest source was used. This is logical since the total activity on the longer source is also higher. If however we look at the dose per disintegration we find that this value depends on source position and also on source length. Both aspects have the same reason: the proximity to radiosensitive organs. If we compare the dose per disintegration value for a 23 mm source in the prox LAD with that for a 55 mm source in the same position, we find that the dose per disintegration is higher for the shortest source. This can be explained if we look at the orientation of the heart and hence the source in the body. Because the heart is tilted in the body, the average distance from the source to ,for example, the oesophagus is longer for the longest source. If we compare the values per disintegration with the MIRDOSE 3.0 value of 9.34 10^{-13} mSv/dis we find that this value is 30 % higher than the mean (7.2 10^{-13} mSv/dis) of the values given in table II. This can also be explained by the geometrical effect. The calculation in MIRDOSE is based on activity uniformly distributed in the hearth wall. The values in table II are for distinct locations on the hearth surface. If we use our model to calculate the dose per disintegration for a source located posterior we find a value of 10.69 10^{-13} mSv/dis, which is 17 % higher than the MIRD value.

4 Conclusions

When considering the use of IRT-treatment in the fight against restenosis, one has to take the potential radiation risk into consideration. To determine this risk Monte Carlo calculations were done to calculate the effective dose associated with these procedures. The mean effective dose found for a PTCA procedure was 9.29 mSv. The mean effective dose found for the IRT-treatment was 9.14 mSv, consisting of 1.24 mSv from the additional X-ray use and 7.90 mSv from the IRT source. It can thus be concluded that the extra radiation burden to the patient from the IRT-treatment is comparable to the PTCA. Thus if one PTCA procedure can be avoided through the use of IRT, then we can conclude that from the perspective of radiation burden, the treatment is justified.

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DOSES OF IONISING RADIATION RECEIVED BY PATIENTS DIAGNOSED AT THE NUCLEAR MEDICINE DEPARTMENT IN WARSAW FROM 1985 TO 1999

J. Chaś[1], M. Marciniak[1], E. Dziuk[2], and M.K. Janiak[1]

1. Department of Radiation Protection and Radiobiology, Military Institute of Hygiene and Epidemiology, Warsaw; and 2. Department of Nuclear Medicine, Central Clinical Hospital of the Military University Medical School, Warsaw, Poland.

Abstract

In order to evaluate the radiological risk incurred by patients diagnosed at the Department of Nuclear Medicine (DNM), Central Clinical Hospital of the Military University Medical School in Warsaw, the collective committed effective dose equivalents (CCEDE) and the mean personal effective dose equivalents (MPEDE) were calculated for the subsequent years of the period from 1985 to 1999 and compared to the respective values obtained for the mid-1970s. The results indicate that although the number of patients and the total radioactivities used in the diagnostic assays at the DNM increased more than 2.5-fold in the second half of the 1980s and in the 1990s, as compared to the years 1975-1976, the MPEDEs calculated for the periods from 1985 to 1989 and from 1990 to 1994 were similar to and two-fold lower, respectively, than those obtained for the years 1975-1976. However, in the second half of the 1990s, these doses rose again and in 1999 they were almost three times as high as in the mid-1970s. This latter observation results from the increased contribution to CCEDE of the doses from the diagnostic use of I-131 which equalled to 88% in 1975, dropped to 20% in 1994, and again rose to 90% of the total dose in 1999. In fact, beginning from 1995, a new whole-body I-131-based screening procedure was introduced for the detection of the thyroid cancer metastases.

Introduction

The constantly increasing numbers of patients diagnosed *in vivo* with use of a variety of radionuclides make it necessary to control and verify the absorbed doses of ionising radiation and to estimate the risk incurred by the exposed persons.

The mean number of patients diagnosed annually at the Department of Nuclear Medicine (DNM), Central Clinical Hospital of the Military University Medical School in Warsaw from 1985 to 1989 and from 1990 to 1999 equalled to 2,661 and 3,111, respectively. The respective annual activities of the radiopharmaceuticals used equalled to 1.02 and 1.27 TBq. For comparison, the mean number of patients diagnosed per year at DNM during the period from 1975 to 1976 equalled to 1,444 and the activities used averaged to 0.06 TBq. The present work was undertaken to compare the exposure to ionising radiation in terms of the collective effective dose equivalent and mean personal effective dose equivalent in patients diagnosed at the DNM in a given year from 1985 to 1999 and, for comparison, in the years 1975 and 1976. The respective dose equivalents were calculated based on the activities of different radionuclides in different organs and tissues and the number of patients diagnosed in each particular year.

Material and Methods

Calculations of both the collective committed effective dose equivalents (CCEDE) and mean personal effective dose equivalents (MPEDE) were obtained for 2,887 patients diagnosed at the DNM in 1975 and 1976, and for 44,413 patients diagnosed during the period from 1985 to 1999 (Fig.1). The diagnostic tests consisted predominantly of scintigraphies and/or radioimmunoassays utilising such radionuclides as I-131, Tc-99m, In.113m, Tl-201, Cr-51 and Hg-203. To calculate the doses we used the values of the committed effective dose equivalents $H_T(\tau)$ obtained by a patient after administration of a given radionuclide per unit radioactivity, as indicated by others.[1-8] By multiplying the $H_T(\tau)$ value by the activity of the administered radionuclide and the number of patients in a given year, the CCEDEs were obtained for all the patients diagnosed per year with a particular test. The quotient of the CCEDEs and the number of tests performed in a given year yielded the total CCEDE per year. The MPEDE was obtained by dividing the CCEDE in a given year by the number of patients diagnosed in that year. Contribution of I-131 to the total collective effective dose equivalent was defined as the

quotient of the CCEDE from this radionuclide calculated for the thyroid gland and the total CCEDE value.

Results and Discussion

As shown in Fig. 2, total activities of the radionuclides used annually from 1985 to 1999 generally paralleled the number of patients tested and averaged 1.01 TBq for the period from 1985 to 1989, and 1.27 TBq for the period from 1990 to 1999. In fact, the highest total activity (1.62 TBq) was noted in 1993, when the number of patients was also the greatest (3,599 patients, as shown in Fig. 1). In contrast, although the numbers of patients diagnosed in 1975 or 1976 equalled to more than one-third of the mean number of patients from the period 1985-1996, total activities of the radioisotopes utilised during 1975 and 1976 equalled to only 0.05 and 0.06 TBq, respectively,. These results reflect the quantitative and qualitative changes in both the radionuclides used and the types of tests employed during the 1970s and 1980s. Indeed, in 1975 and 1976 the I-131-labelled sodium iodide, the Hg-203-labelled neohydrine, and the In-113m-labelled compounds were the predominant radiopharmaceuticals used in the radioisotope-based diagnostics. However, labelling of the compounds with In-113m and Hg-203 was abandoned in 1985 and 1986 when, for the first time, most of the *in vivo* tests were done using agents labelled with technetium Tc-99m and other short-lived radionuclides (e.g. Tl-201).[9-13] Moreover, the traditionally I-131-tagged compounds such as NaI, albumins, albumin microspheres and hipuran began to be less and less frequently labelled with this radionuclide. In fact, in 1989 approx. 42,000 diagnostic tests of the thyroid gland in Poland were done using the I-131-labeled compounds and approx. 10,000 tests using the Tc-99m-labeled compounds, while in 1992 the number of tests in which I-131 and Tc-99m were used as the radionuclide tags approximated to 33,000 and 35,000, respectively.[9] During the second half of the 1990s, however, the whole-body scintigraphy with use of I-131-labelled NaI became more and more popular for the detection of thyroid cancer metastases.

For patients diagnosed at DNM the total CCEDE during the period from 1985 to 1989 approximated 30 man-Sv. For comparison, these doses for 1975 and 1976 equalled to 20 and 16 man-Sv, respectively. With regard to the 1990s, this dose reached its nadir (15 man-Sv) in 1992, then began to rise and in 1999 equalled to 89 man-Sv (data not shown). This substantial increase is associated with the dissemination in the mid-1990s of a new diagnostic procedure utilising I-131 for the whole-body screening for metastases of the thyroid cancer. For example, in 1999 as many as 60 patients were diagnosed with this particular method which alone was responsible for 80% of the total CCEDE received by the patients in 1999.

The total CCEDE data were used to obtain the MPEDE values (Fig. 3) and the contribution of I-131 to the total CCEDE (Fig. 4). As shown in Fig. 3, the MPEDEs were the highest during the second half of the 1990s (mean value 19.6 mSv) and rose substantially compared to the second half of the 1980s (mean value 11.7 mSv) Interestingly, the lowest MPEDE values per patient were noted in 1992 and 1993 (5.0 and 4.9 mSv, respectively). In contrast, in 1975 and 1976, these dose equivalents equalled to 13.4 and 11.4 mSv, respectively, which in view of the low total radioactivities used in those years (Fig. 2) are the relatively very high levels. Nevertheless, these latter values are still below the level received by the total population of patients from the Polish nuclear medicine departments in 1981.[14] However, the values of the MPEDE calculated for each patient diagnosed at the DNM from 1985 to 1995, although generally oscillating around 10 mSv, were still somewhat higher than the respective doses reported for the 1980s from other European countries.[7,8,13,15,16] The reason for this discrepancy is unclear, but it is possible that different types and doses of radionuclides, and/or different diagnostic procedures used in these other countries are responsible.

As shown in Fig. 4, the contribution of I-131 to the total CCEDE indicates that the use of this radionuclide was most responsible for the radiological risk of the patients during the tested period (70-90% CCEDE) except for the first half of 1990s (20-70% CCEDE) when it was often replaced by Tc-99m in the diagnosis of thyroid disorders.

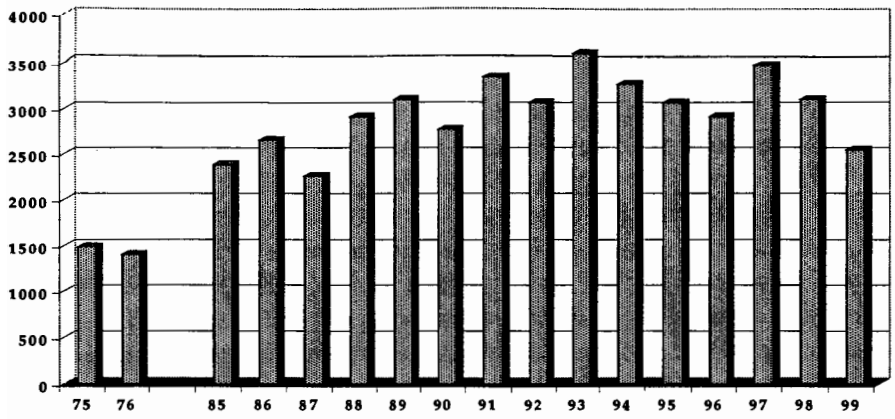

Fig.1. Numbers of patients diagnosed at the DNM per year in 1975 and 1976 and from 1985 to 1999.

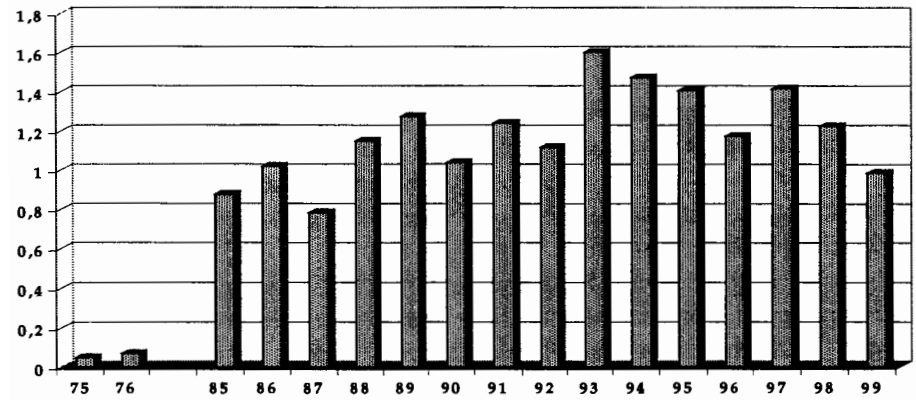

Fig.2. Total activities [TBq] of radionuclides used at the DNM per year in 1975 and 1976 and from 1985 to 1999.

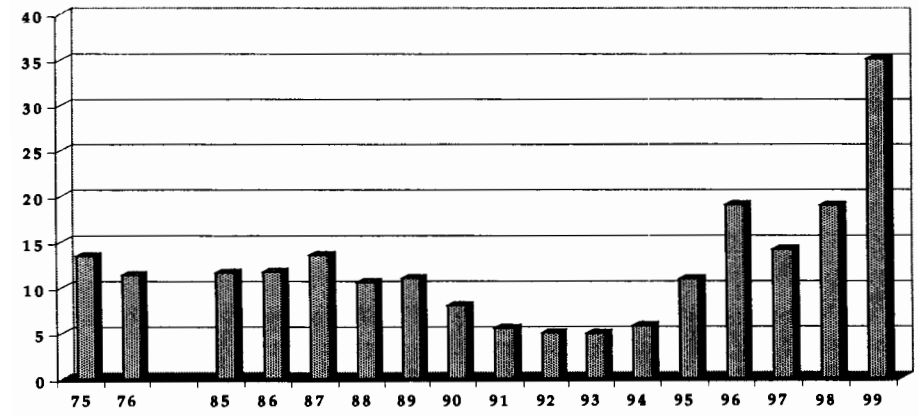

Fig.3 Mean personal effective dose equivalents [mSv] for patients diagnosed at the DNM in 1975 and 1976 and from 1985 to 1999

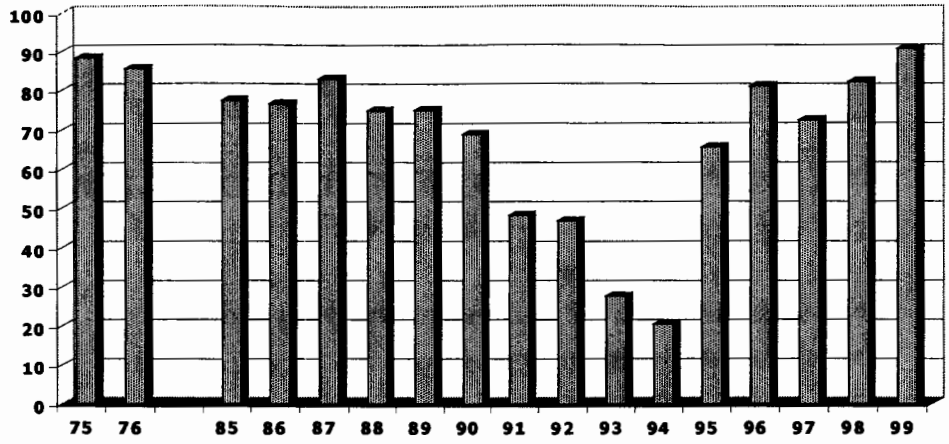

Fig.4. Contribution of I-131 to the total collective effective dose equivalent [%] for patients diagnosed at the DNM in 1975 and 1976 and from 1985 to 1999

In conclusion, the present results indicate that although the number of patients diagnosed at the DNM during the last 15 years almost doubled compared to the mid-1970s the mean MPEDEs obtained **yearly** by the patients from the two periods are similar. However, the lowest MPEDE values were noted in the first half of the 1990s and the highest in 1999. In fact, these values began to rise in 1995 as a result of the markedly increased utilisation of I-131 in the whole-body screening for thyroid-derived metastases, the method rarely used in Poland during the early 1990s. These elevated levels of MPEDE indicate the increased radiological risk for both patients and personnel of the nuclear medicine departments during the last five years, the cost-benefit of which should be carefully re-assessed.

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FORM B
IAEA-CN-85

INTERNATIONAL CONFERENCE ON THE RADIOLOGICAL PROTECTION OF PATIENTS

in

- **Diagnostic and Interventional Radiology**
- **Nuclear Medicine and**
- **Radiotherapy**

organized by the
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co-sponsored by the
European Commission
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in Malaga, Spain, 26-30 March 2001

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TITLE OF THE PAPER AND TOPIC: RADIATION PROTECTION AWARENESS AMONG RADIATION WORKERS, HOSPITAL MANAGERS AND CLIENTELE AT MULAGO HOSPITAL.

EDUCATION AND PROFESSIONAL DEVELOPMENT IN RADIOLOGICAL PROTECTION.

AUTHOR(S) INITIAL(S) AND FAMILY NAME(S)	SCIENTIFIC ESTABLISHMENT(S) IN WHICH THE WORK HAS BEEN CARRIED OUT	TOWN/COUNTRY
1 E. KIGULI-MALWADDE	MULAGO HOSPITAL	KAMPALA/UGANDA
2 P. DDUNGU-MATOVU	MULAGO HOSPITAL	KAMPALA/UGANDA
3 M.G. KAWOOYA	MULAGO HOSPITAL	KAMPALA/UGANDA
4		
5		

AUTHOR WHO WILL PRESENT THE PAPER

(Mr)/Ms.

Initial(s): M. G.

Family Name: KAWOOYA

Mailing Address: DEPT OF RADIOLOGY
P. O. BOX 7051, KAMPALA
UGANDA

Telefax No.: 256-41-532591

E-Mail: radlog@swiftuganda.com Telex No.:

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DOSE ASSESSEMENT DUE TO INTAKE OF I-131 IN THE MEDICAL STAFF TAKING CARE OF PATIENTS TREATED WITH I-131

Authors: Grmek M., Fettich J., Dimic M.
Institution: University Medical Center Ljubljana
Dept. for Nuclear Medicine
Zaloska 7
1000 Ljubljana
Slovenia
tel: --386 1 543 1450
fax: --386 1 432 7272
e-mail: marko.grmek@guest.arnes.si

Abstract:

Measurable activities of I-131 can be detected in the air of rooms where patients treated with low activities (550 - 1100 MBq) of I-131 are held. The concentrations of I-131 in room's air are relatively low; the highest measured value was 130 Bq/m^3. Therefore it is not surprising that internal contamination with I-131 can be detected in the medical staff working at such departments. Immediately after finish of work the highest values of the I-131 in the body of medical staff were smaller than 1000 Bq.
Assessed annual effective dose of the medical staff working at the Department of Nuclear Medicine in Ljubljana (taking care of patients treated with I-131) due to intakes of I-131 is estimated to be less than 1 mSv.

Different thyroid diseases can be treated with I-131. In the University Medical Center, Dept. for Nuclear Medicine in Ljubljana patients suffered from benign thyroid diseases (predominantly different types of hyperthyreosis) are treated. Because of Slovenian legislation patients receiving more than 550 MBq of I-131 have to be hospitalized (1). Commonly used therapeutic activities of I-131 for benign thyroid diseases are between 550 and 1100 MBq. Patients receive therapeutic activity of I-131 in Wednesday and leave the hospital in Monday.
It is well known that I-131 can be measured in air in rooms where patients with therapeutic activities of I-131 are held.
Medical staff working in our department is in contact with patients treated with I-131 five days per week. In this way staff received external irradiation - the average annual effective dose because of this is between 2 and 3 mSv. To protect skin and internal contamination staff use protective clothes, gloves, shoes, head covering and face mask.

Aim:

The aims of the study were to:

- assess of the annual effective dose of medical stuff taking care of patients treated with I-131 due to occupational exposure to I-131,
- assess if additional protective measures for medical staff taking care of patients treated with I-131 at Department of Nuclear Medicine in Ljubljana are required.

Medical stuff:

8 persons, 7 of this are nurses, taking care for patients treated with I-131 in our department.

Six patients are hospitalized per week and received therapeutic activity (550 to 1100 MBq). They are isolated into two rooms. Medical staff which taking care for patients are approximately three hours per day and five days per week in contact with such patients.

Methods:

Direct and indirect measurements were used to assess the dose (2):

- Direct measurement - whole body counting:

  After finished the work staff excluding external contamination and changing clothes. 10 minute measurement on whole body counter using "lung geometry" was than performed. At majority of workers eight measurements were done. First measurement was performed before worker's contact with patients receiving therapeutic activity of I-131. Measurements of staff were repeated after first, second and third day of work. Next week the measurements were repeated in the same time schedule.

- Indirect measurement - determination of I-131 concentration in air:

  In rooms in which were patients with therapeutic activities of I-131 the air concentration of I-131/m^3 was measured pumping known volume of air through charcoal filter in known time. Charcoal filter was then measured on whole body counter using "empty bad geometry".

Direct and indirect measurements were done in winter when ventilation of rooms is lower.

Results:

- Direct measurement - whole body counting

  The average measured activity of I-131 into the body of medical staff was:

  - 402 ± 186 Bq after the first day of work
  - 516 ± 305 Bq after the second day of work
  - 410 ± 173 Bq after the third day of work
  - before contact with patients treated with I-131 (after two or three days pause) in majority of workers the internal contamination with I-131 was below 150 Bq. (150 Bq is minimal detectable activity on our whole body counter.)

- Indirect measurement - determination of I-131 concentration in air

The average activity of I-131 in m^3 of air:

- 77 ± 32 Bq after the first day of work
- 31 ± 20 Bq after the second day of work
- 15 ± 2 Bq after the third day of work

Dose assessment:

Realistic approach (3,4,5). We supposing:

- medical stuff taking care of patients treated with I-131 get each day the some activity as in first day,
- medical stuff is in contact with patients treated with I-131 220 days per year, 3 hours per day,
- AMAD of particles is 5μm.

- Direct measurement - whole body counting

Annual effective dose = 402 Bq/day x $1{,}1 \times 10^{-8}$ Sv/Bq x 220 days

= **0, 97 mSv**

- Indirect measurement - determination of I-131 concentration in air

Annual effective dose = 77 Bq/day x $1{,}1 \times 10^{-8}$ Sv/Bq x

660 hours/day x 1,5 m^3/hour

= **0,84 mSv**

Conclusion:

Assessed annual effective dose of the medical staff at the Department of nuclear medicine in Ljubljana due to intake of I-131 (using realistic) approach is estimated to be less than 1 mSv. Because this dose is small additional protective measures are not required.

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RADIOLOGICAL PROTECTION OF PATIENTS IN GENERAL DIAGNOSTIC RADIOLOGY

Author: Alice W. Karigi
Institution: Radiation Protection Board
Address: P.O. Box 19841, NAIROBI - KENYA
Fax No: 714383
E-mail: rpbkenya@nbnet.co.ke

ABSTRACT

With medical radiation exposures to mankind ranking the highest among man-made radiation, radiation protection safeguards have to be put in place in all countries. Competent authorities should have the legal legislation and adequate infrastructure to ensure implementation, enforcement and compliance with the radiation protection standards. Justification, optimization, quality assurance and control are to be the guiding ideals for those who prescribe and/or carry out radiographic procedures. Radiation dose limitation in medical practices is to be encouraged so far as it does not compromise image quality and the provision of a direct benefit to the exposed individual.

INTRODUCTION

Medical exposures contribute the highest man-made doses to the world population. When risk of medical irradiation is compared with the risk from other sources of man-made exposures or from natural background radiation, the doses received in medicine range over four orders of magnitude[1] .Through out the world, there is over use of diagnostic radiology, and in developing countries the economic aspect of unnecessary radiology is significant. Patients have come to believe that no examination by their doctor is complete unless they have been "x-rayed"[2] . The actual procedure is satisfying because it is usually dramatic, yet causes little discomfort or inconvenience. There is, therefore, great need for radiological protection of patients in diagnostic radiology.

1. JUSTIFICATION OF MEDICAL EXPOSURES

Medical exposures should be justified by weighing the diagnostic benefits they produce against the radiation detriment they might cause, taking into account the benefits and risks of available alternative techniques that do not involve medical exposure. [7]
The decision as to whether an examination involving a certain radiation dose to patient is justified is the responsibility of the physician requesting the examination or of the practitioner who carries out the procedure.

In all cases, the practitioner shall satisfy himself that the necessary information is not already available from other previous examinations and investigations or that equal information could not be obtained at a lesser risk from investigations using other techniques. [8]

There is therefore no need to request for a radiological examination without determining whether a similar examination had been performed. Any previous radiographs are part of the patients' record and are essential when interpreting the new examination. A proper storage and

retrieval system is essential for the efficient use of radiology and contributes to the limitation of unproductive examinations. [2]

In order to prevent unnecessary exposures, no practice involving exposure to ionizing radiation shall be authorized by the relevant competent authorities unless the introduction of the practice produces a positive net benefit. [3]

2. OPTIMIZATION OF PROTECTION FOR MEDICAL EXPOSURES:

The design, plan, and subsequent use and operation of sources and practices shall be performed in a manner to ensure that exposures are as low as reasonably achievable. [3]

2.1 The x-ray equipment should be so designed to ensure that: -

(a) failure of a single component of the system is promptly detected to avoid unplanned exposures to patient.

(b) there is minimal human error in the delivery of exposures.

(c) they conform to the International Electrotechnical Commission (IEC) standards and the ISO standards.

(d) operating terminology and values are displayed on operating consoles in a language understood by the user.

(e) radiation beam control mechanisms are provided.

(f) exposure rates outside examination area are as low as reasonably achievable.

(g) the devices automatically terminate irradiation after a preset time.[7]

2.2 The medical practitioners who prescribe or conduct radiological diagnostic examinations should ensure: -

(a) exposure to the patient be the minimum necessary to achieve the required diagnostic objective.

(b) whenever feasible, shielding of radiosensitive organs is provided.

(c) highest kV_p that permits good diagnostic image is used.

(d) faster intensifying screens are used.

(e) use of carbon fiber cassette fronts and table tops. Patients dose is reduced to as much as 50%.

(f) Use of tight collimation. This means a smaller irradiated area and less risk to the patient. Good collimation also improves image quality.

(g) Proper beam filtration. Addition of a proper amount of filtration to the x-ray tube offers reduced patient exposure.

(h) For pregnant patients, any procedure which exposes the foetus to the direct beam is delayed to the third trimester or if possible after completion of pregnancy.[8]

3. QUALITY CONTROL AND QUALITY ASSURRANCE OF RADIOGRAPHIC EQUIPMENT:

Quality Assurance (QA) is a program to produce high quality radiographs with minimum cost and minimum patient exposure. Quality Control (QC) is the routine measurement of the physical parameters of the various components of the x-ray imaging system. The major components are the x-ray generator, the x-ray tube and image receptor, the image processor and ancillary equipment.[6]

Regulatory Authorities should establish procedures for quality assurance to ensure maximum protection to patient. In Kenya for example, this is carried out by the 'The Radiation Protection Board', the competent authority that keeps a record of all radiation facilities in the country. The program determines when maintenance or repairs are required in order that a facility may continue to produce high quality radiographs with minimum patient exposure. Various test tools are used to evaluate parameters like Kvp accuracy, mAs reciprocity, focal spot size evaluation, x-ray beam alignment, Half Value layer (HVL).

3.1 The quality assurance programme ensures that:

(a) planned and systematic actions aimed at providing adequate confidence that the specified design and operational requirements related to protection and safety of patients are satisfied[7]

(b) production of optimum quality radiographs, increasing patient safety [9]

(c) accurate and reproducible performance of the x-ray generator and ancillary equipment ensuring a consistent technique chart thus reducing radiographic errors[9]

(d) unnecessary exposures due to improper film development [10] or a faulty x-ray machine are avoided.

(e) There is no variation of the machine output, ensuring that the patient is not needlessly overexposed[8]

Quality control tests should be performed periodically to ensure continued good performance, equipment initially installed in good condition and proper calibration can deteriorate over time, and very often this deterioration is so gradual that it is only detected when QC checks are made. [8]

4. QUALIFIED RADIOGRAPHIC STAFF

In some hospitals and other institutions, doctors or nurses who have no radiographic qualifications are obliged occasionally to make an x-ray examination. Responsibility for

ensuring that this does not happen lies with the competent authorities. In Kenya, for example, this is safeguarded by the establishment of the Radiation Protection Act, 1982. The Act in section (9) states that "No person shall cause ionizing radiation to be applied to any other person for the purpose of diagnosing or treating a disease unless the application is prescribed by a medical or dental practitioner registered under the Medical Practitioners and Dentist Act. No person shall administer ionizing radiation to another person unless he is in possession of a valid licence issued under the Act". [4]

If the x-ray operator is not well trained, he may make a mistake in setting the various controls on the x-ray unit or in positioning the patient, resulting to unnecessary repeat x-ray [10], and even to over exposure of patients.

A properly informed radiographer is able not only to help reduce the radiation risk to the patient, but also help soothe any unnecessary fears that might arise. [8]

The practitioner should have adequate training in the field of radiation protection accepted by the competent authority. [5]

5. DOSE LIMITATION IN MEDICAL EXPOSURES

Medical exposures are usually intended to provide a direct benefit to the exposed individual. If the practice is justified and the protection optimized, the dose in the patient will be as low as is compatible with the medical purposes. [11]

When the examination is directly associated with illness, the dose limitation system can be applied, except for the dose limits.

In each individual case of exposure, the individual who is to be exposed to the risk is also the individual who has the benefit of examination. The limit is therefore not required because the outcome of the justification and optimization procedures should always be in the best interest of the individual incurring the risk at any level of dose. [3]

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NUEVAS PERSPECTIVAS PARA LA PROTECCION RADIOLOGICA DE LOS PACIENTES SOMETIDOS A ESTUDIOS DE DIAGNOSTICOS CON RADIACIONES IONIZANTES EN LA REPUBLICA DEL PARAGUAY

SOSKY, RUBEN A. DR.; GAMARRA, MIRTHA ARQ.

Ministerio de Salud Publica y Bienestar Social–Departamento de Protección Radiológica
Avda. Silvio Pettirossi esq. Brasil.
e-mail: **ras@telesurf.com.py**
ASUNCIÓN - PARAGUAY.

ABSTRACT

The Government in Paraguay approved by Decree Law 10754, dated of October 6, 2000 its National Regulation on Basic Safety Standards for Radiation Protection and the Safety of Radiation Sources, based on the IAEA Safety Standards 115.
The primary goal on Patient Protection is to ensure the both, Regulatory Authorities and all Responsible parties in Medical Practices, need to observe procedural process in conducting their responsibilities on regulatory and administrative affairs. By one side the Government, "Departamento de Protección Radiologica", under the Health Ministry and Comisión Nacional de Energia Atómica and by the other side, the medical practitioner who prescribe or conduct diagnostic or therapeutic treatment, both to ensure that the exposure of patients be the minimum.
This document describes how the Regulatory Authorities intend to implement this recent act and by the other hand to take the advantage of this.
Conference to understand better this subject, especially on the following subjects, essential requirement for licensing, inspection and enforcement programmed in the Country's Capital and in the Interior, where difficulties are higher, also workers and medical training and lessons learned applied to developing countries.

INTRODUCCIÓN

Desde el año 1990, el Ministerio de Salud Publica y Bienestar Social, a publicado, por Resolución Ministerial las NORMAS BASICAS DE PROTECCIÓN RADIOLÓGICA EN EL AREA DE LA SALUD, las cuales a partir de esa fecha son de observancia obligatoria por parte de todos los Establecimientos de Salud que operan con fuentes ionizantes, en todo el territorio Nacional.
Dicha Resolución fue derogada por Decreto No: 10754, del Poder Ejecutivo, recientemente, de tal forma a tener un Reglamento Único sobre LA PROTECCIÓN CONTRA LAS RADIACIONES IONIZANTES Y PARA LA SEGURIDAD DE LAS

FUENTES DE RADIACIÓN. Debido a que en el país existían dos Autoridades, el Ministerio de Salud, por un lado, y la Comisión Nacional de Energía Atómica por el otro, con una superposición de coberturas entre ambas Instituciones, con la promulgación de este decreto se estableció la Autoridad Competente así como, un único Reglamento de Protección contra las Radiaciones Ionizantes, cuyo alcance es en todo el territorio Nacional y fue elaborado por un Comité de Estudio, integrado por varias Instituciones involucradas en el tema.
Esto constituye para el país un avance de gran importancia, porque se cuenta con un Marco Legal acorde a las NORMAS BASICAS DE SEGURIDAD, Colección No: 115, del OIEA.

SITUACION DE LA PROTECCION RADIOLOGICA EN EL PARAGUAY EN EL AREA DE RADIODIAGNÓSTICO MEDICO – ODONTOLÓGICO.

Población nacional 5.123.550.

Región Occidental 97.208 Habitantes
Area 246.925 Km^2

Región Oriental 5.026.342 Habitantes
Area 159.827 Km^2

1.2 AREA del país 406.752 Km

1.3 **N° estimado de TOE. Total País =550** (Tegnólogo=500 Radiólogo= 50)

1.4 **Registro de las Instalaciones de Radiología diagnostica:**

El Departamento de Protección Radiológica, en sus funciones de establecer los requisitos necesarios para las instalaciones que conllevan el empleo de radiaciones ionizantes ha tenido la prioridad de evaluar las condiciones que existen de Protección Radiológica en las diferentes instalaciones, previa realización de un Censo Nacional de

todos los equipos generadores de radiaciones ionizantes distribuidos en todo el territorio Nacional, teniendo así:

Instalaciones dependientes del Ministerio de Salud Publica y Bienestar Social (Hosp.. Regionales y Centros de Salud)	85.
Instalaciones de Docencia e Investig.	19.
Instalaciones Privadas	183.
Instalaciones del Seguro Social	69.
Instalaciones de las Fuerzas Armadas	32.
T O T A L E S	**388**

PROTECCIÓN DE LOS PACIENTES EN RADIODIAGNOSTICO

En lo que respecta a la forma como se realicen los examenes, esta generalizado el concepto que los Programas de Garantía de Calidad dirigidos al equipo y al funcionamiento del operador pueden contribuir en gran medida a que mejore el contenido de la información de diagnostico, a que se reduzcan la exposición a las radiaciones y a los costos médicos y que se mejore la administración del servicio.
Como respuesta a esta necesidad, muy en especial en lo referente a la protección del paciente el Departamento de Radio protección, puso en practica un programa de evaluación del desempeño de los equipos, exigiendo a cada Instalación tener un programa de Garantía de Calidad en la esfera de la radiología diagnostica.
Paraguay cuenta en la actualidad con mas de 400 equipos de Rx diseminados por todo su territorio, un numero reducido de especialistas dedicados al radiodiagnóstico y un gran numero de tecnólogos en dicha área, sin embargo en lo que se refiere a la implementación de programas de garantía de calidad, la situación no es la mejor, debido a varios factores que juegan un papel fundamental para la practica de dichos programas:

Servicios sin equipos de medición, debido al alto costo de los mismos.
Falta de profesionales con capacidad para llevar a cabo estas tareas.
Falta de concientización en la cultura de calidad y seguridad radiológica.

IMPLEMENTACIÓN DEL PROGRAMA DE GARANTIA DE CALIDAD

Debido a la importancia de la protección radiológica para el paciente, que tienen los programas de Garantía de Calidad en la practica de radiodiagnóstico, el Departamento de Protección Radiológica, lleva adelante la ejecución de programas de Control de Calidad, en las diferentes instalaciones controladas, puesto que las estadísticas señalan que el mal funcionamiento del equipo contribuye en medida considerable a la elevada

prevalencia de mala CALIDAD de la imagen, especialmente aquellas tomadas con equipos portátiles, los cuales existen en mayor porcentaje en nuestro país.
El Programa de Garantía de Calidad que aprobamos para su implementación en los diferentes servicios tiene como objetivo vigilar cada una de las fases del funcionamiento de la instalación del equipo de diagnostico por imagen, comenzando por la solicitud de una exploración y terminando por la interpretación del examen y la comunicación de esa interpretación al medico que envía al paciente.
La responsabilidad fundamental del programa de Garantía de Calidad de todo Servicio de Diagnostico por Imágenes recae sobre el medico licenciado para explotar el servicio
Las autoridades reguladoras cuentan con un programa de inspección para todo el año 2001, que comprenderá a la gran mayoría de los servicios detallados más arriba.
Otra acción es la edición de cuadernos con las recomendaciones básicas para el cuidado de paciente sometido a medicina nuclear, radiodiagnóstico y/o radioterapia que será distribuida en los servicios de diagnostico y tratamiento tanto en el área estatal como en servicios de practica privadas.
Se emitieron precisas instrucciones a los poseedores de licencia para trabajar con radiaciones ionizantes, que deberán tener señalizado con símbolos internacionales los lugares de sus servicios donde se encuentran los equipos o fuentes para que los pacientes que se encuentran en sala de espera se encuentren conciente de que deberían tener el cuidado de no exponerse innecesariamente a los efectos de las radiaciones.

CONCLUSIÓN

1. Se esta implementando el Programa de Control de Calidad en equipos de Rayos X, sobre la base de las recomendaciones Internacionales en este campo. En términos generales podemos afirmar, según las recomendaciones de AGENCIAS INTERNACIONALES que se establecen dos tipos de estudios:

   INSPECCIONES BASICAS: estas se refieren a las que se realizan para la puesta en operación del servicio. Son las mas profundas de las inspecciones y sirven como parámetros de control de las sucesivas, constatando con esto que las características ofertadas por el fabricante se cumplen en la realidad, y cuando las INSPECCIONES SISTEMATICAS señalen alguna desviación en el funcionamiento.

   INSPECCIONES SISTEMATICAS: se realizan comprobaciones sencillas y rápidas dando seguridad de que todo el Servicio sigue funcionando bien.

2. Sé esta diseñando un programa que apunta a diagnosticar la CALIDAD de los **RECURSOS HUMANOS** que se desempeñan en las diferentes instituciones asistenciales, en sus diferentes modalidades de gestión, abarcando al profesional técnico y administrativo, conllevando con esto a la adecuación de dichos recursos con los perfiles organizativos de la institución asistencial y niveles de formación, capacitación, perfeccionamiento y actualización para el desempeño de la tarea, con

referencia a patrones establecidos por Asociaciones académico - científica de cada especialidad.

CAN PATIENT POSITIONING USING AN ULTRASHORT FLUOROSCOPIC PULSE BE JUSTIFIED?

Tom Deprez, Lode Schrijvers, Herman Pauwels, Hilde Bosmans, Guy Marchal

Department of Radiology, UZ Gasthuisberg, KU Leuven, Herestraat 49, B-3000 Leuven, Belgium; Fax: +32 16 34 37 65; Tom.Deprez@uz.kuleuven.ac.be

1. Introduction

The use of fluorography to position the patients for conventional X ray examinations is forbidden in many European countries. In other countries, however, this is common practice. Whether this procedure necessarily leads to higher averaged patient dose depends on the retake rate of radiographs due to wrong positioning when fluorography is not applied. With a retake rate because of wrong positioning of n%, the use of fluorography is acceptable if the associated extra dose for the patient is less than n% of the dose for the radiographs. A few dose measurements have shown that in most cases the use of fluorography cannot be justified. Recently, we have modified a digital X-ray system such that pressing the fluorography button results in a fixed fluorography time of 0.5s only. We have studied the doses necessary for positioning with this fluorography mode and we investigated whether this practice could be justified.

2. Material and methods

The study was performed in an X-ray room in which radiographs of thorax and skeleton are acquired.

The equipment consisted of a Seregraph CF fluorospot (Siemens, Erlangen) and storage phosphor plates of Agfa (Mortsel, Belgium). The newly developed so-called pré shot technique restricted the fluoroscopy time to a maximum of 0.5s per shot. As the digital system was foreseen of an image hold option, the fluoroscopic image remained visible and allowed for further improvement of the positioning. Occasionally, this position adjustment could be verified with an extra fluoroscopy shot.

The doses caused by this new procedure for patient positioning evaluations were measured. Two parts of a RANDO phantom were used for this purpose: the skull to simulate an exposure with a lot of bony structures and the abdomen mainly consisting of soft tissue. An experienced radiographer was asked to position the phantoms 5 successive times using the pré shot fluoroscopy mode with the same characteristic curve and mA as had been used before. Doses were measured with a PMX-III solid state dosimeter (Mölndal; Sweden). This device measures the entrance dose without taking into account the back scatter fraction.

During a period of 8 weeks, the following data were recorded for all examinations: the type of examination, the incidence, the number of necessary pre-shots and the number of radiographs per imaging session. For each examination, the radiographers indicated also how the positioning was performed: (1) without fluorography, (2) using 1 scopy pulse without any further need for correction, (3) using 1 scopy pulse and correction of positioning, however without any further fluorographic control, and (4) using more than 1 scopy pulse. In total, 2363 examinations were performed. Only examinations with a high occurrence rate were further evaluated in the study.

3. Results

The comparative dose studies for fluoroscopy versus radiography in the phantom studies are summarized in Table 1. For the examination of the skull, the averaged entrance dose for fluoroscopy was 27.4 μGy (st dev 4.5 μGy). The entrance dose for the radiography of the skull phantom was 3998 μGy (stdev 0.7 μGy). The dose associated with the pre-shot fluoroscopy technique was therefore 0.69% of the dose for the corresponding radiograph. For the abdomen, the dose from fluoroscopy was 17.6 μGy (st dev 3.6 μGy) and the radiography gave a dose of 704.5 μGy (stdev 2.5 μGy). The dose ratio in this case was higher: 2.49%.
The number of pre-shots for the whole series of examinations is summarized in Table 2. In up to 40% of the cases more than 1 shot has been used. In Fig. 1 we show the average number of pre-shot fluoroscopy pulses for the 20 most frequently performed small musculoskeletal examinations in the X-ray room. Fig. 2 represents the frequency of necessary adjustments to the patient positioning after a first fluoroscopic pre-shot pulse. In our radiological practice, an average of 1.4 pre-shots is necessary. The number of shots for the skull examination is up to 1.9. The abdominal examinations require only 1.2.

4. Discussion

From the dose investigations, it is clear that the dose associated with a single pre-shot exposure is very low as compared to the dose from radiography. For the skull, we note a dose ratio between fluoroscopy and radiography of 0.69% and for the abdomen 2.49%. Taking into account the number of fluoroscopic pulses for these examinations, the relative amount of patient entrance dose increases up to respectively 1.31 % and 3.0 %. This dose ratio has to be compared with the retake rate due to false positioning.
This parameter is, however, not always known. From a literature search we retrieved a few retake rates for centers using blind positioning. Arvanitis [1] reported an overall retake rate of 3.2%. Lewentat [2] reports up to 7.6%. After improving the working procedure, it went down to 5.0%. These values represent an upper limit of the real retake rates due to wrong positioning. Hence, when using conventional cassettes, a major source of retakes is caused by over or under exposure. Hill [3] summarizes his literature review with the indication of a 10% retake rate, of which 19% is due to wrong positioning. Highest retakes are observed for skull (18.9%) and abdomen (19.2%) and lowest for IVU (5.3%) and chest (6.3%). Retake rates due to wrong positioning for skull and abdomen are thus about 3.6 %. It is obvious that for these type of examinations, patient doses would be reduced if the pre-shot fluoroscopic technique would be used for positioning instead of blind positioning. This situation may be different for other types of examinations.
In centers in which positioning is usually performed by means of fluoroscopy, the dose reduction is guaranteed. For departments that use fluoroscopically guided positioning, the results of this study may be important. Indeed, the use of fluoroscopy as it is today is usually not justified. This new option justifies the use of fluoroscopically guided positioning, as long as the number of pre-shots is limited. There are multiple other advantages of the technique when used in combination with storage phosphor plates. First, the patient can leave the radiology department immediately after the X-ray is taken. Hence, both problems due to positioning or wrong exposure are eliminated. This leads to a significant increase in through put. Second, there is no need anymore for a clear room. Third, the total patient dose can be lower, especially for departments with high retake rates.
A surprising result from this study is that in more than 40% of the cases repositioning of the patient was performed after the fluoroscopy pulse. This may be due to several reasons: (1) only a few radiographers are expert in blind positioning; (2) requirements on image quality are

very high; (3) radiographers want to reach perfection. In the frame of the European directive 97/43 and the ALARA principle, it may be necessary to reduce the image quality requirements in a controlled manner. Finally, the teaching about how to position the patient in a blind way remains important since doses can then be reduced even when the pre shot technique is available.

5. Conclusion

This study shows that the use of ultrashort fluoroscopic pulses for patient positioning may be justified for a large number of X-ray departments.

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Table I: Comparative dose evaluation of pre-shot fluoroscopy versus radiography.

Phantom:	**SKULL**			**ABDOMEN**		
	Scopy [S]	***Graphy [G]***	**ratio**	***Scopy [S]***	***Graphy [G]***	**ratio**
Settings:	dose [uGy]	dose [uGy]		dose [uGy]	dose [uGy]	
	87 kV 2,2 mA	*73 kV 70,1 mAs*		*87 kV 2,2 mA*	*73 kV 12,7 mAs*	
Measurement:		*AEC 0*	S/G		*progr. AE*	S/G
1	31,33	3999	0,78%	15,54	703,2	2,21%
2	31,93	3998	0,80%	20,91	704,2	2,97%
3	29,20	3998	0,73%	21,61	705,1	3,06%
4	21,74	3998	0,54%	16,64	701,6	2,37%
5	24,14	3997	0,60%	13,10	708,3	1,85%
Average:			0,69%			2,49%

Table II: Overview of the use of fluoroscopy for conventional X-ray examinations: skeletal and abdominal radiography.

Overview of fluoroscopy	n	
No scopy used	213	8,45%
One scopy without correction	482	19,12%
One scopy with correction	657	26,06%

More than one scopy	1011	40,10%
Total examinations	2363	

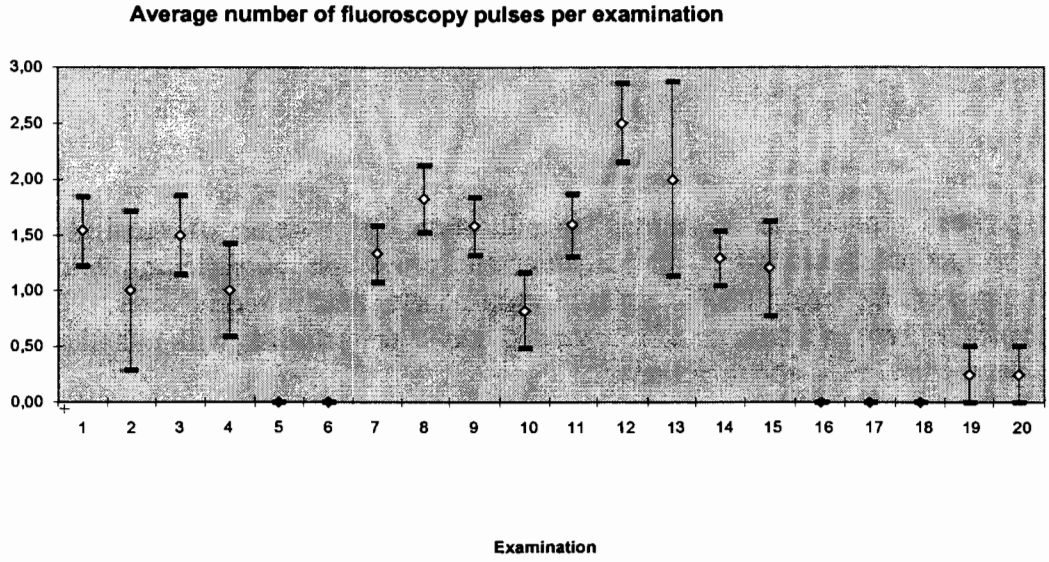

FIG. 1. Average number of fluoroscopy pulses for musculoskeletal examinations. (1: upper arm, 2: ankle P, 3: femur ¾, 4: femur F/P, 5: hand ¾, 6: hand F, 7: knee ¾, 8: knee ax, 9: knee condyl, 10: knee F, 11: knee P, 12: nose F, 13: nose P, 14: lower leg F, 15: lower leg P, 16: wrist ¾, 17: wrist F, 18: wrist P, 19: foot ¾, 20: wrist P)

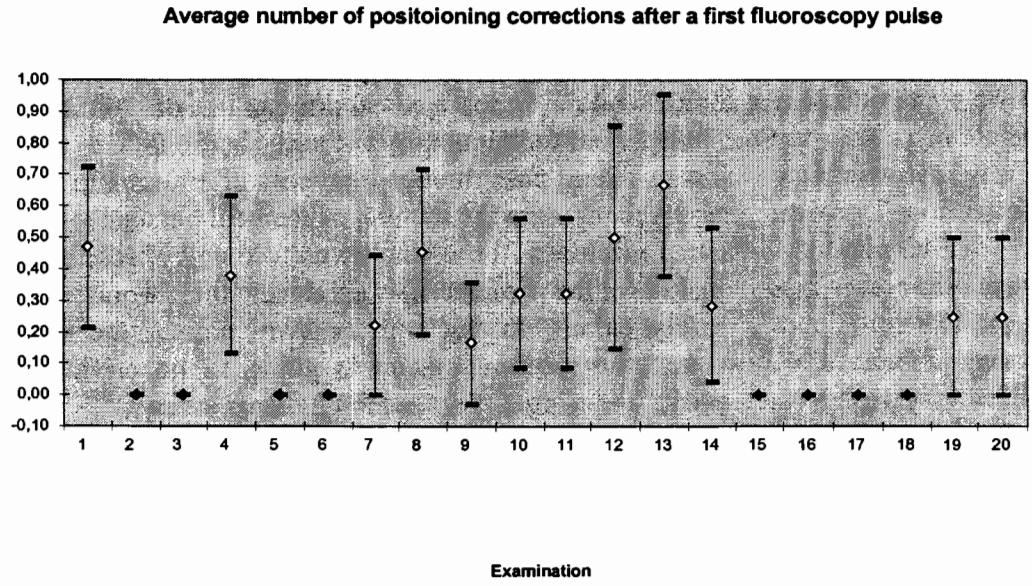

FIG. 2. Average number of corrections to the position of the patient. Same examinations as in Fig. 1.

THE NEW SYSTEM OF EDUCATION AND TRAINING OF MEDICAL STAFF IN RADIATION PROTECTION IN ALBANIA

B. Grillo - Radiation Protection Office
K. Preza, V. Titka, G. Shehi - University Hospital Centre - Tirana

ABSTRACT

The present situation as regarding the education and training of medical staff in radiological protection is discussed. In particular the protection of patients, children and pregnant women were the most sensible topics in some courses held in recent years.

Emphasis is given in a number of courses and course units dealing with radiation safety problems in the medical field and their content.

1. INTRODUCTION

It is the third consecutive year that Albania has begun to implement a national strategy for training of personnel involved in the work with sources of ionising radiation in the medicine.

As a matter of fact some 95% of all the applications with radiation sources in the country fall into the medical field, mostly in the diagnostic radiology. We are in backward in other directions with 1 department of radiotherapy and 1 department of Nuclear Medicine both located in the University Hospital Centre "Mother Theresa" in Tirana. But there is a tendency nowadays to open private clinics and in the last year 3 CT scanners, 2 private diagnostic clinics and some 10 clinics in dentistry have been licensed to begin the operation.

There are some 600 professionals working in the medical domain out of 700 radiation workers in the country. This number has pushed the regulatory authority in the field to seek and find a proper way that this big contingent should pass through a process of training in the field of radiation protection. Two other reasons to regulate the training of medical personnel are

- The majority of x -ray machines in the country are old and obsolete and are cause of increase in personal doses the professionals get during their work.
- There is not a safety culture in the country even among the radiation workers. Especially now that the medical system is going to be privatised the radiologists rush to their profit and forget their and the patients safety.

In the frame of the Model Project of IAEA our regulatory authority began to implement a national system of training of all the radiation workers in the medicine. The first national course was held in October 1998 with the financial support received from IAEA. 30 radiologists have participated chosen from some medical institutions in the country where radiation sources are used. The lecturers were local people who had taken part in more than three IAEA courses and seminars on the topics they would present.

The great success of this course and many claims from medical personnel especially in the districts that they were not informed to apply for it, made the authorities to think about setting up a scheme through which all radiation workers in medicine must be trained in some level.

2. RADIATION PROTECTION COURSES HELD BY RPC

Under the Model Project we have developed the legislation i.e. the Radiological Protection Act of 1995, some regulations and are embarked in preparing the code of practices in the medical uses of radiation. In the regulation "On safe use of ionising radiation" it is stated that :

"All radiation workers should undergo a process of training and retraining. The management of the facility is responsible for training of their employees. It is the duty of the inspectors of RPC (regulatory authority) to ask for certificates of training...". [2]

These regulations require that health physicists acting as radiation protection officers (RPO) should take certified including examinations. A comprehensive knowledge of radiation protection rules and regulations is a prerequisite of appointment as RPO but also for physicians who apply radiological procedures for diagnostic and/or therapeutic purposes.

Continuing in this direction we asked the IAEA and the second training course was planed for October 1999 but organised in February 2000 with the participation of 60 radiologists where two experts sent by IAEA were present. It was well received by radiation workers community and the bulletin of Albanian Radiological Society published many lectures.

Another training course this time in radiotherapy and nuclear medicine was held in October 2000. This time 30 participants from two departments of University Hospital Centre "Mother Theresa" attended. Two foreign lecturers from UK and Sweden together with local lecturers made this course the best organised in last few years. We have got now much experience from this.

3. RADIOLOGICAL PROTECTION OF THE PATIENTS

We have set up a general program of training of medical staff with the main topic being:

Lectures given	By
. Legislation and regulations	Radiation Protection Office
. Code of practice in the particular activity	Expert in the U H Centre
. Potential exposures	Expert from scientific society, UHC
. Exposure of personnel	RPO of Institute Nuclear Physics
. Exposure of patients	Expert from UHC- Tirana
. QA and QC	Foreign expert from IAEA

The exposure of the patients is always a subject lengthy treated during the training courses. This is because there has been much interest in reducing the doses received by patients especially during routine diagnostic x-ray investigations.

In the lectures for legislation and regulations always is stated the principles that form the basis of radiation protection system. In the following we want to give some items always the medical staff should bear in mind :

. The exposure of patients should always be subject to the normal principles of justification and optimisation.

. No patient be administered a diagnostic or therapeutic medical exposure unless the exposure is prescribed by a medical practitioner.[2]

. For therapeutic uses of radiation (including teletherapy and brachytherapy), the calibration, dosimetry and quality assurance requirements of the Standards be conducted by or under the supervision of a qualified expert in radiotherapy physics.

. To optimise the protection for medical exposures the practitioner should ensure the appropriate equipment.

. The diagnostic and possibly the therapeutic benefit must exceed the risk of applying ionising radiation.

. Radiological examination causing exposure of the abdomen or pelvis of women who are pregnant or likely to be pregnant be avoided unless there are strong clinical reasons for such examination.

. Every effort should be made to keep doses to a reasonable minimum because of the higher expected risk of radiation induced effects in children than in adults.

4. TRAINING AT ORGANISATIONAL LEVEL

Numerous opportunities intended to improve radiation use and protection standards are offered every year by various scientific or medical institutions at different levels and times aimed at employees.

For more than 10 year the UHC hold a national 9 months course for technicians working in diagnostic radiology. This certificate has been a necessary document to find a job in medical care system.

Last year University Hospital Centre and Institute of Nuclear Physics has applied to the regulatory authority to get accreditation as organisations which hold one week courses in Radiotherapy and Nuclear Medicine the first and in industrial radiography the second.

Besides these activities different scientific societies often organise specific training on radiation matters. Very active in this regard is Albanian Society of Radiologists (some 200 members). Some time ago it has formed its physics section dealing with doses that patients receive during different examinations.

5. CONCLUSIONS

We will continue with organising such training courses in the next two year under IAEA regional project. A scheme is presented in Radiation Protection Commission asking that beginning in 2005 all radiation workers should go through a system of training and retraining every two years and the sum of points they get will influence to the salary.

Education programmes on radiation protection are not yet available in schools and universities. Some efforts are made recently to include lectures of it into the contents of such disciplines as radiological physics, radiation chemistry and radiation biology.

A peer review mission which came in Albania in October 2000 to evaluate achievements under IAEA Model Project has acknowledged progress made in the direction of education and training [3].

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DOSIMETRÍA A PACIENTES EN FLUOROSCOPÍA EN BUSCA DE NIVELES DE REFERENCIA PARA BRASIL

L. Canevaro[1]; G. Drexler[2]

[1] Instituto de Biologia. Departamento de Biofísica e Biometria. Pós-graduação em Biociências Nucleares. Universidade do Estado do Rio de Janeiro, Brasil. E-mail: luciacanevaro@zipmail.com . Rua Rogério Karp 101/205. CEP 202795-210. Recreio dos Bandeirantes. Rio de Janeiro, Brasil.

[2] GSF Forschungszentrum. Institut für Strahlenschutz. D85764 Neuherberg. Germany y Laboratório de Ciências Radiológicas, Universidade do Estado do Rio de Janeiro. E-mail: drexler@lcr.uerj.br

Abstract

This work was performed to investigate the actual exposure levels of the patients submitted to fluoroscopic procedures in diagnostic radiology. The data will be useful for a baseline in the establishment of local reference levels for fluoroscopic procedures, as recommended by the European Commission and IAEA. At present time there are not internationally accepted definitions for references levels for fluoroscopic complex procedures. Dose-area product (DAP) meters were employed in a pilot survey expressing the radiation exposures in terms of this quantity. This class of instrumentation has not been employed in Brazil yet. Parameters recorded were radiographic technique, fluoroscopy time, number of images, fluoroscopic and radiographic field sizes and DAPs. For fluoroscopy practice, a reference parameters set is recommended, instead of one diagnostic reference level. High patient exposures were found, calling for joined actions of health authorities, physicians, medical physicists, technicians and manufacturers. Monitoring of patient exposure, optimizing the radiation protection and establishing quantitative assessments of the exposition to the population in Brazil in this kind of procedure is important.

1. Introducción

Las Normas Básicas Internacionales para Protección Contra las Radiaciones Ionizantes (BSS) [1], recomiendan el uso de niveles orientativos para fluoroscopía en téminos de tasas de dosis de entrada en la superficie de la piel. En 1999 la Comisión Europea publicó un documento con orientaciones relacionadas a los niveles de referencia de diagnóstico [2], teniendo en cuenta que la directiva 97/43/Euratom [3] exige que los Estados-Miembros promuevan la fijación y uso de niveles de referencia. Este documento presenta valores de referencia propuestos para fluoroscopía, expresados en la magnitud producto dosis-área (DAP), y reconoce que aun no se han resuelto todas las cuestiones en relación a esta práctica.

En Brasil, el Reglamento Técnico del Ministerio de Salud, Portaria 453/98 [4], establece niveles de referencia para algunos procedimientos radiográficos. Para fluoroscopía exige el registro de la tasa de dosis al paciente y del tiempo de examen o del producto dosis-área, y una tasa de kerma menor que 50 mGy/min en la entrada de la piel. Esta reglamentación fue establecida siguiendo las orientaciones de las BSS [1]. Sin embargo, en procedimientos fluoroscópicos los estudios dosimétricos a pacientes son relativamente recientes, existen pocos datos disponibles [5][6][7][8], los medidores del producto dosis-área han sido usados apenas en forma experimental [9] y aún no está definida la metodología que debe aplicarse para determinar niveles de referencia de diagnóstico locales. El presente trabajo forma parte de un proyecto de optimización de la protección radiológica en fluoroscopía, apoyado por la IAEA [10] aplicado en instituciones médicas de Rio de Janeiro, siendo uno de los objetivos la evaluación de las dosis recibidas por pacientes, a fin de conocer los niveles de exposición y servir de punto de partida para el establecimiento de niveles de referencia. Se presentan aqui algunos resultados preliminares de esta investigación en un departamento de radiodiagnóstico.

2. Materiales y métodos

Los exámenes fluoroscópicos evaluados fueron realizados en un equipo de rayos X telecomandado marca GE, con generador de alta frecuencia MPG 50 e intensificador de imagen de 23 cm de diámetro, debajo de la mesa de exámenes. La técnica fluoroscópica es determinada por el control automático de brillo. En el panel de comando, se puede seleccionar la tensión del tubo, el producto mAs y el tiempo de exposición para grafía, presentando también opciones para dividir automaticamente la película. El foco grueso (2mm) es utilizado para grafía y el foco fino (1,2mm)

para escopía. Dispone también de un indicador de tiempo de escopia con alarma sonora a los 5 minutos.

Se utilizaron medidores Diamentor M4 y E (PTW, Freiburg, Alemania) para medir el producto dosis-área (DAP). La calibración de los instrumentos fue realizada *in situ*. El fabricante garantiza una incertidumbre de ±1% en la medida del DAP [11]. Se aplicó un único factor de calibración: el promedio de los obtenidos para los diferentes kVp utilizados, porque esto no introdujo errores significativos.

La dosimetría a pacientes fue realizada en 60 procedimientos: 9 enemas de bario con duplo medio de contraste (clisteropaco), 39 esofagografías, 5 seriografías gastroduodenales, 4 uretrocistografías y 3 urografías intravenosas, siguiendo los protocolos médicos de la institución. Los exámenes fueron conducidos por médicos del primer año de la residencia en radiología.

Los datos registrados en cada examen fueron: técnica fluoroscópica (kVp, mA), tiempo de exposición, técnica radiográfica (kVp, mAs), número total de imágenes, tamaño de campo fluoroscópico y radiográfico, distancia foco-piel, distancia foco-receptor de imagen, DAP de la parte fluoroscópica del examen, DAP de la parte radiográfica del examen, DAP por imagen y DAP total. Se calculó la tasa de dosis de entrada en la superficie de la piel en fluoroscopía de la siguiente manera:

$$Tasa = \frac{DAP_{escopia}}{tiempo_{total}} \cdot \frac{\mathrm{BSF}}{Área_{fluoro}} \cdot 10$$

Donde $DAP_{escopia}$ es el DAP medido correspondiente a la parte fluoroscópica del examen, en $cGycm^2$. El $Área_{fluoro}$ fue calculada en la superficie de entrada del paciente, a partir de las distancias foco-receptor de imagen y foco-piel y del área del intensificador de imagen. BSF es el factor de retro-dispersión, adoptado como 1,35, y el factor 10 es un factor de conversión de cGy para mGy.

3. Resultados y discusión

En la tabla I se presentan los resultados obtenidos en los exámenes evaluados. Los valores de DAP totales son muy elevados si se comparan con los propuestos en la literatura [12][13][14][15] como niveles de referencia para fluoroscopía (entre parentesis y en negrito en la tabla I).

Las grandes desviaciones estandar obtenidas en el número de imágenes y en el tiempo total de examen sugieren la necesidad de una revisión de los protocolos médicos de los exámenes por parte de los médicos radiólogos, a fin de establecer procedimientos estandarizados para cada tipo de examen.

Las tasas de dosis variaron entre 46 y 77 mGy/min (tercer cuartil), con valores promedios entre (42 ± 20) y (65 ± 21) mGy/min, superiores a los recomendados por la Portaria 453/98 [4] (50 mGy/min) y por las BSS [1] (25 mGy/min, bajo nivel), lo que sugiere que debería realizarse una revisión del equipo.

La parte fluoroscópica del examen osciló entre 40 y 76% del DAP total, dependiendo del tipo de procedimiento: para esofagografías fue de (58 ± 15)%, para enemas de bario de (66 ± 13)%, para seriografías de (76 ± 16)%, para uretrocistografías de (61 ± 10)% y para urografías intravenosas de (40 ± 7)%.

En la tabla II se muestra un resumen de los parámetros ("valores típicos") considerados importantes para caracterizar cada tipo de examen. En todos los casos, el criterio usado para establecer los valores típicos fue el de adoptar el tercer cuartil de la distribución del parámetro correspondiente, considerando que estos datos fueron adquiridos por primera vez.

En el presente trabajo se propone la caracterización de los exámenes complejos mediante un conjunto de "parámetros de referencia". Debido a los diversos factores que intervienen en los procedimientos fluoroscópicos, un único parámetro de referencia no posibilita la identificación de los posibles motivos de exposiciones elevadas o alejadas de los valores típicos, si es que esto sucede. En un primer nivel de información, consideramos fundamental cuantificar tres "parámetros de referencia": DAP total, tiempo de irradiación del paciente y número de imágenes. Un analisis mas profundo debería considerar las contribuciones fluoroscópica y radiográfica al DAP total, aspectos mas relacionados con el protocolo médico. Esto permite una revisión del procedimiento de realización

del examen. Un conjunto completo de "parámetros de referencia" debería incluir también la tasa de dosis de entrada en la superficie de la piel y el tamaño de campo (área irradiada).

Tabla I Resultados de las medidas realizadas. n: número de exámenes evaluados. Los valores de los niveles de referencia disponibles internacionalmente [12][13[14][15] están indicados entre paréntesis y en negrito en la tercera columna.

	Tiempo [min]	No. Imágenes	DAPtotal [Gycm^2]	Tasa Dosis escopia[mGy/min]
ESOFAGOGRAFIA (n = 39)			**(10)**	
Rango	0,7-6,4	2-27	4-33	
Media ± Desv. Estandar	2,7 ± 1,5	11,2 ± 5,5	13 ± 7	46 ± 15
3er Cuartil	3,6	14,0	17	56
ENEMA DE BARIO (n = 9)			**(37-62)**	
Rango	3,8-23	7-24	37-324	
Media ± Desv. Estandar	10,1 ± 6,6	13,8 ± 5,8	118 ± 81	65 ± 21
3er Cuartil	12,1	19,0	108	77
SERIOGRAFIA (n = 5)			**(25-53)**	
Rango	5,8-17,9	15-24	26-140	
Media ± Desv. Estandar	12,4 ± 4,4	20,0 ± 3,3	84 ± 41	42 ± 20
3er Cuartil	13,6	21,0	93	46
URETROCISTOGRAFIA (n = 4)			-	
Rango	2,8-5,8	9-10	38-46	
Media ± Desv. Estandar	4,3 ± 1,5	9,3 ± 0,6	43 ± 4	51 ± 10
3er Cuartil	4,5	10,0	44	48
UROGRAFIA INTRAVENOSA (n = 3)			**(20-40)**	
Rango	1,5-3,5	6-11	23-59	
Media ± Desv. Estandar	2,4 ± 1,0	8,7 ± 2,5	42 ± 18	56 ± 14
3er Cuartil	2,9	10,0	52	64

Tabla II "Valores típicos" obtenidos para los diferentes exámenes evaluados.

Examen	Tiempo total [min]	No. de imágenes	DAP total [Gycm^2]	Tasa de dosis [mGy/min]
Enema de bário	12	20	108	77
Seriografia	14	21	93	46
Esofagografia	4	14	17	56
Uretrocistografia	5	10	44	48
Urografia intravenosa	3	10	52	64

4. Conclusiones

Este trabajo proporciona los primeros valores locales de DAP para los tipos de exámenes fluoroscópicos evaluados, con la intención de servir de punto de partida para, que una vez evaluados otros equipos y prácticas, se pueda llegar a proponer valores provisionales de referencia en fluoroscopía en Brasil. Los elevados valores de DAP medidos en todos los casos, sugieren la necesidad de implementar una metodología padronizada para definir niveles de referência regionales en fluoroscopía y su posterior optimización, mediante el analisis de las causas que originan estos resultados. Es imprescindible la monitoración de las exposiciones a pacientes durante los procedimientos, mediante la instalación de medidores del producto dosis-área en los equipos fluoroscópicos y del registro dosimétrico del paciente, aspectos ya obligatorios en otros países [16].

Los niveles de referencia para fluoroscopía deberían establecerse midiendo un conjunto de parámetros, en vez de un único indicador. Tiempo de exposición, número de imágenes y DAP total

constituyen la base de este conjunto. Un conjunto mas completo incluye el DAP de la parte radiográfica y el DAP de la parte fluoroscópica del examen, separadamente.

En función de los resultados, medidas inmediatas deben ser tomadas. Acciones conjuntas entre autoridades sanitarias, médicos, físicos médicos, técnicos y fabricantes deben ser establecidas. Una revisión cuidadosa de los protocolos médicos de los exámenes podría permitir, en ciertas situaciones, la diminución de las dosis. Por lo tanto, los radiólogos deben ser concientizados sobre la importancia de esta cuestión e involucrados en la problemática de la determinación de niveles de exposición de pacientes.

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PATIENT DOSIMETRY IN HISTEROSALPINGOGRAPHY

Khoury, H.J; Maia, A; Oliveira, M; Drexler, G.* and Kramer,R.

Departamento de Energia Nuclear-UFPE
Av. Prof. Luiz Freire-1000- Recife-Brazil
khoury@elogica.com.br

*Laboratório de Ciências Radiológicas-UERJ -Rio de Janeiro
and GSF- Forschungszentrum- Munich, Germany

Abstract: The objectives of this study were to determine the entrance surface dose to the patient and to estimate the dose to the uterus and ovaries due to hysterosalpingography (HSG) diagnostic examinations performed in Recife-Pe, Brazil. The entrance doses were measured using four thermoluminescent dosimeters per patient, attached to anatomical landmarks on the patient's skin. The study was carried out on 25 patients between 21 and 45 years of age who underwent the HSG examinations in two training hospitals and one private radiodiagnostic institute. The number of exposures performed ranged from 4 to 15 radiographs per patient measured. Entrance surface doses varied between 4.99 and 36.6 mGy, with an average of 12.6mGy. The doses to the ovaries and uterus ranged from 0.80 mGy to 5.8 mGy and 1.10mGy to 8.05 mGy, respectively.

1. Introduction

Hysterosalpingography (HSG) is a common radiological procedure which is performed on young women to investigate the causes of infertility and sterility or to check the patency of the tubes following reversal of sterilization. Many patients undergoing HSG are between 20 to 40 years old and desire pregnancy. The average patient age according to Tyrell et.al is 31 years [1]. During this diagnostic examination many different radiographic projections and fluoroscopies are made resulting in a high patient dose. The uterus and the ovaries are the main irradiated organs [2,3]. For this reason, this examination requires rigorous optimization of the procedures in order to have the image quality required for the diagnosis with the lowest patient dose possible.

There are only few publications on patient dosimetry in HSG in Brazil, one of which is the study made by Canevaro in Rio de Janeiro [4].

The current study was undertaken to evaluate the dose received by the patients during the HSG examination performed in Recife, the Capital of the State of Pernambuco, located in the Brazilian northeastern region. Its aim was to obtain dose values for the same procedure performed in different hospitals in order to help to estabilish reference dose levels for radiodiagnostic procedures in Pernambuco.

2. Material and Methods

This study was performed in two hospitals (A and B) and one radiodiagnostic private institute (C). Both hospitals are educational institutions were radiologist residents performed specialized training. At A and C HSG was performed by series of exposures and the tube potential (kV) and mA were set manually by the radiographer. The X-ray equipment used are, respectively, Siemens Polimat B and EMIC. Hard copy images were obtained on 24 x30 cm film using standard film screen radiography. In hospital B a fluoroscopic technique was used to position the patient adequately for radiography. The equipment is the Phillips Super 80CP. On this unit both kV and mA are controlled automatically following operating algorithms programmed into the x-ray generator.

The measurements were made with in a total of 25 patients with ages ranging from 27 to 42 years and abdomen thickness ranging from 16 to 20 cm. The examinations were performed with 100 to 110cm focus-film distance and the field size, determined by the radiographer, varied between 19 cm x 15cm and 30cm x 24cm on the patient's surface. Table I shows some of the exposure parameters.

Table I - Values of The Main Technical Parameters for the institutions A,B and C

Parameter	Mean Value			Min- Max		
	A	B	C	A	B	C
Tube potential (kV)	70.8	73.0	69.9	66-77	71-75	64-77
N. of films	5.9	6.8	4.7	4-15	5-7	4-5

The dosimetric evaluation was performed with LiF TLDs (TLD-100) calibrated with radiation energies similar to the ones used in clinical setting. The results were corrected to take into account backscattering. Two dosimeters were packaged in a polyethylene case and heat sealed. Two bags were placed on the surface of each patient, one on the right and the other on the left side of the abdomen, 3 cm from the field center. The TLDs were processed on a Victoreen readout system model 2800M and the average of their readings corresponds to the entrance surface dose.

In order to obtain reasonable estimates for the dose to the uterus and to the ovaries, the HSG was simulated with the Monte Carlo program EVA [5]. This program determines among other doses quantities also conversion coefficients between organ doses and entrance surface dose. A simple multiplication of the measured entrance surface doses (Table II) with the appropriate conversion coefficient leads to the organ doses shown in Table III.

3. Results

Figure 1 shows the distribution of entrance surface doses. Table II on the other hand shows the mean values obtained for the three institutions. In spite of having more experience physicians in the institution C, the entrance dose received by the patients during the exams were higher than those observed in the other two (A and B). Probably this is due to the fact that the value of the total filtration of the x-ray equipment used in institution B (2.5mm of Al) is lower than the ones used in the other two institutions (3.5mm of Al).

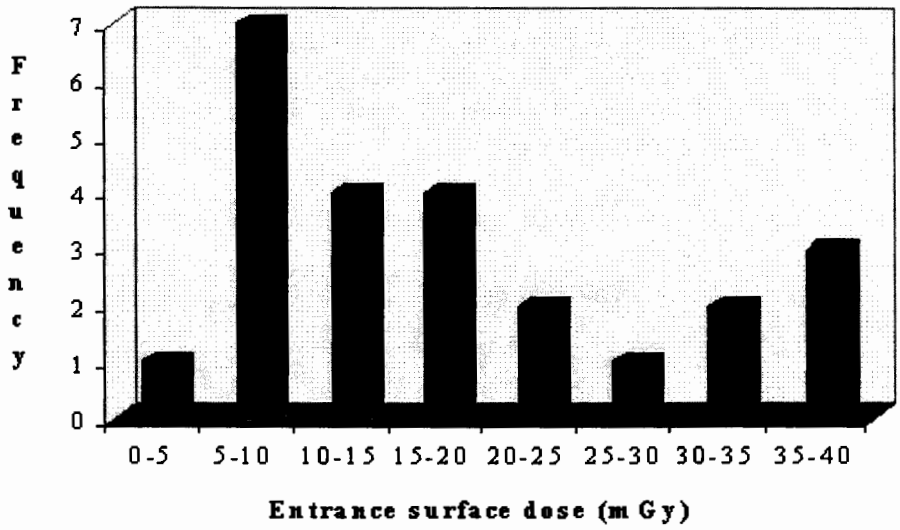

Figure 1: Frequency distribution of entrance surface doses for HSG Examinations

Table II- Entrance surface doses in mGy obtained at institutions A,B and C, for HSG examinations

Institution	Entrance Surface Dose (mGy)	
	Mean	Min-Max
A	8.44	4.99 - 14.28

B	17.36	6.08- 36.40
C	31.74	26.41- 36.60

Table III shows the doses to the uterus and to the ovaries determined as the mean absorbed dose to each organ. The results are similar to the other found in the literature.

Table III- Mean ovaries and uterus doses obtained at institutions A,B and C for HSG examinations

Institution	Ovaries dose (mGy)	Uterus dose (mGy)
A	1.18	1.71
C	2.38	3.42
B	5.27	6.97
Mean Dose (mGy)	2.94	4.03

4.Conclusion

The large range of entrance surface doses found is due to several factors like variation in patient thickness, field size, potential x-ray tube, etc. It must be emphasized that no consideration was given to image quality in this study. It was assumed that the exam achieved its diagnostic purpose. The results obtained provide useful guidance on dose levels and strategies for dose setting optimization in Pernambuco.

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A TRIAL TO ESTABLISH DIAGNOSTIC REFERENCE LEVELS FOR RADIOLOGICAL EXAMINATIONS IN GREECE

AUTHORS
E.Papageorgiou [1], P.Dimitriou [1,2],E.Vardalaki [3], C.J.Hourdakis [1], L.Vlahos [2]
[1] Greek Atomic Energy Commission, P.O. Box 60092, 153 10 Ag. Paraskevi, Greece
Tel.: +30-1-650 6771, Fax: +30-1-650 6748, e-mail: epapag@eeae.nrcps.ariadne-t.gr
[2] University of Athens, Radiology Dept., "Aretaieion" Hospital
[3] University of Athens, Physics Dept.

ABSTRACT
A research for the estimation of doses received by patients undergoing radiological examinations in order to establish diagnostic reference levels (DRLs) was conducted in Greece. A total of 7 big hospitals in Athens were selected and 450 patients consisted the sample. The Entrance Surface Doses (ESDs) to patients undertaking 5 common X-ray examinations (chest, cervical spine, lumbar spine AP & LAT, pelvis) were estimated using both thermoluminescent dosemeters (TLDs) attached to the patient's skin and ionisation chamber for air kerma measurements. Patient's data and exposure settings were recorded. The results from both methods coincided perfectly. The lumbar spine AP & LAT and the pelvis examinations proved to demonstrate lower DRLs than the ones recommended by the E.U. For the cervical spine examination, where there is no E.U. recommendation, the value of 1.0 mGy was established as the national DRL. In the case of the chest examinations the DRL was found to be 0.7 mGy, more than twice the recommended value. Discrepancies in the patient doses and techniques used for the examinations studied were found among the different hospitals. Results concerning the kilovoltage and Focus-to-Film-Distance (FFD) were also analysed and compared to those recommended by the E.U. Correlation between the kilovoltage and milliampere-second product (mAs) settings was found only in the cases where the Automatic Exposure Control was operated.

INTRODUCTION

Previous studies on radiation exposures during common medical diagnostic procedures have demonstrated that doses may have a range of up to two orders of magnitude, making clear that there is considerable need for dose reduction [1]. The Diagnostic Reference Levels (DRLs), which were set down by the European Community, are dose levels in medical radiodiagnostic practices for typical examinations for groups of standard-sized patients for broadly defined types of equipment. These levels are not expected to exceed for standard procedures when good and normal practice regarding diagnostic and technical performance is applied [2].
This work is a continuation of a previous survey [3] on the estimation of doses received by patients in Greek hospitals.

MATERIALS AND METHOD

The following routine examinations were studied: chest PA, cervical spine, lumbar spine AP & LAT and pelvis. Seven big radiology departments belonging to hospitals located in Athens participated. According to the E.U. recommendation [4], the dose measurements should be performed on standard-sized patient with an average weight of 70 ± 3 kg. In this survey the NRPB protocol [5] was followed which has suggested that at least 10 patients for each examination from every X-ray unit should be taken into account for the estimation of ESD, having weights 70 ± 20 Kg.
ESD is defined as the absorbed dose to air at the intersection point of the X-ray beam axis with the entrance surface of the patient, including backscatter radiation and can be determined by two types of dosemeters: TLDs and ionisation chambers [1].
ESD was directly measured using 3 TLDs placed on the patient's skin. The calibration procedure of the TLDs used in this survey (LiF TLD-100) showed: TLDs' batch homogeneity 20%, reproducibility 3%, minimum detectable dose 30μGy [6], energy response curve ±18% for 50-150 kVp, linearity 1%.

Indirect estimation of ESD was obtained by measuring the primary beam air kerma from the X-ray tube. For each X-ray unit a quality control test was performed in respect to kilovoltage & timer accuracy and consistency, tube output measurement (at 75 cm and 20 mA.s), tube linearity and filtration. The tube output measurements were then corrected using the inverse square law, kVp & mA.s values for each patient's examination and appropriate backscatter factors to estimate the ESD using the formula:

$$ESD = K_{air} x \frac{(\mu/\rho)_{muscle}}{(\mu/\rho)_{air}} x \frac{mAs}{20} x \left(\frac{75}{FSD}\right)^2 xBSF$$

where K_{air} is the air kerma measured, (μ/ρ) is the ratio of mass absorption coefficient to density (the ratio of μ/ρ for muscle to that for air can be taken as 1.06 for all typical diagnostic X-ray qualities) [7], FSD is the Focus-to-Skin-Distance (in cm) and BSF is the backscatter factor. The BSFs values depend on beam quality, field size and FSD and were determined from literature [8-11].
The measurements with the TLDs and the calculations with the ionisation chamber for estimating the ESD showed a very high correlation (R=0.97).
For each patient the following data were recorded: hospital, X-ray tube, examination, sex, age, weight, height, kVp and mA.s settings, Automatic Exposure Control (AEC), Focus-to-Film-Distance (FFD), film size and sensitivity of intensifying screen-film.

RESULTS

A total number of 450 patients from 7 hospitals and 13 different X-ray units were monitored in this survey. The examination types selected (chest PA, cervical spine, lumbar spine AP & LAT and pelvis) are either the commonest or represent techniques with the highest absorbed dose to the patient.
The exposure parameters and the ESD values for each type of examination are presented in Table 1. It should be noted that the ESD values are given as the 3rd quartile of the estimated value, according to the European Commission suggestions [2]. For each type of radiograph included in the CEC Working Document [12] there is "an example of good radiographic technique" in which values are recommended for various parameters, such as kilovoltage and Focus-Film-Distance, which should enable the dose criteria to be met. Table 2 presents the suggested exposure parameters and the percentage of the examinations meeting them.
The formula for the ESD values shows the inverse relation between kVp and mA.s. Table 4 presents the findings for such relation for all the X-ray units.

DISCUSSION

Table 2 shows that in the case of the chest examinations 90% of them had FFD in the range of 140-200 cm but in less than 10% the 125-kVp setting was used. The ESD value was found to be 0.7 mGy, which is more than twice the recommended value of 0.3 mGy. The non-compliance of the ESD with the E.U. guideline is quite surprising since the latest has been set rather high so as not to discourage users. It is obvious that the "hard setting" technique recommended by the E.U. is not adopted by the radiology labs. 50% of the cases had ESD values exceeding the recommended one. Considering the cases where at least one of the recommended E.U. settings (either kVp or FFD) was followed, the ESD for the chest examination reaches the value of 0.5 mGy. Only when both the FFD and the kVp recommendations are fulfilled (the kilovoltage taken in the range 120-130) the ESD falls to 0.2 mGy.
As far as the cervical spine examinations is concerned there are no E.U. recommendations. The survey showed that, considering the ESD value of 1.0 mGy as acceptable, the optimal kilovoltage and FFD ranges would be 60-80 kVp and 140-180 cm respectively.
It can be seen that the lumbar spine AP & LAT and the pelvis examinations fulfilled by 100% the recommendations for the 100-150 cm FFD range.
As far as the kilovoltage setting is concerned, the lumbar spine AP & LAT examinations followed by approximately 60% the recommendation for 75-90 kVp and 80-95 kVp range respectively while the pelvis examinations followed by less than 50% the range of 75-90 kVp.

Almost 100% of the estimated ESD values for the lumbar spine LAT and pelvis examinations and more that 80% for the lumbar spine AP were below the E.U. DRLs.
Table 3 shows the maximum-to-minimum ratio of ESD values for individual patients and between hospitals. It can be seen that the ESDs for chest examination vary up to 57 times individually but only 5 times between the various hospitals. While each hospital has a wide range of ESD values due to the different radiographic techniques used, the mean ESD for each projection does not vary as greatly from hospital to hospital.
It is obvious from Table 4 that only in the cases where the Automatic Exposure Control was used, the choice of mA.s was inversely proportional to the kVp setting. The findings, surprising enough, make the need for revision of the radiographic techniques used urgent.
It is clear that in the case of the chest examinations immediate measures have to been taken in order to minimise the ESD value. In the other examinations the ESD values proved to be quite satisfactory and below the European guidance dose levels.
Differences from the results presented in a previous paper [3] may be attributed to different sample sizes.

CONCLUSION

This study clearly showed that there is a need to harmonise the practices followed by the technologists in order to meet the European criteria for radiographic images and to this direction the establishment of examination protocols provided by the new radiation protection regulations will be of great importance. Additionally, efforts to update the equipment installed in the radiology departments should be made. DRLs can encourage changes in working procedures and equipment by showing what is possible and achieved in other departments.

TABLES

Table 1: Exposure parameters and ESD values

Examination	Kilovoltage	FFD (cm)	ESD (mGy)
Chest PA	94 (39)	177 (27)	0.7 (0.3)
Cervical spine	75 (43)	144 (23)	1.0 (0.6)
Lumbar spine AP	83 (40)	108 (8)	9 (3)
Lumbar spine LAT	89 (9)	111 (11)	16 (8)
Pelvis	76 (7)	107 (8)	7 (3)

The values in parenthesis represent 1SD value

Table 2: Recommended exposure parameters and coincidence in this study

Examination	E.U. kVp Coincidence (%)	E.U. FFD (cm) Coincidence (%)	E.U. DRLs (mGy) Coincidence (%)
Chest PA	125 6%	140-200 90%	0.3 50%
Cervical Spine	60-80** 80%	140-180** 63%	1.0** 75%
Lumbar spine AP	75-90 61%	100-150 100%	10 85%
Lumbar spine LAT	80-95 59%	100-150 100%	30 100%
Pelvis	75-90 46%	100-150 100%	10 100%

*The recommended kVp are taken as 120-130
** These values are considered to be the recommended ones

Table 3: Maximum-to-minimum ratios for ESD values

Examination	Max/Min of ESDs for all patients	Max/Min of mean ESDs between all X-ray units
Chest PA	57	5
Cervical Spine	31	7
Lumbar spine AP	20	6
Lumbar spine LAT	26	8
Pelvis	17	9

Table 4: The kVp-mA.s correlation

X-ray unit	AEC	mA.s v kVp
TUR D703, Siemens Tridoros 5S	No	$mAs \propto kVp^{n}$
Philips Optimus, Siemens Opti 150, Siemens Opti 150	Yes	$mAs \propto kVp^{-n}$
Siemens Gigantos 1012E, Siemens Polyphos 50, CGR Triplunix T	No	mAs constant
CGR Dualix a, CGR Dualix 825, Siemens Tridoros 150,Siemens Tridoros 5S, Siemens Tridoros 5S	No	No correlation

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RADIATION HAZARD FOR PATIENTS AND RELATIVES AFTER PAIN PALLIATION WITH ^{153}Sm-EDTMP

H. Sinzinger, S. Ofluoglu, E. Havlik, Susanne Granegger

University of Vienna, Dept. of Nuclear Medicine, Währinger Gürtel 18 – 20, A 1090 Vienna, Austria
Fax: #43-1-40400-5532 e-mail: helmut.sinzinger@akh-wien.ac.at

Abstract

^{153}Sm-EDTMP is one of the radioisotopes of choice for treatment of painful bone recurrences. We determined radiation dose in 14 patients being treated for bone metastases after breast (6) or prostate cancer (8) receiving a single treatment. Radiation dose was also measured in the partners of 5 of the patients. Patients received 2,79 ± 0,87 mSv, their respective partners 0,24 ± 0,14 mSv. One patient apparently not wearing the dosimeter all the time exhibited a radiation dose of 0,32 mSv (and was therefore not included in the statistics). Female partners exhibited higher radiation dose (0,40 - 0,49 mSv) as their male counterparts (0,24 – 0,42mSv). Their dose was 16,26 % for female and 10,25 % for male partners from treated patients. Furthermore, we assessed the finger dosis of the staff (tracer preparing technician and applying physician) with and without lead shielding of the syringe containing the radioisotope. Shielding resulted in an increase of finger dose for the technician (+ 20 %) due to a longer preparation time, while the physicians one was decreased (to 20%).

Key words: ^{153}Sm-EDTMP, finger dose, radiation exposure, syringe shielding

Introduction

Skeletal recurrences causing bone pains are a central problem in patients suffering from various types of cancer, but mainly in breast and prostate cancer, 50 and 80 % respectively developing metastatic bone disease. They are a main challenge for the physicians. About a decade ago ^{153}Sm-EDTMP has been introduced successfully as one of the 3 radioisotopes of choice in these patients for bone pain palliation [1, 2]. Beside its routine clinical application many questions still need to be answered: Has ^{153}Sm-EDTMP also an effect on lesion stabilization and/or regression, what is the optimal therapy dose? Should the dose administered be calculated in advance by uptake measurement? What are the factors influencing uptake and can they be influenced favourably? While dosimetry and toxicity of ^{153}Sm-EDTMP is well defined [3], concerning radiation hazards to staff, patients and relatives almost no information is available so far. Aim of our investigation was to get some insights into radiation exposure of the patients and their partners as well as to assess the influence of lead shielding of syringes on the finger doses the technician and the physician are exposed to, respectively.

Material and Methods

Patients with painful skeletal recurrences secondary to breast or prostate cancer were studied (for details see patients characteristics in table 1). In a small group patients as well as their partners were investigated (table 2). They were treated according to our Vienna protocol, i.e. 30 mCi (1,1 GBq) ^{153}Sm-EDTMP intravenously repeated in 3 months intervals. Patients and their partners then were wearing a film dosimeter from immediately after application of radioisotopic therapy to day 8. The 5 partners investigated were all staying with their partners and did not go to work..

A team consisting of one technician and one physician was wearing finger ring dosimeters when they either prepared or administered the ^{153}Sm-EDTMP dose. Different rings were used for preparation / application of the isotope with and without lead shielding of the syringe. The ring dosimeters were worn only during the respective activity for a total of 18 procedures with (n = 9) and without (n = 9) shielding.

Table 1

Patients characteristics

Initials	sex	age	cancer	treatments (n)	mSv
J.K.	m	84	P	3	3,53
K.B.	f	60	B	3	3,16
W.W.	m	60	P	3	4,82
H.O.	f	65	B	1	3,01
W.P.	m	60	P	3	1,76
K.T.	m	61	P	1	2,01
H.W.	m	68	P	3	2,52
S.S.	f	54	B	1	2,18

x: 2,87 ± 0,93 mSv
+ corr: 2,71 ± 0,98 mSv
B.....breast cancer; P.....prostate cancer

Table 2

Characteristics of patients and their partners

PATIENT						PARTNER		
Initials	sex	age	cancer	treatments (n)	mSv	Initials	sex	mSv
W.S.	f	72	B	2	3,16	R.S.	m	0,42
M.J.	f	47	B	2	3,33	H.J.	m	0,24
W.W.	m	77	P	1	2,74	M.W.	f	0,49
R.P.	m	63	P	1	2,17	M.P.	f	0,45
J.E.	m	76	P	3	3,94	R.E.	f	0,40

x: 3,07 ± 0,59 mSv
+ corr: 2,91 ± 0,64 mSv
mean background: 0,16 ± 0,05

x: 0,40 ± 0,09 mSv
+ corr: 0,24 ± 0,14 mSv

Statistical analysis
Values are presented in x ± SD; calculation of significance was performed by means of Students t-test.

Results
The patients were exposed to a dose ranging from 1,76 – 4,82 mSv (tables 1, 2) with a mean of 2,71 and 2,91 respectively, after background correction. One female patient (40a, breast cancer) despite declaring the dosimeter wearing all the time apparently did not do so, showing a dose exposure of only 0,32 mSv (this patient is therefore not incorporated in the table). No apparent age- or sex-dependence or correlation to bone uptake or number and extent of bone lesions could be discovered. Patients partners receive about one tenth of their partners dosis (table 3), female partners getting 16,26 %, male ones only 10,25 %. After background correction the dose the respective partner received ranged between 8 and 33 %.
Finger dosimetry revealed that syringe shielding resulted in a 20 % dose-increase (table 3) for the preparing technician, while reducing the physicians finger dose down to 20 % as compared to administration without shielding. In contrast, working without shielding reduced the technicians finger dose by 20 %, while increasing the one of the physician 5-fold in parallel.

Table 3

Finger dosimetry

shielding	+	-	factor
technician	5,5556	6,6667	1,2
physician	1,1111	5,5556*	5,0

* $p < 0,01$

Discussion

Radiation exposure data of staff, patients and their relatives after therapy of painful bone metastasis with ^{153}Sm-EDTMP are extremely rare. Roberts [4] calculated dose rates after therapy at 1m distance. Only Hušak [5] reported on an effective dose of 0,03 – 0,20 mSv to family members administering about 65 mCi ^{153}Sm-EDTMP to the patients.

The number of patients is too small yet in order to elucidate a correlation between skeletal uptake and number of bone lesions, respectively with radiation exposure. Neither was there any correlation detectable to the drop in peripheral blood cell count after 3, 6 and 9 weeks repectively.

Our findings show, that family members are exposed to about one tenth of the patients exposure and that at least 4 treatments with a dose of about 30 mCi ^{153}Sm-EDTMP can be administered to a patient to keep his partner within the tolerated limits of 1 mSv/a.

Concerning the question of shielding our data clearly show, that this is associated with an increased radiation exposure to the technician, but on the other hand by a severe reduction for the physician administering the dose.

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Dosis periféricas en haces de fotones de un acelerador lineal con colimador multiláminas

[$]R. Lope Lope, [$]F. Lozano Flores, [$]J. Gracia Sorrosal, [$]J.A. Font Gómez, *,[$]A. Hernández Vitoria
[$]Servicio de Física y Protección Radiológica. Hospital Clínico Universitario Lozano Blesa de Zaragoza.
*Area de Radiología y Medicina Física. Facultad de Medicina de Zaragoza.
Dirección electrónica: fpro@hcu-lblesa.es

Abstract

Radiation doses outside the radiotherapy treatment field are of radiation protection interest when anatomical structures with very low dose tolerances might be involved.
One of the major sources of peripheral dose, scatter from secondary collimators, depends on the configuration of the collimator.
In this study, peripheral dose was measured at two depths for 6 and 18 MV photons from a linac Primus (Siemens) with a multileaf collimator (MLC). Comparative measurements were made both with leaves and with the upper jaw positioned at the field edge near to the detector.
Configuring the MLC leaves at the field edge yielded a reduction in peripheral dose.

Introducción

Al realizar un tratamiento radioterápico con haces de fotones, a veces se plantea la necesidad de estimar la dosis que puede llegar a los órganos críticos del cuerpo no contenidos dentro del haz directo. La dosis en zonas fuera del haz primario, conocida como dosis periférica, se debe principalmente a la radiación de fuga, la dispersada por el colimador y modificadores del haz y a la dispersada por el propio paciente. Las dos primeras dependen de cada unidad de radioterapia mientras que la última se puede estimar de modo general en función de la energía de los fotones [1].
Con el fin de reducir la dosis periférica en órganos críticos con una determinada unidad se puede intentar modificar la técnica de tratamiento o bien tratando al paciente de modo que sea el colimador inferior el que defina el borde del campo más cercano al órgano crítico [2].
En este estudio, se presentan los resultados de las estimaciones de la dosis periférica originada en un acelerador lineal con un colimador multiláminas, para dos energías de haces de RX.

Material y Método

Las medidas de dosis periférica se han hecho con un acelerador Mevatron Primus (Siemens) dotado de un colimador multiláminas (MLC). En este colimador, cuando el ángulo de giro del mismo es de 0ª, la dimensión X del campo viene definida por las láminas y la dimensión Y por dos mandíbulas situadas por encima de las láminas. El acelerador dispone de energías de RX de 6 y 18 MV.
Las medidas relativas de dosis se hicieron con un conjunto de 12 diodos Isorad, situados en un maniquí de agua sólida, y conectados a un electrómetro Multidos (PTW). Para

colocarlos dentro del maniquí de agua sólida, previamente se colocaron en sandwich dentro de unas capas de Geliperm (Geistlich).
Los diodos se colocaron a distintas distancias del eje central, que correspondían a distancias desde el borde del haz comprendidas entre 2 y 40 cm. Las medidas se realizaron para cada energía, para tres tamaños de campo (5 x 5,15 x 15 y 25 x 25 cm^2) y a profundidades de 5 y 10 cm. La distancia fuente –plano de colocación de los diodos fue de 100 cm.
Las medidas se hicieron en primer lugar con el colimador a 0° y luego, sin mover los diodos, se repitieron con el colimador a 90°, con el fin de determinar la dosis periférica cuando eran las multiláminas las que definían el borde del campo situado más próximo al punto de medida y cuando este borde era definido por una de las mandíbulas superiores.
Posteriormente, las dosis periféricas se estimaron como porcentaje respecto a la dosis en el eje central, teniendo en cuenta el factor de calibración de cada diodo.

Resultados y discusión

En las figuras 1 a 4 se muestran los resultados de dosis periféricas calculados a partir de las medidas de los diodos, con el colimador a 0°, es decir, con el borde del haz más cercano a los diodos definido por las multiláminas. Se observa que la dosis periférica:

- Aumenta con el tamaño de campo, como era de prever.
- A distancias pequeñas del borde del haz disminuye al crecer la energía a las profundidades seleccionadas. La diferencia encontrada entre las dos energías fue siempre inferior a un 3 % respecto a la dosis en el eje del haz.
- Para cada energía, es mayor a profundidad 10 cm que a 5 cm., siendo este aumento mayor en el caso del haz de 6 MV . La diferencia mayor encontrada entre las dos profundidades fue del orden de 2 % respecto a la dosis en el eje del haz.

Este comportamiento general concuerda con los obtenidos por otros autores [3]. A distancias pequeñas del borde del campo, la mayor contribución a la dosis periférica se debe a la radiación dispersada por el maniquí. Esta contribución aumenta al crecer la profundidad.
Lo mismo ocurre con la dosis periférica medida con el colimador girado 90ª, es decir, con el borde del haz más cercano a los diodos definido por una de las mandíbulas superiores.

Comparando los resultados obtenidos en los casos estudiados de colimador a 0° y 90°, hemos observado que, en todos ellos, la dosis periférica es mayor con el colimador a 90°, siendo esto más notable en el caso del haz de 18 MV. La diferencia obtenida es pequeña en ambos casos (siempre inferior a 1 % respecto a la dosis en el eje del haz). Así pues, la radiación dispersa que llega a los diodos procedente del colimador es siempre menor en el caso del colimador a 0°.
Como ejemplo, en las figuras 5 y 6 se muestran, para cada una de las energías y el mayor tamaño de campo estudiado, los resultados obtenidos con el colimador en cada una de las posiciones y para la profundidad de 10 cm.
Un estudio similar realizado para un haz de 6 MV en un acelerador Mevatron KD2 (Siemens) dotado de un colimador con cuatro mandíbulas, muestra diferencias inferiores entre las dosis periféricas para las dos orientaciones del colimador que las determinadas en el acelerador estudiado en este trabajo[4].

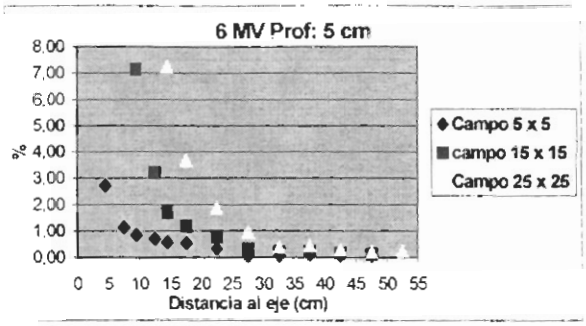

Figura 1
Dosis periférica (% respecto a dosis en el eje del haz). Haz de 6 MV. Profundidad 5 cm.
Borde del haz más próximo a los diodos definido por las láminas.

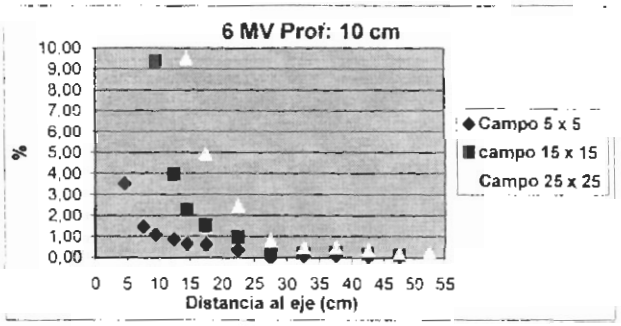

Figura 2
Dosis periférica (% respecto a dosis en el eje del haz). Haz de 6 MV. Profundidad 10 cm.
Borde del haz más próximo a los diodos definido por las láminas.

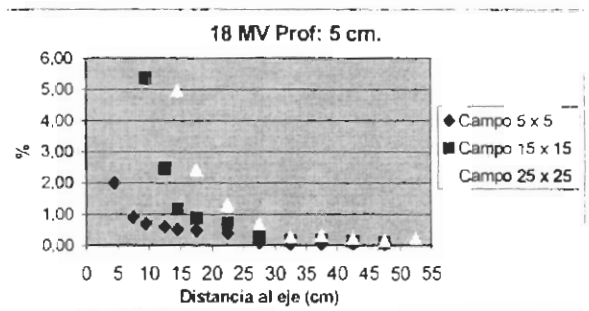

Figura 3
Dosis periférica (% respecto a dosis en el eje del haz). Haz de 18 MV. Profundidad 5 cm.
Borde del haz más próximo a los diodos definido por las láminas.

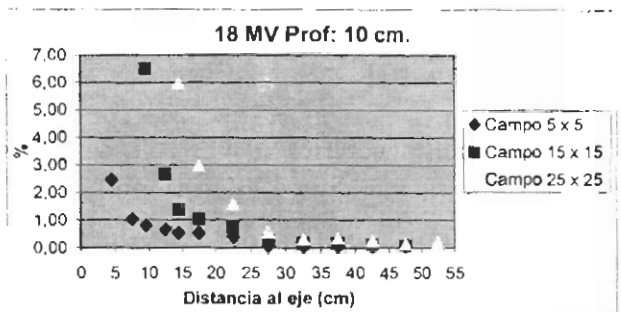

Figura 4
Dosis periférica (% respecto a dosis en el eje del haz). Haz de 18 MV. Profundidad 10 cm.
Borde del haz más próximo a los diodos definido por las láminas.

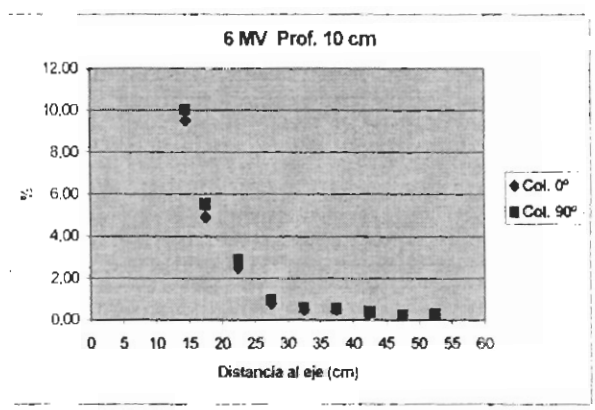

Figura 5
Dosis periférica. Haz de 6 MV. Campo 25x25 cm^2. Profundidad 10 cm. Borde del haz más próximo a los diodos definido por **las multiláminas (Col.0°) y por la mandíbula superior (Col.90°).**

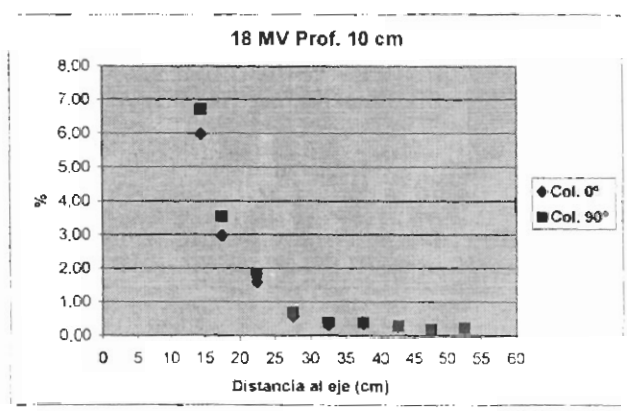

Figura 6
Dosis periférica. Haz de 18 MV. Campo 25x25 cm^2. Profundidad 10 cm. Borde del haz más próximo a los diodos definido por **las multiláminas (Col.0°) y por la mandíbula superior (Col.90°).**

Las dosis periféricas medidas con el acelerador estudiado son inferiores a las publicadas por otros autores [3] para otro acelerador dotado de un colimador multiláminas pero con mandíbulas en las direcciones X e Y.

Como aplicación de los resultados obtenidos, en el supuesto de un tratamiento efectuado con un haz de RX de 18 MV y un tamaño de campo de 25 x 25 cm^2, con una dosis de 50 Gy en el eje del haz y a 10 cm de profundidad, la dosis en un órgano situado a la misma profundidad y a 2 cm de distancia del borde del haz sería de un 6 % (borde del campo definido por las multiláminas) frente a un 6.7 % (borde del campo definido por la mordaza superior en función del giro del colimador (0°/90°). Esto supondría una diferencia de dosis de 0.7 %, es decir 35 cGy.

Conclusión

En el acelerador estudiado, para disminuir la dosis periférica en aquellos órganos en que la dosis pueda ser clínicamente significativa, es preferible colocar el ángulo del colimador de modo que sean las multiláminas las que definan el borde del haz más cercano al órgano crítico.

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THE REDUCTION IN DAP VALUES POSSIBLE WITH OPERATOR EDUCATION AND ADDITIONAL FILTRATION IN A CARDIAC CATHETERISATION LABORATORY

Helen M. Warren-Forward[1] & Lisa Duggan[2]

[1] Discipline of Medical Radiation Science, University of Newcastle, Newcastle, NSW, AUSTRALIA Fax: +61 2 49217053 e-mail: hwf@mail.newcastle.edu.au

[2] Radiation Oncology, Mater Hospital, Newcastle, NSW, AUSTRALIA

Abstract:

Radiation doses were recorded for over 1,000 patients undergoing interventional procedures at a cardiac catheterisation laboratory at a local teaching hospital. The laboratory was equipped with two Toshiba DRX C-arms units. The only differing factor between the units was the inclusion of a tantalum rare-earth filter on Unit B. Each unit was fitted with a DAP meter which readily allowed the collection of dose-area product (DAP) readings for all patients. Information was collected over a 12-month period and data analysis showed that the median radiation doses from Unit B was on average 50% lower than those delivered from unit A for the same radiographic procedure and operator. Further analysis also showed that there was a large variation in dose given by the operators and as expected for the type of examination performed.

Introduction:

A decade ago, deterministic effects were seldom, if at all, associated with the current use of x-rays in diagnostic radiology. This last decade has seen cardiology becoming a highly imaging-dependent specialty, routinely using the greatest variety of imaging in diagnosis and treatment. These developments in cardiac imaging have been associated with a growth in treatment methods, which are moving towards minimally invasive therapy [1]. Most of this change has occurred with the development of sophisticated equipment for coronary angioplasty and stent insertion.

So x-rays are now being used not just to diagnose, but to guide in therapeutic procedures. As a result of these advances, deterministic effects are again becoming associated with diagnostic radiology procedures. While it is recognised that without this range of procedures the life expectancy of many patients would be very low, care must also be taken to reduce the induction of the deterministic effects whilst minimising the occurrence of stochastic effects.

This paper aims to investigate the use of tantalum as an effective filter to reduce radiation dose given to the patients in a cardiac catheterisation laboratory, while at the same time recognising the important role of the operator in this regard.

Materials

The cardiac catheterisation suite used in this study comprised two rooms, each containing almost identical Toshiba DRX C-arm units. Each unit was ceiling mounted with a triple mode image intensifier (RTP 9211J) with field sizes 9/7/4.5 inches. For the majority of clinical examination studied pulsed fluoroscopy (15p/s) was used and digital image acquisition was also collected at 15 frames.s^{-1}. The input dose rate to the II for pulsed fluoroscopy and digital image acquisition were 0.34 μGy.s^{-1} and 0.114 μGy.f^{-1} respectively for unit A and 0.28 μGy.s^{-1} and 0.124 μGy.f^{-1} for unit B.

The significant difference between the units was that unit B had been fitted with an additional tantalum filter. Tantalum, is a transition metal obtained from Tantalite has an atomic number of 73 and an atomic mass of 181. Its use as a filter in diagnostic radiology is fairly new, and with its K-edge of 67.5 keV its has potential benefit as a filter in diagnostic radiology, for those techniques employing higher energies.

Exposure parameters such as the applied potential (kVp) and tube current are set by automatic exposure control and can not be chosen manually. Typically the applied potential varied between 80 and 120 kVp, and was dependant on patient habitus and projection of the X-ray beam. Both were installed with a DAP meter (Diamentor from PTW, Germany) which were calibrated according to standard protocol [2].

Method

Information was collected on a variety of factors for 1,200 patient over a twelve month period. Patient data included gender, age, height, weight, type of procedure and consultant name. Dose related data consisted of total DAP value, total examination time, number of digital image acquisition, number of frames per run, number of frames per second and projection angles. Information was not specifically collected on mA and kVp for each projection as its variability is thought to even out between operators and more importantly the variability in fluoroscopy time and DAP values is seen to be more important than variations in technical factors.

Information on the number of digital image acquisitions, number of frames per run, number of frames per second and the average length of each frame, allowed the total examination time to be broken down into relative contributions for both digital acquisition (DA) and fluoroscopy modes. This fraction is important, as the dose rate during a DA is far greater than the dose-rate during fluoroscopy. This information together with the projection angle allows a profile to be built of operator technique.

Results

The results for some of the most common procedures are summarised in Table I. The median values range from 15.3 Gy.cm^2 for an electro-physical simulation (EPS) to as high as 117 Gy.cm^2 for an investigation of the left and right arteries. The median examination times varied from 5.6 minutes for a left and coronary angiogram up to 25 minutes for an EPS. Thus an EPS was associated as the lower dose examonation on average but recorded the highest examination time, this is because the examination is primarily carried out under fluoroscopy and with a highly collimated beam giving a small radiation area. Therefore the dose given to a patient is dependent

on the complexity and type of procedure and generalities can not be made simply on overall examination time.

Looking at table I in a little more detail shows that unit B delivers slightly lower DAP values than unit A for all examinations and nearly 50% in the case of left and coronaries. These differences are not associated with differences in times between the examinations, as in the C+G procedures, the median examination time for unit B is nearly double that of unit A, but the DAP value is lower. Also for L+C, the median examination times are close, but there are large differences in the median DAP values. The variations observed are related to the frequency that the operators use each room. Thus differences in operators may not only be indicative of differences in the methodologies adopted but in differences in the pathology severity treated.

In order to better demonstrate the effect of the operator and the additional filtration on the variation in dose, a little more detailed analysis will be given for the most common procedure: the left and coronaries, which represented 77% of all examination studied in this study. The median values for examination times and DAP values for the operators are given in Table II. There are a number of issues to draw from this table, the first is the variation in DAP readings in each room. The median value ranges from 45.6 $Gy.cm^2$ to 74.4 $Gy.cm^2$ representing an increase of 63% in DAP values. Comparing the examination time for each operator with their respective DAP values informs us that there is a very small correlation between the two parameters, $r = 0.54$, $p = 0.46$ and $r = 0.33$, $p = 0.77$ for units A and B respectively. The reason for this can in part be explained by the techniques used by the operators, especially in differences in the proportion of digitally acquired images and fluoroscopy used, figure I. Some examinations were performed with DA representing as low as 5% of the total examination time, while others were using as much as 50%. The median use of DA was approximately 20%.

However, detailed investigations on the use of DA and fluoroscopy did not fully account for the differences in DAP readings. The other reason for the low correlation's seems to be in the differences in radiation field sizes, with some operators collimating down more than others.

The second issue to be seen from Table II is the large differences for the same operator between the two units. The reduction in median dose per operator varies from 41% to 54%. The differences in the examination times are much smaller than the changes in DAP, patient size have been averaged out, and difference in operator have obviously been negated, the differences in DAP values between the two units can be attributed to the filter in unit B.

Conclusions

While interventional procedures provide significant advantages over alternative therapies in terms of improved clinical outcomes and reduced overall patient risk, the physicians performing these procedures should be made aware of the potential for injury caused by long periods of fluoroscopy occurring with some of these procedures.

The study has shown that some operators were giving nearly twice the DAP values as others for the same examination type and unit, with this difference being accounted for by differences in the proportion of fluoroscopy and DA images, and in the extent of collimation used. Therefore, basic instruction to the operators in terms of the significant differences in dose-rates between fluoroscopy and DA images and the importance of collimation is needed.

There was also a reduction of approximately 50% between the two units, with this difference being explained by the tantalum filter in unit B. While image quality has not been assessed, there have

been no reports in difference in quality as a result of the filter. In total the variation in DAP readings is nearly a factor of 4 between the operator with the lowest dose using unit B compared to the operator with the highest dose using unit A. Thus there can be a significant reduction in dose at a very low cost to any department.

Regular measurements of patient dose is therefore an essential step to optimising exposure. It makes operators aware of their own performance and allows comparisons with the generally accepted practice. The easiest way for first line assessment is to use Dose-area product meters, which provide continuos guide to the performance of both equipment and operator and should be used as part of quality assurance programme.

However, in the overall framework of assessing the probability of producing a radiation induced deterministic injury, all staff members in a cardiac facility should be aware of the approximate levels of radiation dose resulting from the various radiographic projections that are routinely used. This study has highlighted two cost-effective ways to reduce DAP values, and the next stage will be to use the data collected on projection angles to investigate the potential of estimating radiation skin dose for a range of procedures using thermoluminescent dosimeters, radiographic film and an anthropomorphic phantom.

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Table I: Summary Values for the most common procedures

Procedure	Median (St.Dev) Time Minutes		Median (St.Dev) DAP Values Gy.cm^2	
	Unit A	Unit B	Unit A	Unit B
EPS	—	25.2 (17.2)	—	15.3 (19)
Left + Coronaries	6.1 (6.1)	5.5 (4.9)	67 (30.4)	33.5 (18.6)
Coronaries & Graft	9.95 (14.4)	17.5 (17.8)	69.7 (28.5)	68.2 (20.6)
PTCA	13.5 (17.9)	17 (15.6)	82.0 (54)	81.35 (39.2)
Lt & Rt Angio.	19.1 (8.6)	15.9 (4.6)	116.9 (30.9)	113.8 (21.5)

Table II: Summary values for operator and room for left heart and coronories

	Summary values per Consultant per room					
	Median Time (sec)			DAP (Gy.cm^2)		
Consultant	Room A	Room B	Diff (%)	Room A	Room B	Diff (%)
A	420	426	+ 1.4%	71.8	42.4	- 41%

B	486	405	- 16%	68.5	31.5	- 54%
C	186	----		57.1	----	
D	300	288	- 4%	45.6	22.8	- 50%
E	300	228	- 31%	74.4	37.7	- 49%
F	246	234	- 5%	53.5	30.9	42%

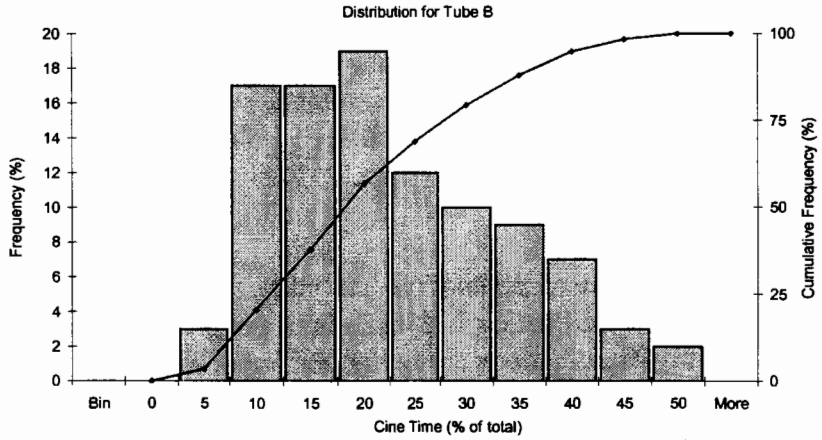

Figure I: Distribution for Cine use for Left Heart Angiography

RADIATION PROTECTION OF PATIENTS IN GENERAL DIAGNOSTIC RADIOLOGY IN LITHUANIA

Gendrutis Morkunas, Julius Žiliukas
Radiation Protection Centre, Kalvariju 153, Vilnius, Lithuania
Fax 370 2 75 46 92, e-mail genmo@takas.lt

1. Abstract

The situation in control of exposure due to general diagnostic radiological examinations in Lithuania is described. Experience in creation of legal basis for radiation protection, results of measurements of patients' doses and quality control tests of x-ray units are given. The main problems encountered in implementation of international recommendations and requirements of European Medical Exposure Directive are discussed.

2. Introduction

Lithuania with 3.7 million of population has more than 1100 diagnostic x-ray machines. According to the UNSCEAR classification Lithuania is in the group of states of health care level I. More than 2 million of x-ray examinations are being performed each year. It indicates that medical exposure due to diagnostic radiology is the important source among all the other sources. Individual doses to patients in some cases may be rather high, because units older that 20 years are still in operation. It is evident that control of doses to patients and their radiation protection are very important.

3. National requirements for radiation protection in medicine

Development of the legal system was started in 1996 with adoption of the Lithuanian Hygienic Norm HN 73-1997 *Basic Standards of Radiation Protection.* Three international documents [1-3] were taken for a basis of this Hygienic Norm. Specific hygiene norms on radiation protection in x-ray radiology, nuclear medicine and radiation protection have been adopted later.

General principles of radiation protection of patients (justification of medical exposure, optimization of radiation protection) are to be followed in all the fields of medical applications of radiation including diagnostic radiology. Medical exposure may be applied only in case the patient has a prescription for this procedure. Medical practitioner is responsible for radiation protection of individual patient. Special measures shall be taken to protect the pregnant women.

Guidance levels of dose for diagnostic radiography are established. The levels recommended by [1] are taken as a basis for the guidance levels. Some modifications of these levels are based on results of measurements of patients' doses. These modifications recommend higher entrance surface doses than doses, given in [1].

Criteria of acceptability of performance of diagnostic x-ray units are established using [4]. Results of pilot tests of quality control of x-ray units were used for establishment of these criteria. These results showed that the significant part of old x-ray units can not meet some of the recommended criteria. For this reason exceptions are applied to units which are manufactured before January 1st of 1997. The exceptions are for such parameters as the maximum dose rate at the entrance screen of conventional image intensifier (1.6 μGy/s. instead of recommended 0.8 μGy/s.), minimum operating tube voltage of dental units (45 kV instead of 50 kV), deviation of exposure time from set values, some features of automatic exposure control. Such approach allows use of

available x-ray units without major reconstruction of them. In many cases this reconstruction is not possible nor feasible.

Two particular problems should be mentioned. One of them is connected with the requirement of [3] not to use fluoroscopy units without image intensifier. There are such units still available in Lithuania. Lithuanian Hygiene Norm on radiation protection in x-ray radiology does not allow use of such units after the January 1st of 2002. This deadline is 2 years later than the deadline determined by the Medical Exposure Directive. It is connected with the restricted financial possibilities of the state.

Photofluorography units are still used in Lithuania, mainly for screening purposes. More than 100 examinations are being performed each year per 1000 population. Higher doses and poorer image quality are the reason for abandoning of this type of procedure in many countries. The complicated tuberculosis situation in Lithuania requires chest examinations, and not always conventional x-ray units are available. Investigation of justification of this type of examinations has been started. It will be basis for taking decision about expedience of photofluorography.

The experience from creation of legal basis shows that close co-operation between regulatory authority and interested health care institutions and availability of results of actual investigations of patients' doses, quality control of radiological equipment may be helpful in creation of effective legislation.

4. Doses to patients

RADOS TLD system is used for measurements of patients' doses. Measurements are performed in randomly selected x-ray departments all around Lithuania. LiF pellets without slide holders in black bags are taped on the skin of the patient in the centre of x-ray field in the direction to the x-ray tube. Sex of patient, his/her weight, height and thickness in the centre of x-ray field, exposure parameters such as kVp, mA or mAs, size of x-ray field, focus-film distance, total filtration are written down in the special protocols. Since there is a shortage of standard size patients, doses to all the patients available during period of measurements are recorded. The average weight of patients in different departments was (66±12) to (77±18) kg (95% of confidence). It indicates that if a number of patients is not large enough, differences in their weights are not essential.

The results of measurements are presented in Fig. These results show that in some hospitals the reference levels, established by the Lithuanian *Basic Safety Standards* are exceeded more than 2 times. It indicates that these levels should be reviewed. New reference levels at the 75^{th} percentile of measured doses should established [5]. For this reason the trial which includes larger number of hospitals of different level is about to started.

The effective doses due to the chest (PA) examinations have been calculated using [6]. The distribution of doses is log normal, with the maximum at 0.2 mSv. The average of effective dose received during chest PA examinations is (0.06±0.02) mSv.

The average effective dose received during photofluorography in two hospitals was (0.32±0.10) mSv per image. It should be pointed out that averages of effective doses in these hospitals are rather different - (0.46±0.14) and (0.14±0.03) mSv per image. These results show, that the risk/benefit analysis of such type of examinations shall be performed though not only doses but quality of image should be taken into account.

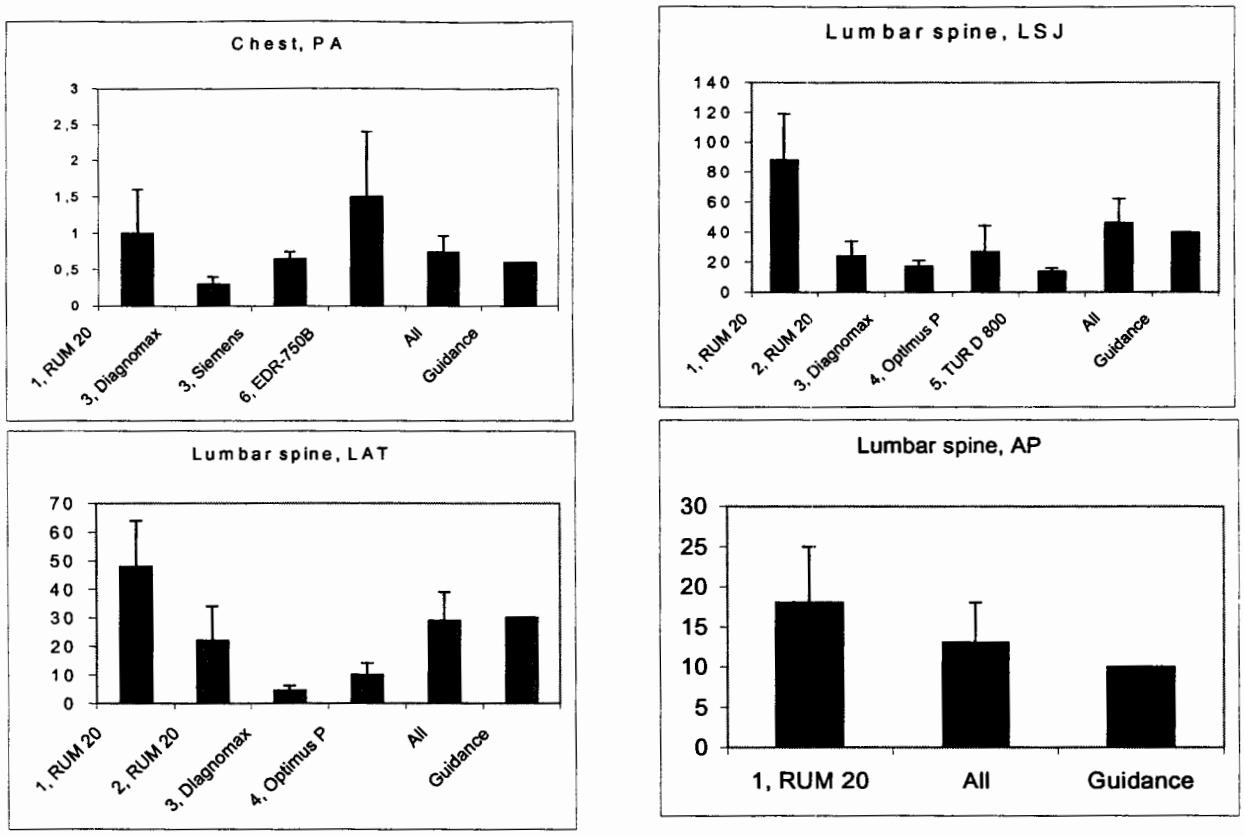

Fig. Results of measurements of patients' entrance surface doses (in mGy) in different departments using different x-ray equipment (indicated). Error bars are for 95% of confidence

5. Performance of x-ray units

Quality control of x-ray machines is performed with the help of PMXIII by RTI Electronics. 143 units were checked in 1998, 150 - in 1999. In 2000 this number increased because quality control became a condition for licensing. The results of these tests are presented in the Table.

Table. Results of quality control of diagnostic x-ray units

	Checked	Did not pass	Fixed	Not fixed
Dental units	142	4	3	1
Portable units	59	5	3	2
Conventional units	85	25	24	1
Mammography units	7	0	0	0
Photofluorography units	28	5	5	0
Angiography units	2	0	0	0
Total	323	39	35	4

Most frequently x-ray units do not pass tests because of problems with high voltage generator (poor waveform), too low x-ray tube voltage, dose linearity and timer accuracy. Dose repeatability and too low voltage are the main problems in dental x-ray units during acceptance testing.

It is seen that quality control is the powerful tool in improving of performance of x-ray units. Nearly 90% of units were successfully repaired. On the other hand, even new dental units do not pass testing. It shows the importance of acceptance testing.

6. Conclusions

During the last 5 years Lithuania is making intensive efforts in improving of radiation protection of patients. International recommendations and requirements of European Directives is the powerful moving force. However, many radiologists are used to very prescriptive system, which was in force until the beginning of 90s. The lack of qualified experts is to be mentioned on this occasion. It results in very heavy workload of regulatory authority, which should perform calculations of shielding thickness, quality control tests, measurements of dose rate in workplaces.

On the other hand, the Radiation Protection Centre shall collect the most recent information on operational radiation protection in order to prepare the effective standards, rules and recommendations. These documents shall be drafted in close co-operation with radiologists, radiation protection advisers, hospital physicists. However, it remains the problem. Hospital radiation workers are not motivated to take part in drafting of these documents, even in discussions of drafts.

Quality assurance remains the very sensitive point in the whole system of the patient radiation protection. Hospitals are trying to rely on results of annual quality control checks, performed by the Radiation Protection Centre and other organizations. Everyday control of developing process, analysis of image quality should be introduced.

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Estimation of dose loads in carrying out radiology research (manipulation)

D.A.Zaredinov[1], M.M.Giyasova[2], G.V.Kazimova[2]

Second Tashkent State medical institute, Tashkent, Uzbekistan

Abstract

In our country we pay great attention to the protection of medical personnel working with sources ionizing radiations. The equipment of radiotherapy departments with semi-automatic protective complexes has significantly changed the technology of working with radioactive materials, organization of labor and levels of irradiation doses of the medical personnel. The design of devices of semi-automatic protective lines should provide for the maximum reduction of manual operations, decrease of radiation dose capacity at workplaces, reduction of contact time with radioactive materials, and consequently, reduction of radiation loads for the medical personnel. We have analyzed the data on levels of dozes received as a result of radiation use in medicine.

Keywords: radioactive substances, radiotherapy, personnel, organization of labor.

In the reports of Committee for 1958, 1962, 1972, 1977 and 1982 [1-5] there were analyzed the data on levels of dozes received as a result of radiation use in medicine. We are facing the influence of ionizing radiation on human body when carrying out X-ray examinations, radioisotope diagnostics, and radiotherapy with the use of external and internal sources. The list of the countries, on which we have information on frequency of examinations has now widened. Average annual frequency figure significantly vary in different countries [6]. In less developed countries radiological methods are applied (converting per capita of population) approximately 30 times less frequent, than in industrially advanced countries. The annual number of procedures in 13 countries with I level public health service makes 450 - 1300 per 1000 people, whereas average value is 800 procedures per 1000 people. The number of examinations grows gradually as estimated in different countries. Mass thorax and gasrtointestinal tract X-ray examination makes the basic contribution into the radiological procedures in Japan. In conformity with Y. Kumamoto data [7] 26,6 mln radiological thorax examination were carried out (242 per 1000 people) which is 1,5 times higher, than in the previous years. As B.Wall and others report [8], 488 radiological examinations per 1000 people are carried out in Great Britain annually. Average annual increase of examinations made up to 3 %.

In our country great attention is paid to the protection of the medical personnel working with the sources of ionizing radiations. The equipment of radiotherapy departments with semi-automatic protective complexes has significantly changed the technology of working with radioactive materials, organization of labor and levels of irradiation doses of the medical personnel. The design of devices of semi-automatic protective lines provides for the maximum reduction of manual operations, decrease of radiation dose capacity at workplaces, reduction of contact time with radioactive materials, and consequently, reduction of radiation loads for the medical personnel. At the same time the problem of radiation safety in medical institutions carrying out the radiological manipulations has not been solved yet. In available publications we have not found the information on the efficiency of protection and radiation loads for the medical personnel at the use of modern semi-automatic protective lines. Therefore, we have carried out the complete radiation-hygienic

research of working conditions and levels of irradiation doses for separate professional groups of the medical personnel in the departments of radiotherapy equipped with semi-automatic protective lines, which design provides various principles of a storage, transportation, patients' treatment and etc. Five of radiotherapy departments of the oncology institutions have been surveyed in 3 cities of the Republic.

The efficiency of protection of the personnel workplaces was determined by the dosimeter device FAIT-1 (8) and gamma-dosimeter DRG3-03; the level of the irradiation dose for the personnel – by "IFKU" method with the use of dosimeter film type RM and a set of thermoluminescent dosimeters type KTD-02M-02.

As research has showed, the labor conditions and radiation loads for the medical personnel of radiological departments depends on a rational building planning, design peculiarities of semi-automatic protective lines and protective equipment, way of preparing the radioactive applicators and labor organization. The radiological departments can conditionally be divided into three groups according to the design of the used protective equipment:

- First group - equipped with typical protective devices (protective containers, wash-bowls, sterilizer, screens);
- Second group - equipped with the semi-automatic lines and typical protective devices;
- Third group - equipped with the semi-automatic protective sets.

Dosimetry results have shown, that not all the typical protective equipment and the semi-automatic lines provide appropriate protection of the personnel. In radiological departments the first group of radiation doses capacity of workplaces make 0,5 -30 mcR.c^{-1} (0,129 - 7,74 per kg), and levels of irradiation dozes for the medical personnel - 17-285 mcR per month.

The second group radiological departments the semi-automatic protective lines does not always meet the primary purposes due to the unreasoned binding to the rooms planning premises and other reasons. The irradiation doses of the medical personnel at these departments make 25-313 mcR per month.

In the third group of departments semi-automatic protective complex is combined with relevant planning of the functionally important rooms, therefore the level of irradiation doses for the personnel here makes 10-37 mcR per month, i.e. 2-5 times lower, than in the first two groups of departments.

By results of inspection there have been determined several rules and principles, adherence to which will make it possible to reduce irradiation doses:

1) to limit the number of unnecessary examinations, in which this or that worker annually takes part;
2) to use remotely controlled means; additional protection means for the personnel (attached and suspended screens), especially in horizontal position of device stand.
3) medical irradiation is characterized by its extremely irregular distribution in human body. Therefore, it is necessary to take into account the effective dose concept - for estimating of radiation influence on the man at various types of procedures and for comparing irradiation of the population as a result of medical interventions with irradiation from other sources.

There has been made a decision on the formation of the state specialized program for decreasing the dose of irradiation from medical sources for the population without reducing of necessary number of diagnostic research examinations and at the same time, increasing their quality.

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FORMATION OF DOSE FIELDS IN SHORT-DISTANCE GAMMA- THERAPY

Kazimova G.V[1]., Zaredinov D.A[2].

Second Tashkent State MedicalInstitute, Tashkent, Uzbekistan

Abstract

In clinical radiology there has been a tendency for developing specialized devices. One of them is short-distance gamma-therapy device for irradiation of centers with depth of bedding - 2-6 cm. We have studied the devices for short-distance gamma- therapy and their design provides for static and mobile irradiation. For assessing irradiation efficiency of short-distance device we have compared dose fields of distributions received in static irradiation with X-ray and long-distance Co devices. Efficiency factor, average dose and the degree dose homogeneity in the center, surface dose were taken for criteria. Absorbed doses were calculated by numerical integration up to 10% of isodose provided that 100% dose was equal to 1 Gray For the average dose in the center we have taken an average dose value in the depth of the center depth, calculated by numerical integration as per isodose map. . For the degree of dose homogeneity in the depth of the center we have taken percentage dose deviation at edges of the center from average value. The comparison of dose fields at various methods of irradiation of the center with small depth of bedding has proved the expediency of use of short-distance Cs gamma-devices, especially in mobile mode.

Keywords: gamma, therapy devices, Cs, Co, X-ray, dose distribution.

In clinical radiology there has been a tendency for developing specialized devices. One of them is short-distance gamma-therapy device for irradiation of centers with depth of bedding - 2-6 cm. From dose distribution it has to meet the following requirements: sharp recession of doze after specified depth, uniformity of dose within the limits of the center, mild influence on coverlets. Out of isotopes of ^{60}Co and ^{137}Cs used in remote gamma-therapy International Atomic Energy Agency (IAEA) recommends Caesium for short-distance irradiation, for several advantages:

- long half-life period - 30 years (in one year the activity of Cs source falls only by 2%, and the devices with this isotope practically do not require recharging);
- Cs devices are more economical. Owing to the fact that ^{137}Cs radiation energy is almost two times less than that of ^{60}Co, the devices with ^{137}Cs source can be more compact, light and can enable the irradiation of difficult of access body parts of a patient. For this reason they can be installed in smaller rooms, and the protective walls can be much thinner. A typical room for X-ray therapy can easily be reequipped into Cs gamma-therapy room by having strengthened protection only from a primary beam (energy of radiation quanta diffused in patient's body does not exceed 270 keV).

In short-distance gamma-therapy the problem of penumbra connected with the large sizes of Cs source does not arise, as it can be reduced by using replaceable collimators to be placed very closely to the irradiated surface. At the same time, by using Co-60 of the same activity it is impossible to ensure adequate protection with limited sizes of the radiation head, but using replaceable collimators is practically impossible because of their large weight. We have studied the devices for short-distance gamma- therapy and their design provides for static and mobile irradiation. The device is charged with Cs source with activity 3,7 Terrabecquerel, diameter – 10mm, height - 20 mm. For

irradiation period the source with the help of a flexible cable moves from container - depository along a curved - linear cannel into the working head. Replaceable collimating insets made of tungsten alloy and replaceable localizer-pipes are fixed to the working head for the formation of gamma-radiation beam.

During mobile irradiation the source rotates uniformly around the axis of the working head and owing to collimating inset radiation beam is formed, and the axle of which describes a conic surface with the center on in the axis of rotation. This way of beam formation makes it possible to concentrate the energy of radiation on certain depth, to form much more even irradiation of the center and to reduce radiation load on skin. By changing beam parameters (its size, form, angle of inclination to the rotation axis), changing source rotation radius and source - surface distance, it is possible to form dose fields that meet the set requirements.

Dose fields were investigated with "Minirad" dosimeter as well as with calibrated scintillation dosimeter DRG3-02 and phototechnical film such as FP. The phantom with dimensions 25x25x25 cm represented a set of plates of plexiglass with thickness 1cm.

When drawing a table of doses distribution in static mode of irradiation we take maximum dose capacity along beam axis for 100 %. The field size was determined according to 50% isodose at a depth of the maximum ionization. On the basis of experimental data we compiled a set of isodose maps. Dose capacity on the depth of 0,15 cm and the distance between beam source and irradiated surface 7, 10 and 15 cm makes 50, 24 and 7 $R.min^{-1}$, accordingly.

In short-distance therapy special attention should be paid to the influence of electronic components into surface dose, which is connected with short distance between collimating system and the surface of patients body. The results of experiment have shown, that the filter made of brass of 0,3mm thickness and strengthened on the outlet of the forming opening (in the absence of compression bottom on the tubule) considerably removes secondary electrons.

For assessing irradiation efficiency of short-distance device we have compared dose fields of distributions received in static irradiation with X-ray and long-distance Co devices. Efficiency factor, average dose and the degree dose homogeneity in the center, surface dose were taken for criteria. Absorbed doses were calculated by numerical integration up to 10% of isodose provided that 100% dose was equal to 1 Gray. For the average dose in the center we have taken an average dose value in the depth of the center, calculated by numerical integration as per isodose map. For the degree of dose homogeneity in the depth of the center we have taken percentage dose deviation at edges of the center from average value. Surface dose was determined at a depth of h=0 cm. The values of the chosen criteria were determined at irradiation of the conditional center: cross size - 4 cm, vertical - 2,5 cm, average depth of bedding – 3 cm, and size of a body along beam direction - 15 cm. Irradiation time - 30 minutes.

The comparison of dose distributions at static irradiation on short-distance Cs and long-distance Co devices has shown, that efficiency of the latter is 1,8 times lower, and it is reduced with increase of body size along beam direction. Average dose in the center at a depth on long-distance Co device makes 68 % of all dose loads, and on short-distance - 97 %. The error of dose homogeneity degree at a depth of the center makes ± 25 % and ± 15 % accordingly.

Technical and economic factors play a special role under such conditions. Alongside with long service life, use of ^{137}Cs provides for not only the economy of shielding materials, but, owing to reducing of radiation head dimensions, makes it possible to reduce source - center distance and thus to decrease the dimensions and weight of the device, which is especially significant at rotary irradiation.

The comparison of dose fields at various methods of irradiation of the center with small depth of bedding has proved the expediency of use of short-distance Cs gamma-devices, especially in mobile mode.

Estimating relative advantages of such device and opportunities for its use, it is necessary to remember, that it gives relatively small dose capacity of gamma-radiation on the axis of rotation.

NEW PROSPECTIVE MATERIALS FOR MEDICAL ROENTGENOLOGY

V.I.Pechonkin, I.S.Nosov
Russian Medical Technologies, St-Petersburg, Russia,
Tel.+007 812 126 16 49, E-mail:Besotra@mail.neonet.Lv

ABSTRACT

The authors in collaboration and with the aid of a range of Russian and Ukrainian research and industrial enterprises worked out and developed production of elastic material for manufacturing means of individual protection for patients and for the medical staff. The designed material is lead-free, has the density about 3 g/cm^3 and its protection characteristics are 1.5-2 times those calculated. By the present time the authors have been working hard at designing and developing production of other protective materials containing polydisperse fillers. The same proportion between the weight and protection characteristics is typical for other materials.

Another very important area of practical application of polydisperse materials is using them as a base for producing items with roentgen-contrast characteristics which are widely used in medicine .

The filaments designed by the authors can be successfully used in surgery as sutures or as cloth or tampon markers at intracavitary operations; they also can be used for making skin or cavity markers for X-ray diagnostics or X-ray therapy, and be introduced as well into the materials of catheters for conducting intervention radiology.

NEW PROSPECTIVE MATERIALS FOR MEDICAL ROENTGENOLOGY

V.I.Pechonkin, I.S.Nosov
Russian Medical Technologies, St-Petersburg, Russia,
Tel.+007 812 126 16 49, E-mail:Besotra@mail.neonet.Lv

Since Roentgen's discovery of X-rays that was a little more than a hundred years ago a huge practical and theoretical experience has been obtained in the field of X-rays application in various areas. The most impressive area is medicine where about 80% of total number of diagnoses are made on the grounds of radiological examination [1].

Together with its obvious advantages, wide use of X-rays has a certain number of negative points, such as harmful influence on the organism, as medical practice of many years has shown. This gives a boost to the development of a large technical and research area that designs means of protection both for individual and public use.

Designing of screens of different kind should be admitted to be the major direction of development in this area. Those screens allow either to detect the source of radiation, or to protect people from unnecessary radiation. Usually X-ray screens are made of materials that include metal-containing fillers. The principle of their work is based on the interaction of ionizing radiation quanta with the chemical elements having a high section of interaction. This principle can be described by well-known equation [2]:

$$I = I_0 e^{-\mu x}$$

Before recent time there were no doubt that to increase protective properties of a material you have to increase the screen thickness X and that coefficient of linear attenuation μ is an individual parameter of a material and doesn't depend on its state of aggregation.

However recent research, fulfilled on the materials being in polydisperse state demonstrated the results which allow to consider the above-mentioned provision in a more critical way. In this paper we are going to review only practical application of the results, the details of the research procedure being described in [3-6]. Analysis of the experiments shows that using polydisperse fillers for designing X-ray screens significantly increases their efficiency, which, providing the thickness X is constant, is possible only by increasing the values of μ.

From the practical point of view this means broad perspectives of creating a new range of highly effective protective materials, where either fillers of lighter elements or traditional heavy fillers, but in smaller proportion, might be used. In the area of building construction from this group of materials plasters, under-paint putties, panels, paints, wallpaper etc. are used; in the field of machinery construction -plastic materials, composition materials of different kind, paint primers, films etc.; in medicine - fabrics, fibrous materials, stretches and rubbers.

As it is seen from the short list above, the area of using materials with polydisperse fillers is really wide, although on the way to practical realization of the perspectives mentioned above there is quite a number of difficulties of both theoretical and technical kind. Nevertheless, at the moment it is already possible to report some results of introducing our work protected by patent [7] into practice.

The authors of the patent in collaboration and with the aid of a range of Russian and Ukrainian research and industrial enterprises worked out and developed production of elastic material for manufacturing means of individual protection for patients and for the medical staff. The designed material is lead-free, has the density about 3 g/cm^3 and its protection characteristics are 1.5-2 times those calculated. It means that, for example, a radiologist's apron, which has a lead equivalent 0.35 mm, weighs twice as little as the usual

-6 kg of an apron made of leaded rubber. The same proportion between the weight and protection characteristics is typical for other materials.

By the present time the authors have been working hard at designing and developing production of other protective materials containing polydisperse fillers. First of all it includes developing of construction compositions which could replace barytes in short supply. Experiments with panels, blocks and plasters based on gypsum with polydisperse metal-containing filler show that at density between 1.3 -1.4 g/cm^3 these materials provide the protection which is equivalent to 0.8 -1 mm lead layer. Items made of such materials unlikely those made of barytes can be used in manufacturing load-carrying structures, because strength characteristics of gypsum practically don't change.

Besides those mentioned above some other materials with protective properties are being designed and tested. They include film-forming compositions for building and machinery construction, for example such materials as under-paint putties, paint primers and paints.

Another type of materials for machinery building includes thermosetting and thermosoftening plastics for manufacturing machine elements, mainly frame details aimed either to protect the surrounding environment from internal X-ray radiation or to protect parts and units of the machines, mainly electronic parts, from external radiation.

It is also important that technological process of manufacturing a protective material itself with polydisperse filler, whatever it is (elastomers, plastic materials, construction materials etc.), doesn't differ from the traditional one. Hence in this process the standard industrial equipment available can be used. Only the part of the equipment which is intended for preparing fillers will require some adapting or modernization.

It should be noted that abnormally high ability of polydisperse mediums to decrease the intensity of X-ray radiation allows to create an absolutely new type of protective materials, both woven and non-woven, which are both light and efficient. Such materials will become widely used in making different types of protective clothing for the sphere of medicine and other fields where there is a hazard of X-ray injury. Pre-conditions for developing such materials underlie in the nature of polydisperse mediums, because particles of metal-containing fillers being the sizes of the order of μm and nm easily penetrate into the structure of fibrous materials and get fixed there firmly.

Another very important area of practical application of polydisperse materials is using them as a base for producing items with roentgen-contrast characteristics which are widely used in medicine . For instance, at the present time roentgen-contrast sutures for surgical operations are made from either high-filled synthetic compositions, which might be bad for the patient, or by means of intertwining roentgen-contrast metal filaments into the textile warp [8-9]. In both cases such tendencies as deterioration of the filaments, decreasing of their mechanical properties, bad influence of the filler material on the organism tissues have been observed.

Sutures made by means of treatment in polydisperse mediums practically don't suffer any of the above mentioned disadvantages. As a metal filler we have chosen chemically pure wolfram with the size of particles 10^6 and less, and as a warp -filaments of various origin, such as silk, viscose rayon, flax, polyester and others. Treated in poly-disperse mediums filaments were subjected to sterilization by different means, kept in neutral and biologically active mediums, introduced into bodies of experimental animals. This research was conducted during six months. Visual examination of the experimental rats didn't show any negative reaction of the body to the material of the filler forming the filaments [10]; control radiography showed no change in the filaments contrast during the whole experimental period. On the X-ray photographs density of blackening of the patterns of the filaments having the optical diameter between 0.2 and 0.3 mm was at the same level as 0.05 mm Pb, the filaments with diameter between 0.5 and 0,7 mm show higher contrast on X-ray photographs than filaments of the same type "Micropake - 600" (Great Britain) [5].

Simultaneously with studying contrast features of the filaments we carried out comparative testing of their mechanical characteristics before and after then-treatment in polydisperse mediums. The results show that the filaments strength didn't change significantly and was 90 -95% of their strength before the treatment. The treatment didn't influence the knotting strength of the filaments either. As for mechanical characteristics of the filaments, the results obtained can be simply explained: during the treatment in polydisperse mediums the filaments absorb metal-containing filler in the volume not exceeding their weight by more than 20%. If we take into consideration the fact that filament and filler don't interact chemically but only form a mechanical contact without breaking the intact structure of the warp, we can say that there is no influence on mechanical properties of the filaments. It was also proved by experiments that adhesion of polydisperse particles of the filler is enough to keep them firmly fixed in the warp, which permits use those filaments in practice.

The filaments designed by the authors can be successfully used in surgery as sutures or as cloth or tampon markers at intracavitary operations; they also can be used for making skin or cavity markers for X-ray diagnostics or X-ray therapy, and be introduced as well into the materials of catheters for conducting intervention radiology.

Other materials and items used in medicine may also be made roentgen-contrast if visual observation of the geometry or location of the organs subject to examination is required.

A very important advantage of roentgen-contrast materials designed by the authors of the patent is their clear visualization at radiography examination. It sounds especially important if we take into consideration the fact that radiological examination can be conducted at reduced energies of X-rays without loss of essential information. This, in its turn, decreases the load of X-ray radiation on the patient while carrying out various medical examinations.

In conclusion we would like to note that today there isn't any single satisfactory hypothesis which could explain interaction of X-ray radiation with materials in polydisperse state. However this fact shouldn't prevent application of those materials in different fields of activity that would lead to improving our micro-environment.

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EVALUATION OF DIAGNOSTIC RADIOLOGY SERVICES IN FIVE LATIN AMERICAN COUNTRIES

M.-E. Brandan,
IFUNAM, A.P. 20-364, México 01000 DF, Mexico

C.E.M. Caspani,
RFSF, Obispo Gelabert 3586, (3000) Santa Fé, Argentina

R. de la Mora,
CCEEM, Calle 4 e/ 19 y 21 No. 455 altos, Vedado, La Habana, Cuba

A.A. Miranda,
IBTEN, Avda. 6 de Agosto 2905, La Paz, Bolivia

M.-C. Plazas,
INC, Avda. 1, no. 9-85, Santafé de Bogotá, Colombia

and C. Borrás
PAHO/WHO, 525 Twenty-third St., N.W., Washington DC 20037-2895, USA

Abstract

Under the auspices of PAHO/WHO, a multicentric investigation is carried out in five Latin American countries. Its aim is to correlate quality indicators of radiology services with the accuracy of the radiological interpretation as determined by a panel of experts. We present preliminary results from mammographic imaging facilities, which indicate that the failure to comply with the international standards of quality control produces images of unacceptable quality, as measured either by using a phantom or by an independent evaluation of the clinical images.

Correspondence should be addressed to:
María-Ester Brandan, Ph.D.
Instituto de Física UNAM
A.P. 20-364
México 01000 DF
Mexico
FAX: (525) 616-1535
brandan@servidor.unam.mx

1. Introduction

Quality assurance programs in health services, in particular in radiology services are slowly being implemented in Latin America and the Caribbean some under Government Regulations. They will require the conjunction of strong political will, financial support and professional training to become a relevant factor in the routine service offered by radiological facilities. The Pan American Health Organization/World Health Organization, (PAHO/WHO) coordinates and partially funds an investigation aimed at *correlating quality indicators of radiology services with the accuracy of the radiological interpretation.* Grants have been awarded to government, academic and/or professional multidisciplinary teams in Argentina, Bolivia, Colombia, Cuba and Mexico to pursue these studies following common procedures based on internationally accepted protocols. The project should be completed after 12 months of work, and here we present preliminary results obtained during the first half of the grant duration.

2. Experimental procedure

2.1 Selection

The selected pathologies (and their associated radiological technologies) are: breast lumps (screening and diagnostic mammography), gastrointestinal ailments (radiography and fluoroscopy), back pain (computed tomography) and tuberculosis (radiography). The selected services belong to the medium complexity classification and are located in urban areas. The common quality control protocols are based on those endorsed by the American College of Radiology (ACR) [1], the American Association of Physicists in Medicine (AAPM) [2], the European Community (EC) [3], etc. The panels of radiology experts in charge of evaluating the accuracy of the radiological interpretation are endorsed by the national radiological societies.

2.2 Documentation

Records are collected in relation to the population covered by the services (public vs. private), the type of facility, the patient workload, the radiological, imaging and processing equipment and supplies, the staff education and training, the quality assurance and maintenance programs and the radiation safety standards.

2.3 Measurements

The measurements performed include the evaluation of devices (X-ray units, image receptors, and image processors), darkroom and viewing conditions, patient dose, and image quality. The clinical film evaluation by the expert panels considers imaging aspects (view and labeling, patient positioning, contrast and latitude, and artifacts) as well as the radiological interpretation report performed at the radiological service by the local physicians.

3. Results for mammography

Results from the study of mammography services are available from the five teams. The IFUNAM group evaluated a total of 31 parameters in three mammo units [4] functioning in two Mexico City public hospitals. The out-of-compliance results corresponded to beam collimation and alignment (in the three units), viewbox illuminance and homogeneity (in the three units), and darkroom conditions. One of the units, "Number 1", operated at an X-ray tube potential 10% higher than the nominal value and the cleanliness of the intensifying screens was considered totally unacceptable. In this unit "Number 1", chemicals' temperature in the two film processors was monitored during one month, finding unacceptable results (discrepancy larger than 2° C between the unit temperature reading and that given by the control thermometer). Image quality was evaluated using the ACR accreditation phantom under five technical factors, as indicated by the ACR protocol [1]. Unit Number 1 failed the criterion for acceptable contrast, optical density and resolution at all five tube factors. The other two systems passed the test in either one or two, out of the five technical modalities. Mean glandular doses were calculated out of kerma in air measurements performed according to the ACR manual; the obtained values are 1.4, 1.6 and 1.0 mGy respectively.

The RFSF group studied four mamography units, each at a different hospital in the city of Santa Fé. All systems passed the 8 tests performed on the equipment performance (focal spot size, beam alignment, tube potential accuracy and reproducibility, timer accuracy, HVL, air kerma rate, SID, leakage radiation). However, all of the viewboxes were out-of-compliance due to their poor illuminance homogeneity. The radiological interpretation study was performed with 25, 20 and 16 clinical images obtained in three of the hospitals. The image quality was evaluated by a Panel that gave qualifications equal to 2.9, 3.2 and 4.2, over a maximum of 5. The lowest grade was due to finding 24/25 films dirty, 17/25 scratched and 12/25 with artifacts which simulated microcalcifications. The positioning was evaluated by the Panel with grades equal to 3.3, 4.3 and 3.6 over a maximum of 5. The diagnosis by the Panel coincided with that by the hospital facility in 60/61 cases.

The CCEEM group evaluated 255 clinical films corresponding to 80 patients in 2 hospitals. Positioning problems were detected and correlated with technologist training. The radiological interpretation by the Expert Panel coincided with that by the institution in 68/80 patients. Of the 80 patients, 27 received fine needle aspiration biopsy, as part of their clinical management. In 21 of them, the biopsy was done in patients where the panel and the facility physician concurred in the radiological interpretation. 2 biopsies confirmed the institution's assessment, and 4 concurred with the Panel.

The IBTEN group evaluated 64 clinical films from 28 patients obtained at 2 hospitals and one clinic. The Panel detected positioning problems as well as inadequate film labeling for 27/28 patients.

The INCAN group performed quality control measurements on 3 units belonging to 2 hospitals in Bogota. 24 tests on equipment performance were used. The units were out-of-compliance in 4%, 4% and 30% of these tests, respectively. The system which presented the most serious problems, "Hospital 2", lacks a maintenance program and the radiation safety conditions were considered inadequate. The mammo Expert Panel analyzed 20 films obtained with this same system. The results showed that none of the films had a label recording the technical parameters. Furthermore, 28% of the oblique and 18% of the craneocaudal views were considered non acceptable in terms of technical quality, and 45% of the films were considered to present a non acceptable optical density.

4. Conclusions

We have presented partial results for the evaluation of mammographic equipment performance, image quality, dose and radiological interpretation corresponding to 14 systems in five Latin American countries. Even though the study is still in progress, some general results seem to appear already. The UNAM and INCAN results indicate a correlation between the failure to pass the equipment quality control tests and the poor quality of the image;, this one assessed either using the accreditation phantom or as determined by the panel of radiology experts. Concerning the dose to the patient, the only calculations to date (UNAM) indicate values well below the guidance levels published in the BSS [5], but similar to those published by the FDA in their MQSA program [6]. Since the ultimate goal is an image of sufficient diagnostic quality to produce an accurate radiological interpretation, the possibility that low values indicate insufficient film exposure needs to be explored. The completion of the tests, and a careful statistical analysis of the results, as well as the study of other radiological techniques, should help better understand the intricate relation among the various equipment parameters and the final image quality in radiological procedures. The knowledge and experience gained by the participants of these five research teams should promote better conditions for radiological services in Latin America and the Caribbean

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TOTAL BODY ELECTRON BEAM IRRADIATION IN THE TREATMENT OF PATIENTS WITH CUTANEOUS LYMPHOMA

C. Badri, M. Djumadi

Department of Radiotherapy, Dr. Cipto Mangunkusumo Hospital, Jakarta – Indonesia.

ABSTRACT:

Total body skin electron irradiation is a radiotherapy technique that needs special dosimetry system for regulating dose distribution in order to homogenize radiation dose on body surface and to avoid radiation dose that exceed dose tolerance of subcutaneous tissue and other normal tissues. The type of radiation to be used is electron beam with energy depends on the thickness of the target volume of tissue to be treated, usually between 4 to 6 MeV.

Dosimetry system for that purpose in our institution depends on facilities available. For regulating dose distribution, SIDOS U-2 treatment planning system has been used. The method was a combined electron beam angles with multiple fields technique.

Patient's body was divided into 4 parts from head to feet, sizes 50 x 50 cm and each parts received 6 radiation fields with crossing field axis forming 60 degrees angles.

Radiation field borders were shifted regularly using moving strip technique with 2 cm steps and were turned back after 20 % of field encompassed.

Each patient was irradiated with a dose of 3 Gy per week with the total dose of 35 Gy within 12 weeks.

The determination of monitor unit was calculated using conversion of monitor unit of SIDOS U-2 with calibration output factor. The determination of PTV width was calculated by conversion PTV of SIDOS U-2 with calibration factor of electron energy.

Sensitive organ was shielded, i.e using eye shields and additional bolus for nail, fingers and ears.

Dose verification was done by TLD and demonstrated a good result with an average deviation less than 5 % of each patients.

Key words : total body skin radiation, electron beam shaping, dose verification, cutaneous lymphoma

DOSES TO PATIENTS FROM DIAGNOSTIC RADIOLOGY IN ROMANIA

Olga Iacob, Cornelia Diaconescu
Institute of Public Health-Iasi, Radiation Protection Department
14, Victor Babes Street Iasi-6600, Romania, Fax: 40 032 210399, E-mail: **olga.iacob@usa.net**

ABSTRACT

Effective doses to over 2400 patients undergoing 20 most important types of X-ray examinations have been estimated from entrance surface doses or dose-area products, measured in 27 X-ray departments, and the appropriate conversion coefficients calculated by the NRPB for six mathematical phantoms representing 0, 1, 5, 10, 15 year old children and the adult.The patient-weighted mean effective dose from X-ray examinations performed annually in Romania is 1.32 mSv, with 1.40 mSv for the average adult patient and 0,59 mSv for the average paediatric patient. The corresponding annual collective effective dose is about 13,430 manSv, with the main contribution belonging to adult patients (95%), the remainder of 5 percent – to paediatric patients.

INTRODUCTION

Diagnostic radiology represents throughout the world the largest manmade source of public exposure to ionising radiation. In Romania, on our last estimate, its contribution to the annual collective effective dose from artificial radiation sources is about 90 percent [1].

The present work intended to update the magnitude of patient exposure (children and adults) during conventional diagnostic X-ray examinations performed annually in Romania.

METHODS

Individual effective doses to over 2400 patients undergoing 20 most frequently performed types of X-ray examinations at 27 diagnostic X-ray departments have been derived from entrance surface dose (ESD) measured with TLD-100 thermoluminiscent dosemeters directly stuck to the patient's skin or dose-area product(DAP) measured by a Diamentor transmission ionisation chamber attached to the diaphragm housing of the X-ray set [2].Appropriate conversion coefficients, calculated by the NRPB using Monte-Carlo techniques on a series of 6 mathematical phantoms representing 0, 1, 5, 10, 15 year old children as well as the adult, have been applied [3, 4].The age-dependent frequencies of X-ray examinations necessary for the annual collective effective dose and the average patient effective dose calculation are those reported by our last national study on medical exposures, published in the UNSCEAR-2000Report [5].Measurements have been carried out from July 1997 to July 2000 and all dosemeters have been calibrated at WHO Regional Reference Centre for Secondary Standard Dosimetry, Bucharest, Romania.

RESULTS

Tables I –VI summarise the results of our survey on patient exposure during X- ray examinations in terms of Dose-Area Product (DAP), Entrance Surface Dose (ESD) and effective dose per examination.

Table I Individual and annual collective effective doses to **0 year** old patients.

Examinations	Annual number of patients	DAP (Gy cm^2)	Effective dose (mSv)	Annual collective effective dose (man Sv)
Chest radiography	35,998	0.11 ± 0.05	0.18 ± 0.08	6.5
Full spine	1,103	2.2 ± 1.3	3.5 ± 2.4	3.9
Pelvis, hip	8,761	1.7 ± 1.4	3.1 ± 0.8	27.2
Head	8,395	0.80 ± 0.10	0.32 ± 0.07	2.7
Abdomen	3,215	1.2 ± 0.8	2.0 ± 1.3	6.4
Cystourethrography	2,246	2.4 ± 1.0	5.6 ± 2.2	12.6
Urography	473	5.4 ± 2.8	8.6 ± 4.5	4.1
Limbs, joints	3,065		0.08	0.2
All medical examinations	63,256		1.0	63.6

Table II Individual and annual collective effective doses to **1 year** old patients.

Examinations	Annual number of patients	Dose Area Product (DAP) (Gy cm^2)	Effective dose (mSv)	Annual collective effective dose (man Sv)
Chest radiography	63,334	0.17 ± 0.09	0.11 ± 0.07	7.0
Chest fluoroscopy	12,882	0.80 ± 0.45	0.53 ± 0.30	6.8
Full spine	2,190	4.6 ± 3.9	3.2 ± 2.7	7.0
Pelvis, hip	23,280	3.8 ± 1.4	3.5 ± 1.3	81.5
Head	5,025	2.0 ± 0.9	0.28 ± 0.11	1.4
Abdomen	12,860	0.46 ± 0.20	0.20 ± 0.10	2.6
Cystourethrography	3,546	1.8 ± 0.8	2.9 ± 1.1	10.3
Urography	709	10.8 ± 4.7	6.1 ± 2.7	4.3
Limbs, joints	60,872		0.08	4.9
All medical exams	184,698		0.68	125.8

Table III Individual and annual collective effective doses to **5 year** old patients.

Examinations	Annual number of patients	DAP (Gy cm^2)	Effective dose (mSv)	Annual collective effective dose (man Sv)
Chest radiography	65,770	0.31 ± 0.12	0.10 ± 0.04	6.6
Chest fluoroscopy	86,061	0.76 ± 0.42	0.38 ± 0.21	32.7
Full spine	1,314	7.2 ± 4.4	4.0 ± 2.1	5.3
Pelvis, hip	10,200	5.1 ± 2.5	3.0 ± 1.6	30.6
Head	12,530	5.3 ± 2.8	0.30 ± 0.16	3.8
Abdomen	4,296	1.3 ± 0.7	0.8 ± 0.3	3.4
Cystourethrography	2,492	4.6 ± 1.4	2.4 ± 0.7	6.0
Urography	945	6.2 ± 3.3	3.8 ± 1.6	3.6
Barium meal	9,252	1.6 ± 0.8	1.0 ± 0.5	9.3
Limbs, joints	51,676		0.08	4.1
All medical exams	244,536		0.43	104.4

Table IV Individual and annual collective effective doses to **10 year** old patients.

Examinations	Annual number of patients	DAP (Gy cm^2)	Effective dose (mSv)	Annual collective effective dose (man Sv)
Chest radiography	58,192	0.57 ± 0.20	0.12 ± 0.04	7.0
Chestphotofluorography	12,442	1.1 ± 0.4	0.26 ± 0.10	3.2
Chest fluoroscopy	77,565	1.2 ± 0.80	0.38 ± 0.25	29.5
Full spine	2,628	13.5 ± 5.3	5.3 ± 1.8	13.9
Pelvis, hip	13,080	22.0 ± 7.0	3.6 ± 1.2	47.1
Head	11,702	6.8 ± 2.2	0.34 ± 0.12	4.0
Abdomen	3,190	3.9 ± 2.2	1.2 ± 0.7	3.8
Cystourethrography	516	14.5 ± 5.3	2.5 ± 0.9	1.3
Urography	1182	14.1 ± 9.0	4.2 ± 2.7	5.0
Barium meal	10,453	3.8 ± 1.9	1.6 ± 1.0	16.7
Limbs, joints	54,741		0.08	4.4
All medical exams	245,691		0.55	135.9

Table V Individual and annual collective effective doses to **15 year** old patients.

Examination	Annual number of patients	DAP (Gy cm^2)	Effective dose (mSv)	Annual collective effective dose (man Sv)
Chest radiography	47,365	0.73 ± 0.21	0.13 ± 0.04	6.2
Chest photofluorography	49,769	2.9 ± 0.6	0.40 ± 0.10	19.9
Chest fluoroscopy	97,572	1.8 ± 1.1	0.33 ± 0.25	32.2
Spine - lumbar - cervical	10,283 11,437	18.8 ± 7.1 2.4 ± 1.3	4.5 ± 1.9 0.57 ± 0.32	46.3 6.5
Pelvis, hip	7,260	23.5 ± 10.3	3.4 ± 1.5	24.7
Head	25,950	6.1 ± 2.7	0.21 ± 0.11	5.4
Abdomen	2,161	3.8 ± 1.2	0.85 ± 0.27	1.8
Cystography	194	20.4 ± 6.4	2.2 ± 0.7	1.4
Urography	1418	21.4 ± 11.5	4.8 ± 2.6	6.8
Barium meal	20,346	8.4 ± 5.1	2.1 ± 1.1	42.7
Limbs, joints	48,610		0.08	3.9
All medical examinations	322,365		0.61	196.8

Table VI Annual individual and collective effective doses to **adult** patients undergoing some conventional X-ray examinations

Examination	Annual number of patients	ESD (mGy)	Effective dose (mSv)	Annual collective effective dose (manSv)
Chest radiography	943,059	2.4 ± 1.0	0.25 ± 0.11	235.8
Chest photofluorography	2, 330,493	5.9 ± 2.8	0.63 ± 0.30	1468.2
Chest fluoroscopy	2, 263,700	13.4 ± 5.6	0.95 ± 0.40	2150.5
Spine - lumbar - thoracic - cervical	224,849 75,151 196,513	51.3 ± 24.0 29.5 ± 14.1 10.3 ± 4.9	3.0 ± 1.4 2.1 ± 1.2 0.21 ± 0.1	674.5 157.8 41.1
Pelvis	195,708	17.1 ± 9.4	2.9 ± 1.6	567.6
Hip	69,761	19.2 ± 5.6	1.7 ± 0.5	118.6
Head	390,695	20.0 ± 14.1	0.17 ± 0.12	66.4
Abdomen	312,728	19.3 ± 10.3	1.9 ± 1.0	594.1
Barium meal	986,902	55.2 ± 25.6	4.1 ± 1.9	4046.2
Barium enema	221,378	83.0 ± 35.0	9.0 ± 3.8	1992.4
Cholecistography	60,199	39.8 ± 22.4	1.6 ± 0.9	96.3
Urography	62,787	48.2 ± 24.0	5.8 ± 2.9	364.2
Mamography	39,973	31.7 ± 15.3	0.62 ± 0.3	24.8
Angiography	14,206	21.3 ± 7.7	0.22 ± 0.08	3.1
Hysterosalpingography	1,050	57.4 ± 23.5	6.6 ± 2.7	6.9
Lung tomography	52,804	18.0 ± 9.6	2.8 ± 1.5	147.8
Limbs, joints	693,390	6.6 ± 2.5	0.08 ± 0.03	55.5
All medical examinations	9,135,346		1.40	12.812

Table VII presents the patient-weighted effective doses per examination and the annual collective effective doses received by patients as a result of one year of diagnostic conventional X-ray examinations in Romania. The values are of 1.32 mSv from all medical exams and 13,432 manSv for collective dose.

Table VII Exposure from diagnostic radiology in Romania

Examinations	Annual number of examinations (1995)	%	Effective dose* (mSv)	Annual collective effective dose (manSv)	%
Chest radiography	1,213,718	11.90	0.22	269.1	2.0
Chest photofluorography	2,392,704	23.46	0.62	1491.3	11.10
Chest fluoroscopy	2,537,780	24.89	0.89	2251.7	16.76
Spine - lumbar	236,186	2.32	3.02	714.0	5.32
- thoracic	81,332	0.80	2.35	190.9	1.42
- cervical	207,950	2.04	0.21	44.6	0.33
Pelvis	253,837	2.49	2.66	675.4	5.03
Hip (both)	74,213	0.73	2.99	221.9	1.65
Head	454,297	4.45	0.18	83.7	0.62
Abdomen	338,450	3.32	1.81	612.1	4.56
Barium meal	1,026,953	10.0	4.0	4114.8	30.63
Barium enema	221,378	2.17	9.0	1992.4	14.83
Cholecistography	61,428	0.60	1.57	96.3	0.72
Urography	67,513	0.66	5.75	388.0	2.89
Mammography	40,336	0.40	0.61	24.8	0.18
Angiography	14,206	0.14	0.22	3.1	0.02
Hysterosalpingography	1,050	0.01	6.57	6.9	0.05
Lung tomography	52,804	0.52	2.79	147.8	1.10
Limbs, joints	912,335	8.95	0.08	72.5	0.54
Cystourethrography	8,984	0.09	3.4	30.6	0.23
All medical examinations	10,197,474	100	**1.32**	13,432	100
Per capita			**0.59**		

CONCLUSIONS

The new value of the annual collective effective dose resulting from diagnostic X-ray conventional examinations performed in Romania is of about 13,430 manSv with the main contribution of 95 per cent belonging to adult patients and the remainder of 5 per cent - to paediatric patients.

Unfortunately, fluoroscopic examinations have had a contribution of more than 60 per cent to this annual collective effective dose and barium enema was associated with the highest effective dose - 9 mSv.

The patient - weighted mean effective dose from X-ray examinations performed annually in Romania is 1.32 mSV with 1.40 mSv for the average adult patient and 0.59 mSv for the average paediatric patient.The annual per caput effective dose due to diagnostic radiology in Romania is 0.59 mSv.

The knowledge of the real level of patient dose is an essential component of quality assurance programs in diagnostic radiology.

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REFERENCE DOSE LEVELS IN DIAGNOSTIC RADIOLOGY IN ROMANIA

Olga Iacob, Cornelia Diaconescu

Institute of Public Health-Iasi, Radiation Protection Department
14, V.Babes Str. Fax: 40 032 210399, E-mail: olga.iacob@usa.net

ABSTRACT

Reference dose values for diagnostic medical exposure represent a useful and practical tool for promoting the optimisation of patient protection. These reference levels are expressed in terms of directly measurable dose quantities and have the function of investigation levels to help identify hospitals where the dosimetric performance is potentially unacceptable.

In order to establish the reference dose levels in diagnostic radiology in Romania, measurements of entrance surface dose per radiograph and dose-area product per examination were carried out on over 3100 selected adult patients undergoing 11 most frequently performed X-ray examinations in 25 randomly selected hospital X-ray departments.

The entrance surface dose measurements have been made with TLD-100 thermoluminescent dosemeters stuck directly to the patient's skin and dose-area product measurements have been performed by a Diamentor transmission ionisation chamber attached to the diaphragm housing of the X-ray set.

The reference dose values for: lumbar spine (AP, LAT), thoracic spine (AP, LAT), cervical spine (AP, LAT), chest (PA, LAT), skull (AP, PA), abdomen (AP), pelvis (AP), intravenous urography, chest fluoroscopy, barium meal and barium enema have been established as NRPB and EC recommendations, based pragmatically on rounded third quartile values for the distributions of mean dose at individual radiological services participating in survey.

INTRODUCTION

Over two decades surveys of radiological practice in Romania have demonstrated wide variations in patient dose levels between different hospitals. Local and national investigations [1, 2] revealed poor performances as well as of radiological equipment, darkroom procedure or technology of investigation.

Hitherto, the annual collective effective dose to the population of Romania from diagnostic medical exposures attained a value of 13,820 manSv [3]. Since the annual frequencies of radiological examinations remain unchanged over last ten years, this value is mostly attributed to the individual dose levels in different X-ray procedures [4, 5].

Notwithstanding the huge benefits to patients, the reduction of unnecessary exposures and individual doses are our principal concern and the establishment of national reference dose levels should solve this problem. British experience demonstrated that reference doses are a practical tool in this purpose and the adoption of national reference dose values indicated an overall improvement in patient exposure [6, 7, 8, 9]. Even the local of reference dose values proved an useful way to achieve patient dose reduction. In meantime the optimization of patient protection, each X-ray examination should be conducted with lowest necessary dose to achieve the clinical aim.

This paper presents the first approach to establish local reference dose levels for some diagnostic examinations based on the measurements made in six (from the eighth of Eastern territory of Romania) districts, invited to cooperate in this end.

MATERIAL AND METHODS

The survey has been carried out in a representative sample of X-ray diagnostic departments consisted of 27 units selected on their annual workload.

Measurements has been conducted by our radiation protection department during the period from July 1997 to July 2000. We have selected over 3100 adult patients undergoing eight most frequently performed types of diagnostic X-ray radiographs: spine - lumbar, thoracic and cervical - (AP, Lat); skull (AP, PA, Lat); pelvis (AP); abdomen (AP); intravenous urography; chest (PA, Lat) and three fluoroscopic examinatios: chest, barium meal and barium enema.

The doses were expressed in terms of directly measurable dose quantities: entrance surface dose (with backscatter) (ESD) for radiographs and dose–area product (without backscatter) (DAP) for fluoroscopies. The ESD measurements have been made with TLD–100 thermoluminescent detectors directly stuck to the patient's skin. DAP measurements have been performed by using a Diamentor transmission ionisation chamber attached to the diaphragm housing of the X-ray set.

All dosemeters have been calibrated at WHO Regional Reference Centre for Secondary Standard Dosimetry–Bucharest. The measurements indicated the typical dose to an average adult patient by the procedures and equipment in current use in X-ray diagnostic departments.

Local reference dose levels have been established as NRPB and EC recommendations, based pragmatically on the rounded third quartile values of the mean dose distributions at individual radiological services [10, 11].

RESULTS AND DISCUSSION

Table I indicates the maximum, minimum and mean values of ESD for 8 commonly used radiographic examinations and the resulted first and third quartiles.

As figures show the range in mean ESD values varies from a factor of 18 to 83. The lowest factor values between 18 to 20 have been found for pelvis, abdomen, intravenous urography and chest. The wider range of ESD from a factor of 20 for thoracic spine (AP) to a factor of 83 for cervical spine (LAT) has been found for X-ray examination of spine and skull.

As an initial guideline should be recommended that all radiology departments should aim to achieve mean dose levels indicated in Table II.

For the moment, the regional reference dose levels, presently established, must be regarded only as a practical tool to increase the awareness of radiological staff of observed levels of patient dose. They are too high to be considered as optimal from radiological protection point of view. We deliberately choused such values in order to permit those "worst" radiological units to improve their conditions.

Table I. Distribution of individual entrance surface doses for radiographic examinations on adult patients

Examination		Entrance Surface Dose (mGy)					
		Mean	Min	1st quartile	Median	3rd quartile	Max
Lumbar spine	AP	17.6	2.0	8.0	15.7	22.3	70.5
	LAT	42.0	4.4	17.4	36.0	59.4	162
Thoracic spine	AP	11.2	2.0	5.1	10.2	15.1	41.0
	LAT	24.0	3.5	15.4	24.2	29.2	97.0
Cervical spine	AP	6.4	0.4	2.0	9.1	9.7	22.0
	LAT	6.6	0.3	3.4	5.8	9.0	25.0
Chest	PA	1.7	0.3	1.2	1.6	2.2	6.0
	LAT	4.2	0.7	3.5	4.0	4.4	13.0
Skull	AP,PA	11.0	1.0	4.8	11.5	15.7	30.5
	LAT	9.4	1.2	3.5	11.5	13.0	27.5
Pelvis	AP	13.2	1.9	5.0	14.4	17.4	35.3
Abdomen	AP	10.9	2.1	5.5	11.2	15.0	37.0
Urography	AP	47.6	12.0	20.5	46.0	63.0	230

Table II. Reference values of entrance surface dose for radiographic examinations on adult patients

Examination	Projection	Reference dose (mGy)
Lumbar spine	AP	20
	LAT	55
Thoracic spine	AP	15
	LAT	30
Cervical spine	AP	9.0
	LAT	9.0
Chest	PA	2.0
	LAT	4.0
Skull	AP, PA	15
	LAT	13
Pelvis	AP	15
Abdomen	AP	15
Urography	AP	60

Table III indicates for fluoroscopic examinations the same dosimetric quantities of individual measurements. The established reference levels of dose–area product for chest fluoroscopy, barium meal and barium enema are presented in Table IV.

The highest factor value between maximum and minimum doses was for chest fluoroscopies (200). It may be explained by extremely differences of X-ray equipments in use, from very old ones to modern devices with TV chain and image intensifiers.

Table III. Distribution of individual dose–area products for X-ray fluoroscopic examination on adult patients

Examination	Dose – area product (Gy cm^2)					
	Mean	Min	1st quartile	Median	3rd quartile	Max
Chest fluoroscopy	3.7	0.1	0.7	3.1	5.2	23.3
Barium meal	21.6	2.1	8.5	16.6	28.2	100
Barium enema	36.6	2.4	26.4	34.5	53.8	116

Table IV. Reference values of dose– area product for fluoroscopic examinations on adult patients

Examination	Reference dose – area product (Gy cm^2)
Chest fluoroscopy	5
Barium meal	30
Barium enema	55

The x-ray examinations of digestive tract had less annual frequencies than chest examination. Consequently, the radiology department sample diminished, so, the dose values are not quite representative. Under such circum-stances, the present values of reference dose–area products should be regarded only as indicative, especially for barium enema exams (11 hospitals), with a limited practical use. More measurements are need in order to achieve reliable reference dose levels and our further efforts should be directed on.

CONCLUSIONS

Regional dose reference levels for most commonly X-ray examinations at the 3rd quartile level have been established in order to increase the general awareness about patient exposure in diagnostic radiology.

25 % of hospitals needing urgent measures for the improvement of their radioprotection performance have been identified.

Some fluoroscopic examinations like barium enema necessitate further measurements to achieve reliable reference dose levels.

The use of examination-specific reference levels of dose promotes the optimisation of protection for patients in diagnostic radiology in Romania, in line with the ICRP philosophy of dose constraints.

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problemas conceptuales

INFLUENCIA DE LA TECNOLOGÍA DIGITAL EN LAS DOSIS AL PACIENTE EN ESTUDIOS RADIOLÓGICOS DEL APARATO DIGESTIVO SUPERIOR

E.Núñez, X.Pifarré, J.Ruiz, C.Escalada, M.C.Paredes
Scio. de Radiofísica. Hospital Universitario Clínica Puerta de Hierro
C/ San Martín de Porres 4. 28035 MADRID. ESPAÑA
FAX: 91 373 05 35

Summary

The radiological study of the superior digestive apparatus (oesophagus, stomach and duodenum) throughout the barium contrast is a kind of exploration which provides medium-high dosage levels for patients. In these studies the fluoroscopy and the acquisition of images for the diagnosis are shared. The acquisition of images, up until a few years ago, was accomplished through radiographic film and chemical processing; nowadays, the new generation of image-intensifier tube incorporates a new utility to digitally capture the images.

This new capturing method, with higher sensitivity, allows us to obtain images with a mAs 5 times smaller than the classical system of radiological film (reduction of the dosage up to 80%). This leads us to expect very important reductions in dosage in the studies conducted with this new technology. Nonetheless, these expectations haven't been reflected in the dosimetric samples that our work team has conducted in several centers of the community of Madrid these past years. In this work, the reasons of this phenomenum are analyzed.

1. Introducción

El estudio radiológico del aparato digestivo superior (esófago, estómago y duodeno) mediante contraste de bario es un tipo de exploración que conlleva niveles de dosis medios-altos para los pacientes. La bibliografía cita valores de alrededor de 8 mSv de dosis efectiva [1]. En estos estudios se simultanea el uso de escopia y la adquisición de imágenes para el diagnóstico. Suelen usarse equipos telemandados con intensificador de imagen.

La adquisición de las imágenes, hasta hace unos años, se llevaba a cabo mediante películas en chasis con pantallas de refuerzo y procesado químico de las mismas; en la actualidad, las nuevas generaciones de telemandos implementan una utilidad de captura digital de las imágenes a través del intensificador. Este nuevo modo de captura, de mayor sensibilidad, permite conseguir imágenes, a igualdad de kilovoltajes, con un mAs cinco veces menor que el sistema clásico de película+pantalla de refuerzo (reducción de dosis de hasta un 80%). Esto hace esperar unos niveles de reducción de dosis muy importantes en los estudios realizados con esta nueva tecnología.

Sin embargo, estas expectativas no se han reflejado en los muestreos dosimétricos que nuestro grupo de trabajo ha llevado a cabo en los últimos años en varios centros sanitarios públicos de la Comunidad de Madrid. En este trabajo se analizan las razones de este fenómeno.

2. Objetivos

El objetivo del presente trabajo es analizar la influencia de los sistemas digitales de adquisición de imagen en las dosis a pacientes en los estudios del aparato digestivo superior (esófago-estómago-duodeno).

3. Material y método

El estudio se basa en la recogida de datos dosimétricos en muestras suficientes de pacientes y en su posterior análisis estadístico. Las medidas se han realizado en cinco equipos distintos ubicados en cuatro centros de la red pública sanitaria española. Los cuatro centros se encuentran en la Comunidad Autónoma de Madrid y se trata de dos Hospitales grandes y dos Centros de Especialidades. Dos de los equipos incorporan sistemas digitales de adquisición a través de intensificador y los otros tres funcionan con película y pantallas de refuerzo (tabla I). En estos tres casos la sensibilidad de las cadenas de imagen es similar, con una velocidad relativa de 400.

Equipo	Marca	Modelo	Ubicación	Adquisición	Línea de imagen
A	General Electric	Prestilix 1600 X	Hospital 1	Digital	-
B	Philips	Multidiagnost 3	Hospital 2	Digital	-
C	General Electric	Telegem II	Hospital 2	Película	Agfa Ortho Regular/ Agfa ST-G2
D	General Electric	Prestilix 1600 X	Centro Especialid. 1	Película	Agfa Ortho Regular/ Agfa ST-G2
E	General Electric	Telegem II	Centro Especialid. 2	Película	Kodak Lanex Regular/ Kodak PDS

Tabla I: descripción de los equipos en los que se ha medido

Se han medido exclusivamente estudios gastrointestinales realizados mediante ingestión de contraste (papilla de bario), también llamados EED's (Esófagos-Estómagos-Duodenos). Para cada paciente se han registrado los siguientes datos de interés:

1. Número de adquisiciones de imagen
2. Tiempo total de escopia (en minutos)
3. Producto dosis x área (en cGy x cm^2)
4. Técnica media de la escopia (kV y mA)
5. Técnica de cada adquisición (kV y mAs)

Las medidas del producto dosis x área se llevaron a cabo con una cámara de transmisión Diamentor de PTW-Freiburg que, en todos los casos, se instaló en el colimador de los equipos. Dicha cámara estaba convenientemente calibrada y sus lecturas eran corregidas por los factores ambientales de Presión y Temperatura. El resto de datos son proporcionados por los mismos equipos de Rayos-X en sus consolas de control.

Paralelamente se ha medido el rendimiento de los cinco equipos para aquellos kilovoltajes de interés (kV's promedios en escopia y adquisición); estas medidas se han realizado con un analizador de haces PMX-III de RTI Electronics.

Las medidas presentadas en este trabajo han sido recogidas durante el periodo 1997-1999 por este Servicio de Radiofísica, dentro del proceso de registro de datos dosimétricos obligatorio

por ley en España en todas las instalaciones de Radiodiagnóstico médico desde 1996 [2], [3]. Se han rechazado medidas sobre pacientes de complexiones extremas (delgados y/o gruesos).

4. Resultados

En la tabla II se presentan los resultados obtenidos. La tabla contiene el tamaño de la muestra en cada caso, los productos dosis x área, datos radiológicos correspondientes a la escopia (kV medios, mA·min promedio por estudio y tiempos medios de escopia) y datos radiológicos correspondientes a adquisición de imagen (kV medios, mA·min promedio por estudio y número medio de adquisiciones por estudio)

Equipo	Tamaño muestra	Producto dosis x área (cGy x cm^2)	Datos de escopia			Datos adquisición		
			kV medio	mA·min promedio debido a escopia	Tiempo medio de escopia (minutos)	kV medio	mA·min promedio debido a adquisición	Número medio de adquisiciones
A (digital)	54	2796	101	10.0	4.0	123	0.7	17.8
B (digital)	30	2384	81	18.7	5.5	134	1.0	21.3
C (película)	13	3569	119	14.0	4.5	116	3.2	18.1
D (película)	41	1530	111	5.5	2.0	110	4.1	16.6
E (película)	47	1696	111	2.0	1.4	111	2.0	14.2

Tabla II: registro de datos dosimétricos y técnicas radiológicas según centros.

Lo que se quiere determinar es qué proporción de la dosis-paciente es atribuible a la escopia y cuál lo es a la adquisición de imagen. Para ello no basta con comparar los mA·min promedios para cada uno de los dos conceptos, ya que los kV's promedios de escopia y adquisición pueden ser distintos. Como ejemplo, cabe señalar el equipo B: un mA·min de escopia (a 81 kV) producirá una dosis menor que un mA·min de adquisición (a 134 kV).

Lo que se ha hecho es medir para cada equipo y cada kilovoltaje de interés los rendimientos a 1 metro (Tabla III). Estos rendimientos permitirán ponderar los mA·min de escopia y los de adquisición para hacerlos comparables, aún a pesar de haber sido generados a distintas energías.

Modo trabajo	Equipo A		Equipo B		Equipo C		Equipo D		Equipo E	
	KV	X (μGy/mAs)	kV	X (μGy/mAs)	kV	X (μGy/mAs)	kV	X (μGy/mAs)	KV	X (μGy/mAs)
Escopia	101	90.0	81	57.5	119	107.5	111	137.5	111	107.8
Adquis.	123	130.0	134	153.8	116	102.5	110	136.3	111	107.8

Tabla III: Rendimientos a 1 metro (X), en μGy/mAs, para cada equipo y para cada kV de interés.

Con estos rendimientos se puede determinar la relación entre la dosis recibida por el paciente procedente de la escopia y la dosis recibida procedente de la adquisición de imágenes. A esta relación la llamamos r y la calculamos mediante la siguiente relación:

$$r = (mA{\cdot}min_{\text{escopia}} \cdot X_{\text{kV medio escopia}}) / (mA{\cdot}min_{\text{adquisición}} \cdot X_{\text{kV medio adquisición}})$$

donde X es el rendimiento para cada uno de los kV's indicados en los subíndices y mA·min es el mA·min medio por estudio imputable a escopia y a adquisición respectivamente.

La tabla IV contiene los resultados obtenidos para el parámetro r.

Equipo	Datos de escopia		Datos de adquisición		Dosis debido a escopia / dosis debido a adquisición (r)
	kV medio	mA·min medio por estudio	kV medio	mA·min medio por estudio	
A	101	10.0	123	0.7	9.9
B	81	18.7	134	1.0	7.0
C	119	14.0	116	3.2	4.6
D	111	5.5	110	4.1	1.3
E	111	2.0	111	2.0	1.0

Tabla IV: relación entre las dosis imputables a los tiempos de escopia y las imputables a la adquisición de imagen.

5. Conclusiones

La primera conclusión es que la mayor reducción de dosis en este tipo de estudios se consigue al disminuir los tiempos de escopia; los equipos D y E, aún con un sistema de adquisición convencional, son los que menores productos dosis x área han proporcionado a los pacientes debido a sus reducidos tiempos medios de escopia.

No parece que la introducción de sistemas digitales de adquisición influya tanto en la reducción de dosis. Así, en el equipo C, con adquisición convencional y tiempos altos de escopia, la introducción de un sistema digital de captura de imagen podría reducir los 3.2 mA·min que se dedican actualmente a adquisición hasta un 0.7 mA·min (equivalente al de la sala A). No obstante, si se mantienen los 14.0 mA·min usados en escopia, la reducción final de la dosis (de 17.2 mA·min a 14.7 mA·min) no representará más que una reducción del 15%, lejos de aquel 80% que habíamos previsto. (1)

Este factor de disminución será más importante en equipos en los que se trabaja con bajos tiempos de escopia. Así, las salas D y E, de seguir trabajando en las actuales condiciones, conseguirían reducir sus dosis en un 35% y un 40% respectivamente, al implementar un sistema de captura digital de imágenes.

Por otra parte existe la sospecha de que la operativa de un sistema digital, mucho más simple que la de un sistema convencional de chasis con película, puede conllevar la captura de un número mayor de imágenes. En los equipos A y B, la media de adquisiciones por estudio es de 19.1, mientras que en los tres restantes este valor es de 15.7. Hay que tener en cuenta que en un sistema digital se capturan imágenes sin más que pulsar un botón; el sistema clásico supone la colocación de chasis en la bandeja, retirada del mismo y procesado en reveladora luz-día o cuarto oscuro.

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IMAGE QUALITY AND PATIENT DOSE OPTIMIZATION IN MAMMOGRAPHY IN HUNGARY

F. Giczi[2], S. Pellet[1], A. Motoc[1], E. Vano[3], C. Maccia[4], M. Gödény[5], B. Kovács[6], G. Forray[7]

[1]National Research Institute for Radiobiology and Radiohygiene, Budapest, Hungary
[2]County Institute of National Public Health and Medical Officer Service, Győr, Hungary
[3]Universidad Complutense de Madrid, Madrid, Spain, [4]C.A.A.T.S., Bourg-La-Reine, France
[5]National Institute for Oncology, Budapest, Hungary, [6]County Hospital of Vas, Szombathely, Hungary, "Haynal Imre" Medical University, Budapest, Hungary

ABSTRACT

In 1999 the International Atomic Energy Agency initiated a coordinated research program (CRP) of the aims to define a methodology for the implementation of the European QA/QC protocol for mammography in the Eastern European countries. In Hungary three mammography centers with dedicated mammography devices and film-screen systems have been selected for participation in the program. The outcome of mammography can be predicted by image quality evaluation on clinical and test phantom images and the patient doses. The improvement of these performance indicators after QA/QC program implementation should be an outcome of the project. The authors summarize the program of work, the activities and their preliminary results.

1. INTRODUCTION

It is scientifically justified that acceptable performance of mammography can only be achievable through rigorous and consistent Quality Assurance and Quality Control activity. QC helps us to ascertain a constant high quality level of mammography equipment's and auxiliary devices' performance. In 1999 the International Atomic Energy Agency initiated a coordinated research program (CRP) of the aims to define a methodology for the implementation of the European QA/QC protocol for mammography in the Eastern European countries.

Experience shows that the outcome of mammography can be predicted by image quality evaluation on clinical and test phantom images and the patient doses. The improvement of these performance indicators after QA/QC program implementation should be an outcome of the project.

2. PRECONDITIONS

A research group for participation in the CRP has been organized. The chief scientific investigator has been a health physicist and the co-investigator has been a radiologist, an expert of mammography. The coordinator of the National Patient Dose Evaluation Program (NPDEP) and 3 competent radiologists of participating mammography centers have also become the members of the research group.

Three mammography centers with dedicated mammography devices and film-screen systems have been selected for participation in the program. The mammography centers of National Institute for Oncology, Budapest (OOI) and the "Haynal Imre" Medical University, Budapest (HIE) are only involved in diagnostic mammography, but the mammography center of the County Hospital of Vas, Szombathely (VAS) is also involved in mammography screening.

The most important dosimetry and QC devices were available, but the PMMA plates, the image phantom for constancy tests and the film-screen contact test tool were required from the Agency.

3. PROGRAM OF WORK

A Research Coordination Meeting was organized in Prague, 3-6 November, 1999, when details of work plan and timetable were discussed and accepted:

- Evaluation of the image quality of a set of 120 clinical images using the European image quality criteria [1],
- Evaluation of the image quality using mammography test phantom images,
- Film reject analysis using a sample of a minimum 1000 images per mammography centers,
- Intercomparison of TLD systems,
- Assessment of first set of patient entrance doses and glandular doses with their respective radiographic techniques, breast thickness and comparison with reference/guidance levels,
- Implementation of QC program to the mammography units, processors and viewing boxes,
- Corrective actions if necessary,
- Repetition of the above activities (evaluation of image quality and patient doses, QC program).

4. ACTIVITIES AND RESULTS

Total of 120 clinical images (10 patients per center, 4 images per patient) have been evaluated by the field radiologists according to the EC criteria using the forms supplied. The clinical images and the evaluations were sent to Spain and France for independent assessment. All the films were accepted by the field radiologists for diagnostic purposes. However only 63% of images were considered by the French specialist who evaluated the films as accepted.

The image qualities in the mammography centers were evaluated using the RMI 156 mammography accreditation phantom according to the phantom instructions. The phantom images and the evaluations were also sent to Spain for independent assessment. The results of the parallel assessments are correlate and each of our mammography systems could fulfill the accreditation level of the American Mammography Accreditation Program.

For film reject analysis for at minimum 1000 films the rejected films were collected. The rejecter (radiologist or radiographer) and cause of rejection were registered. The results have been analyzed and the rejected films were sent to the Agency. Reject rates by causes of rejection can be seen in Table 1.

Table 1. Reject Rates by Causes of Rejection

Causes	Reject Rate (%)		
	VAS	OOI	HIE
Too light	34,5	13,9	21,0
Too dark	20,4	2,3	11,9
Positioning	32,1	61,9	14,0
Motion	3,8	2,4	1,4

Technical	9,8	12,5	37,6

In cooperation with the Dosimetry and Medical Radiation Physics Section of NAHU, IAEA we participated in an intercomparison of the TL systems. The "European Protocol for Dosimetry in Mammography" requires that the accuracy and precision of the dosimetric results are both to be better than ± 10 % [2]. Our results were outside of these limits (up to 17%) for all 3 beam qualities.

Patient dose measurements were made with TLDs on 10 patients per mammography center for CC projections. The results of dose measurements were sent to the Agency. The mean ESD were 2.73, 14.3 and 15.8 mGy, respectively.

Overall QC measurement were performed based on the European Protocol for the Quality Control of the Physical and Technical Aspects of Mammography Screening [3]. Summary of the QC activity is presented in Table 2.

Table 2.

Summary of the QC Measurements of the Physical and Technical Aspects of Mammography

Mammography center	VAS	OOI	HIE
X-RAY SOURCE			
Focal spot size: star pattern method	X	A	X
Source-to-image distance	A	A	A
Alignment of field/image rec. (chest wall side)	A	X	N
Alignment of field/image rec. (short edges)	A	X	A
Radiation leakage	X	X	X
Specific tube output at 1 m	D	D	D
Tube output rate at FFD	D	D	D
TUBE VOLTAGE			
Reproducibility	A	A	A
Accuracy	N	N	N
Half Value Layer	A	A	A
AEC-SYSTEM			
Optical density control setting: central value	A	N	A
Optical density control setting: range	A	A	A
Opt. dens. control setting: difference per step	A	A	N
Guard timer	X	X	X
Short term reproducibility	A	A	D
Long term reproducibility	N	N	N
Object thickness compensation	N	N	N
Tube voltage compensation	D	A	N
COMPRESSION			
Compression force	A	A	A
Compression plate alignment	X	N	A
BUCKY			
Grid system factor	A	A	A
Grid imaging	A	A	A
SCREEN-FILM			
Inter cassette sensitivity: mAs variation	A	N	N
Inter cassette sensitivity OD variation	D	A	N
Screen-film contact	N	A	A
FILM PROCESSING			

Temperature	N/A	N/A	N/A
Processing time	N/A	N/A	N/A

FILM AND PROCESSOR			
Sensitometry	N	N	N
Artefacts	A	A	N
DARKROOM			
Light leakage	N	A	A
Safelights	N	N	N
Film hopper	X	X	X
Cassettes	A	A	A
VIEWING BOX			
Luminance	A	A	A
Homogeneity	A	A	A
AMBIENT LIGHT LEVEL	A	N	A
SYSTEM PROPERTIES			
Entrance surface air kerma	A	A	
Image Quality	A	N	N

X: The parameter is not measured

A: The measured value is better than the acceptable level

D: The measured value is better than the desirable value

N: The measured value is not acceptable

N/A: The parameter is measured but there is no limiting value

5. CONCLUSIONS

The Directive 97/43 EURATOM of European Council regulates the health protection of individuals against the dangers of ionizing radiation in relation to medical examination or treatment. According to the Directive all doses due to medical exposure for radiological purposes shall be kept as low as reasonably achievable consistent with obtaining the required diagnostic information. This optimization process shall include the consistent production of adequate diagnostic information as well as the QA/QC activity.

In Hungary about 70 mammography equipment are in operation and 12 mammography centers are involved in mammography screening. A significant factor is that there are no any compulsory regulations for the quality assurance activity currently in place in Hungary to ensure optimal exposures and film processing. However, meeting the requirements of harmonization of legislation derived from our partnership with the EU, we also have to complete the regulations of the medical exposures. The present coordinated research program is an outstandingly valuable help of the International Atomic Energy Agency in this process.

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Netherlands

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To be presented on behalf of Toshiba Medical Systems, Nasu, Japan by:

Robert Eastick
Senior Manager – X-ray Systems Business Group
Toshiba Medical Systems Europe B.V.

DYNAMIC FLAT PANEL TECHNOLOGY
MTF, NEQ AND RADIATION SENSITIVITY

With the advent of Dynamic Flat Panel (DFP) technology to compliment static flat panel technology (SFD) and computerized radiography (CR), the concept of a totally digital medical diagnostic imaging environment will soon be technically accessible, assuming the absence of final limitation.
Until digital image archiving capability was realized, permanent records still relied upon the performance of film and intensifying screens.
In the future, the mantle of responsibility for technology and products that limit radiation dose to both the patient and operator will transfer almost entirely to those companies involved with the development and manufacture of FPD systems, be they static or dynamic.
Companies involved with DFP technology are promoting advanced MTF performance, a dramatic improvement in dynamic range, and increased radiation sensitivity for the potential reduced of radiation dose during both digital fluoroscopy and fluorography.
While these claims may be true, even at this early stage different companies are presenting DFP technology that differs in design and performance characteristics.
Toshiba is involved in the development of selenium based direct-conversion flat panel detectors and has determined significant differences and benefits in technical performance relative to those of detectors that identify with indirect-conversion technology. Indirect-conversion technology employs the interaction with fluorescent material by X-ray photons to produce light, which in turn stimulate photodiodes.
Research in association with State University Hospital of New York, USA, has provided a direct comparison of selenium based direct panel detectors performance with that of image-intensifiers and CCD television cameras, in terms of MTF and NEQ (Noise Equivalent Quanta).
Toshiba's research engineering division has also conducted extensive evaluation of direct and indirect dynamic detector technology to establish relative performance in terms of MTF and radiation sensitivity, taking into account both fluorographic and fluoroscopic functionality.
The objective of this presentation is to present these facts and findings, to advance the understanding of the issues and challenges confronting this new aspect of dynamic imaging technology.

Reject

RADIATION DOSES TO PATIENTS IN HAEMODYNAMIC PROCEDURES

Cañadillas-Perdomo,B[1]., Pérez-Martín,C.[2], Catalán-Acosta,A.[1], de Armas-Trujillo,D.[3], Hernández-Armas,J[1].

[1]Servicio de Física Médica. Hospital Universitario de Canarias. La Laguna. Tenerife (España).
[2]Servicio de Ingeniería Biomédica. Hospital Universitario de Canarias. La Laguna. Tenerife.
[3]Servicio de Cardiología. Hospital Universitario de Canarias. La Laguna. Tenerife (España).
Fax: 34922319279
e-mail: jharmas@ull.es

ABSTRACT

Interventional radio-cardiology gives high doses to patients due to high values of flouroscopy times and large series of radiographic images.

The main objective of the present work is the determination of de dose-area product (DAP) in patients of three different types of cardiology procedures with X-rays.

The efective doses were estimated trough the organ doses values measured with thermoluminescent dosimeters (TLDs-100), suitable calibrated, placed in a phamton type Rando which was submitted to the same radiological conditions corresponding to the procedures made on patients.

The values for the effective doses in the procedures CAD Seldinger was 6.20 mSv on average and 1.85mSv for pacemaker implants.

INTRODUCCIÓN

La cardiología intervencionista es una especialidad médica en la que se utilizan los Rayos X como guía para la realización de diversas acciones médicas cardíacas. Se han publicado estudios dosimétricos en diferentes lugares [1], [2], [3] que indican que las dosis a los pacientes son suficientemente altas para que se hayan dado casos incluso de efectos deterministicos. Aunque los beneficios para el paciente pueden ser evidentes es necesario evaluar las dosis recibidas por paciente para poder asegurar el cumplimiento de los principios de justificación y optimización que exige el sistema de limitación de dosis en que se basa la protección radiológica en general y la del paciente en particular.

Los largos tiempos de escopia habituales en estos estudios de Hemodinámica [4], [5], [6] ocasionan altas dosis en la zona irradiada que, en estos casos, suele estar limitada a pequeñas áreas del tórax del paciente. Asimismo, el frecuente gran número de imágenes obtenidas ocasionan también valores importantes de dosis. Esta situación, conocida desde hace años [7], se mantiene a pesar de los continuos avances en la mejora de los equipos radiológicos diseñados para realizar estas actividades.

En el momento presente, en España ha entrado en vigor, hace unos meses, una normativa por la que estos equipos han de funcionar dotados de un sistema de medida y registro de la dosis a los pacientes. Sin embargo, todavía la mayoría de los equipos radiológicos dedicados a cardiología radiológica funcionan sin contar con ese equipamiento, por lo que las determinaciones de dosis han de realizarse mediante el uso de equipamiento adecuado y mediante la colaboración de diversos profesionales: cardiólogos, técnicos, radiofísicos y personal sanitario.

El propósito de este trabajo es realizar la caracterización dosimétrica de diversos procedimientos de radio-cardiología intervencionista y diagnóstica midiendo el producto dosis área correspondiente a cada procedimiento realizado sobre pacientes reales. Además se han medido las dosis equivalentes necesarias para el calculo de la dosis efectiva al paciente a partir de la simulación de los procedimientos en un maniquí antropomórfico tipo Rando, en el que se colocaron dosímetros termoluminiscentes.

MATERIAL Y MÉTODO

El estudio se ha realizado en la Unidad de Hemodinámica del Servicio de Cardiología del Hospital Universitario de Canarias (HUC). Está compuesto de dos salas:
- Sala 1: donde se realizan todos los procedimientos relacionados con marcapasos cardíacos.
- Sala 2: donde se realiza estudios de angiografía coronaria diagnóstica (CAD) tipo Seldinger y tipo Sones ,y estudios de angioplastia coronaria transluminal percutánea (PTCA).

En la sala 1 el equipo usado fue también de la marca Siemens con un tubo Megalix 125/20/82 y generador Polydoros 80.
Todos los estudios realizados en la sala 2 se hicieron con un equipo de la marca Siemens, con generador Polydoros IS-C y con adquisición digital de imágenes. En ambas salas se da escopia pulsada.
Estos equipos cumplieron, durante la realización del estudio, las especificaciones fijadas en el Protocolo Español de Control de Calidad en Radiodiagnóstico [8].
La medida del producto dosis–área se hizo con una cámara de transmisión PTW modelo Diamentor M2, la cual se adosaba al diafragma del tubo de rayos X y cuyo sistema de registro se situaba en la consola de control del equipo radiológico.
En cada uno de los procedimientos se tomaron los siguientes datos:

a) Datos del paciente: edad, sexo, peso, talla, diámetro anteroposterior (AP), y diámetro lateral o transverso. Los diámetros se tomaron a la altura del tórax.
b) Datos del procedimiento:
   - Cinegrafia: kV , mA, distancia foco-intensificaddor (SID), tiempo de grafía, nº fotogramas, todo esto para cada serie.
   - Fluoroscopia: kV, mA, tiempo escopia.

-El tamaño del campo usado en grafía fue siempre de 17 cm de diámetro, y en escopia de 23cm, para las exploraciones realizadas en la sala 2. Para los estudios relacionados con marcapasos cardíacos (sala 1) el tamaño del campo usado fue de 27cm.
El número de fotogramas por segundo usado en grafía fue siempre de 12,5 excepto para el ventrículograma (que es normalmente la última serie de cine) que fue de 50.
Las proyecciones usadas durante los procedimientos, fueron:
Posteroanterior , posteroanterior-caudal, posteroanterior-craneal, derecha anterior oblicua, derecha anterior oblicua - caudal, derecha anterior oblicua - craneal, izquierda anterior oblicua, izquierda anterior oblicua - craneal, izquierda anterior oblicua - caudal.
Se han realizado medidas en 62 pacientes. En 38 de ellos se hicieron CAD tipo Seldinger (18 mujeres y 20 hombres),. En 7 pacientes los CAD fueron tipo Sones En 6 pacientes se realizaron PTCA. En 11 pacientes se realizaron implantes de marcapasos tipo DDD bicameral (colocación de dos cables, uno en aurícula y otro en ventrículo).
Todos los pacientes que fueron incluidos en este estudio tuvieron un peso comprendido entre 50kg y 90kg.
Se ha usado un maniquí Rando para estimar las dosis en órganos, mediante la utilización de dosímetros termoluminiscentes Harshaw tipo TLD-100 que se distribuyeron por todo el maniquí en posiciones correspondientes a los órganos y tejidos establecidos en las recomendaciones ICPR-60 para el cálculo de dosis efectiva.
La dosis asignada a cada órgano fue determinada haciendo un promedio de todos los resultados proporcionados por los TLDs colocados en el mismo,como es habitual [9]
La dosis de cada TLDs fue medida usando un lector Harshaw 4000, siguiendo para ello el procedimiento habitual en nuestro laboratorio.
La reproducción de los datos en el maniquí se hicieron para dos exploraciones: CAD tipo Seldinger y DDD .
En total fueron usados 65 TLD en la reproducción de el CAD tipo Seldinger y 55 TLDs para los implantes DDD de marcapasos.

RESULTADOS

Las medidas realizadas de los parámetros representativos de cada tipo de exploración han dado lugar a los valores medios y desviaciones estándar (SD) que se presentan en la Tabla I.

La complejidad de las exploraciones PTCA se refleja en el alto valor promedio del producto dosis área.
En las exploraciones CAD tipo Seldinger cuyos resultados se presentan en esta Tabla I, sólo se han considerado las exploraciones "típicas": coronariografia y ventriculografia.

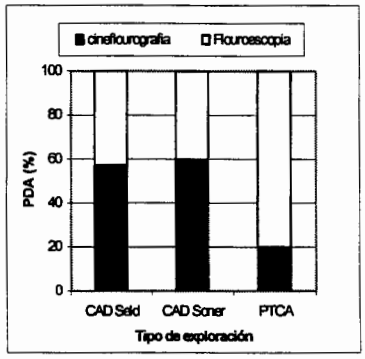
Puede observarse en la tabla como en el cateterismo tipo Sones el valor del PDA es un algo más elevado que en el tipo Seldinger. Probablemente se debe a la mayor dificultad de realización del primer tipo.
La contribución de fluoroscopia y cinefluorografía al PDA en cada exploración, está representada en la figura 1. Se puede observar que en CAD (tipo Seldinger y tipo Sones) se da más cineflourografía que flouroescopia al contrario que en PTCA. En la sala 1, de los marcapasos sólo usa escopia.

Tabla I.- Parámetros radiológicos y dosimétricos de las tres exploraciones

		Cine			Escopia			
Tipo de exploración	**N° pacientes**	**kV (SD)**	**mAs (SD)**	**N° FOTOGRAMA (SD)**	**SERIES CINE (SD)**	**KVp (SD)**	**mAs (SD)**	**DAP cGy*cm² (SD)**
CAD (Seldinger)	38	70,5 (3,7)	3050,2 (231,1)	85,9 (9,5)	8,4 (2,0)	78,8 (7,2)	2271 (2653,3)	1907,5 (1171,1)
CAD (Sones)	8	75,5 (5,1)	3764,7 (511,4)	89,5 (8,1)	9,75 (2,1)	79,4 (1,7)	2567,1 (913,2)	2817 (1092,7)
PTCA	6	90,6(10,5)	2749 (5075)	95,2 (15,6)	9 (3,2)	98,3 (9)	10334.4 (2869)	4115 (4669.3)

Tipo de exploración	**N° pacientes**	**kV**	**mA**	**DAP (cGy*cm²) (SD)**
Marcapaso tipo DDD	11	77	4.6	1495 (632.7)

Figura 1.- Contribución de la escopia y cine al producto dosis área para los tres tipos de exámenes



Para reproducir las exploraciones cuando se usó el maniquí se utilizaron los valores medios de los parámetros medidos sobre los pacientes reales. En particular, se tenía muy en cuenta la máxima similitud entre el valor medio de PDA en los pacientes y el valor alcanzado en la irradiación del maniquí.
En la Tabla II se presentan los valores de las dosis medidas en "órganos" [10] del maniquí antropomórfico utilizando dosímetros termoluminiscentes TLD-100, que habían sido calibrados en el Centro Nacional de Dosimetría. Los datos corresponden a las dos exploraciones anteriormente indicadas. Es de señalar que estas dosis corresponden a los valores medios obtenidos a partir del conjunto de dosímetros colocados en cada órgano.

Tabla II: Dosis tejido/órgano

Órgano / tejido		CAD tipo Seldinger N° de TLDs	CAD tipo Seldinger Dosis (mGy)	Marcapasos tipo DDD N° de TLDs	Marcapasos tipo DDD Dosis (mGy)
Gónadas	Testículos	1	0.18	1	0.06
	Ovarios	2	0.28	2	0.40
Colon		7	0.64	4	0.09
Pulmón		25	15.37	18	2.07
Estómago		1	15.76	1	6.84
Vejiga		1	1.90	2	1.68
Esófago		6	6.90	6	2.80
Hígado		6	9.58	1	0.63
Tiroides		2	0.92	1	0.65
Corazón		3	12.82	3	3.70
Mama		2	2.25	2	2.25
Cristalino		2	0.25	2	0.10
Superficie ósea		1	28.60		
Piel		9	1.48	11	7.43
Total TLDs		**68**		**55**	

CONCLUSIONES

1.- La dosis efectiva (considerando solamente los órganos para los que ICRP-60 establece un factor de ponderación) para los dos tipos de exploraciones de cardiología intervencionista, estimada a partir de las medidas de dosis en órganos con dosímetros TLD en maniquí Rando son:

- CAD tipo Seldinger : 6.2 mSv
- Implante de marcapasos tipo DDD: 1.85 mSv

2.- En los cateterismos, el 60% del PAD total fue impartido en cine-radiografía, este datos es similar al de otros autores (6). En el caso de los procedimientos PTCA el valor impartido en cine-radiografía fue de un 20% del total, este valor es inferior al porcentaje aparecido en la bibliografía.

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ABSORBED DOSES TO PATIENTS FROM ANGIORADIOLOGY

Rodríguez – Romero, R.[1], Díaz – Romero, F.[2], Hernández – Armas, J[1].

[1]Servicio de Física Médica. Hospital Universitario de Canarias. La Laguna, Tenerife (España). Fax: 34922319279; e – mail: ruthrod@fnmail.com

[2]Servicio de Radiodiagnóstico. Hospital Universitario de Canarias. La Laguna, Tenerife (España).

ABSTRACT

The aim of study was to know patients doses exposes when three different procedures of angioradiology were carried out. The explorations considered were drainage biliary, varicocele embolization and dacriocistography made in the Radiodiagnostic Service at the University Hospital of Canary Islands, Tenerife (Spain). In total 14 patients were studies. The measurements were made using large area transmission ionisation chamber which gives the values of Dose Area Product (DAP). In adition, thermoluminiscent dosimeters type TLD-100 were used in anthropomorphic phantom in order to obtain values of organ doses when the phantom was submitted to the same procedures than the actual patients. Furthermore, the Effdose program was used to estimate the effective doses in the procedures conditions. The values for DAP were in the range of 70 – 300 for drainage biliary, 43 – 180 for varicocele embolization and 1.4 – 9 for dacriocistography. The organ doses measured with TLD-100 were higher than the corresponding values estimated by Effdose program. The results for varicocele embolization were higher than other published data. In the case of drainage biliary procedure, the values were closed to other published results. It was not possible to find data for dacriocistography from other authors.

INTRODUCCIÓN

Los valores de las dosis de radiación a pacientes debidas a diversos procedimientos de Radiología Vascular e Intervencionista han sido determinados por diversos autores[1,2,3,4,5] en los últimos años. En general, las dosis medidas o estimadas son altas debido a las características propias de estos procedimientos radiológicos: grandes tiempos de escopia y alto número de imágenes. Al mismo tiempo se ha constatado la gran dependencia de las dosis con las características técnicas y con la experiencia del personal médico que la realiza. Por todo ello, la comparación entre resultados de diversos autores puede ser complicada y también la comparación entre medidas directas de dosis y estimaciones de las mismas haciendo uso de diversos procedimientos de cálculo.

El procedimiento más frecuentemente usado para la caracterización dosimétrica de los procedimientos de Radiología Vascular e Intervencionista es la medida de la magnitud Producto Dosis Área (P.D.A.). También se han llevado a cabo medidas de dosis, aplicables a los pacientes, usando dosímetros termoluminiscentes en maniquíes.

En este trabajo, se han realizado ambos tipos de medidas en 3 procedimientos propios de Angiorradiología: drenaje biliar, embolización de varicocele masculino (en adelante varicocele) y dacriocistografía (en adelante dacrio). Las dos primeras corresponden a procedimientos de Radiología Intervencionista, mientras que la tercera de la exploraciones sirve para diagnosticar el estado del conducto lacrimal.

En los tres procedimientos hemos planteado el objetivo de conocer el nivel de riesgo estocástico y determinístico en los pacientes, como también han hecho otros autores[6]. Asimismo, se realiza un estudio comparativo de los valores de dosis obtenidos utilizando un programa de cálculo (con los parámetros radiológicos de la exploración y el P.D.A.), con los resultados de las medidas con dosímetros termoluminiscentes colocados en un maniquí antropomórfico (RANDO) .

MATERIAL Y MÉTODO

Se tomaron datos referidos a 14 pacientes (6 mujeres y 8 hombres). A 5 de ellos se les realizó drenaje biliar; a otros 5 pacientes, con edades comprendidas entre 16 y 27 años, la intervención fue por varicocele masculino. A los 4 pacientes restantes se les hizo un estudio diagnóstico de dacriocistografía.

En todos los casos, se registraron los siguientes parámetros radiológicos: kV, mA, tamaño de campo, tiempo de escopia, número de disparos en grafía, y proyección utilizada. Todas las exploraciones se realizaron en un equipo de rayos X marca Philips, modelo Integris V3000. En todos los casos, se midió el P.D.A. (escopia y grafía) con una cámara de ionización DIAMENTOR M2 suministrada y calibrada por PTW – Freiburg (Alemania).

Posteriormente, se hizo uso de un maniquí antropomórfico Rando y de dosímetros termoluminiscentes marca Harshaw tipo TLD – 100 para realizar medidas de dosis en el maniquí. Los dosímetros empleados fueron calibrados para las energías de Rayos X diagnósticos (50 – 120 kV) en el Centro Nacional de Dosimetría (Valencia) . También se verificaron frente a una cámara de ionización PTW calibrada (conectado a un electrómetro PTW DL4-DI4) utilizando Rayos X de 80 kV proporcionados por un equipo radiológico que cumplía las especificaciones del Protocolo Español de Control de Calidad en Radiodiagnóstico.

Los tratamientos térmicos de los TLD (previo lectura, borrado + restaurado) se llevaron a cabo con una estufa PTW THELDO siguiendo los procedimientos estándares de nuestro laboratorio y se realizaron las lecturas de los dosímetros utilizando el Lector termoluminiscente HARSHAW 4000.

Las medidas del PDA, dadas en $Gy \cdot cm^2$, para cada exploración y paciente, se realizaron distinguiendo entre el modo escopia y el modo grafía en las distintas proyecciones utilizadas.

Se utilizaron los valores medios de los parámetros radiológicos de cada exploración y los datos de PDA promedios registrados en los pacientes para reproducir cada uno de los 3 procedimientos sobre el maniquí Rando en el que se colocaron los dosímetros TLD-100.

Por otra parte, se utilizó el programa de cálculo de dosis efectiva EFFDOSE, que utiliza los factores de ponderación tisulares propuestos en las recomendaciones ICRP-60[7] y que permite también estimar las dosis en órganos en cada una de las exploraciones teniendo en cuenta todas las características de las mismas.

RESULTADOS Y DISCUSIÓN

Los rangos de los valores de los parámetros medidos en cada una de las exploraciones se presentan en la Tabla I.

Tabla I.- Resultados obtenidos con pacientes

Exploración	Diámetro Campo (cm)	ESCOPIA				GRAFÍA				P.D.A. TOTAL
		kV	mA	t (min)	P.D.A.	kV	mA	Nº imágenes	P.D.A.	
Drenaje biliar	31-38	81-110	5 - 6	10-34	68-273	70-110	310-425	1-2	1-28	70-300
Varicocele	20-25	68-80	4 - 5	14-61	42-180	70-76	386-486	1-5	0,28-7	43-180
Dacrio	17	73-77	3 - 5	0,1-0,3	0,44-1	70-75	120-585	12-15	1-7,6	1,4-9

Los rangos de valores de P.D.A. se expresan en $Gy \cdot cm^2$.

Las diferencias entre las características de las exploraciones debidas, sobre todo, a las diferencias anatómicas entre pacientes, quedan reflejadas en esta tabla. Así, el diferente grado de

dificultad entre pacientes justifica las importantes variaciones observadas entre los tiempos de escopia para la realización del drenaje biliar que se refleja en el amplio rango de valores de P.D.A. Asimismo, los distintos datos en el modo grafía, para esta exploración, ocasionan una gran variabilidad en los valores de P.D.A. totales. Es de señalar que estos resultados hacen poco representativo un valor medio de P.D.A. como característico de esta exploración. Estas circunstancias se repiten, como puede observarse en la Tabla I, en el caso de varicocele y también para la dacriocistografía.

Después de la reproducción de las condiciones de irradiación para cada una de las exploraciones, utilizando un maniquí antropomórfico Rando, se midió las dosis en los "órganos" del mismo mediante la colocación en ellos de un conjunto de dosímetros termoluminiscentes en número y distribución variable según las características de la exploración y los órganos considerados. En total se usaron 40 dosímetros TLD-100 colocados en los órganos indicados en la Tabla II en el caso de la reproducción del estudio de drenaje biliar,, mientras que se utilizaron 38 dosímetros para las medidas en los órganos correspondientes al estudio de varicocele. En la exploración diagnóstica de dacriocistografía fueron 17 los dosímetros utilizados.

También en esta Tabla II se muestran los valores de dosis estimadas en los mismo órganos mediante la aplicación del programa Effdose para cuyo uso se utilizaron los datos promedios para cada exploración de kV, filtración, P.D.A. y la proyección más similar a la exploración real de entre las propuestas por NRPB[8].

Se observa que, en general, las dosis estimadas con el programa Effdose en cada órgano son inferiores a los valores promedios medidos con dosímetros termoluminiscentes. Puede deberse esta circunstancia al hecho de que los valores promedios utilizados para estimar las dosis usando el programa informático, tienen una gran desviación estándar consecuencia del amplio rango de valores que se indicaron en la Tabla I. Por tanto, para disminuir esta causa de incertidumbre se requiere incrementar el número de pacientes analizados o bien analizar poblaciones homogéneas de pacientes, próximos a las dimensiones del hombre estándar representado con el maniquí antropomórfico.

Tabla II.- Dosis en órganos (medidas y estimadas) para las 3 exploraciones.

Órgano	DOSIS (mGy)					
	Drenaje biliar		*Varicocele*		*Dacrio*	
	Medida	estimada	Medida	estimada	medida	estimada
Tiroides	0,35	0,09	0,12	0,00	0,15	0,30
Estómago	29,18	38,03	1,71	2,39	0,07	0,00
Esófago	6,00	8,72	0,66	0,08	0,10	0,06
Hígado	116,31	59,76	2,85	1,99	0,06	0,00
Mama	2,92	1,07	0,26	0,02	0,07	0,00
Vejiga	8,02	0,79	8,02	14,80	0,05	0,00
Pulmón	24,44	7,71	1,50	0,08	0,11	0,01
Colón	28,92	4,96	43,61	24,45	-	-
Testículos	0,17	0,06	1,30	8,08	-	-
Ovarios	1,48	4,02	-	-	-	-
Vesícula biliar	-	45,89	-	-	-	-
Cristalino	-	-	-	-	0,82	2,03
Parótidas	-	-	-	-	1,33	-

Por otra parte, la reproducción precisa del estudio con el maniquí es compleja debido a la diversidad de proyecciones utilizadas y al tiempo de radiación correspondiente a cada una de ellas,

así como a los cambios de tamaño de campo que tienen lugar durante el estudio. Por todo ello, se considera conveniente que los sistemas de medida y registro de dosis que han de colocarse obligatoriamente en estos equipos en España desde hace unos meses, incorporasen el registro de dichos parámetros para una mejor estimación de la dosis a pacientes.

El cómputo de la dosis efectiva a los pacientes realizada mediante el programa Effdose, proporcionó los valores siguientes: 19 mSv para el drenaje biliar; 9 mSv para el varicocele y 0.13 mSv para dacriocistografía. Como ya se observaba en la Tabla II, las características de la exploración lacrimal (campo pequeño centrado en los ojos durante toda la exploración) justifican tanto los bajos valores de dosis en órganos como el pequeño valor de dosis efectiva.

Aunque no se colocaron suficientes dosímetros para poder medir todos los datos necesarios para la obtención de la dosis efectiva, la aproximación que puede darse con los valores medidos es de: 17 mSv para el drenaje biliar, 7 mSv para el varicocele y 0.04 mSv para dacriocistografía. Considerando únicamente los mismos órganos con sus correspondientes dosis medidas y estimadas, las diferencias entre ambos métodos son grandes. Este resultado parece indicar una cierta tendencia del programa Effdose a repartir la dosis total entre los diversos órganos estrictamente determinado por las características geométricas de la exploración establecidas matemáticamente.

Por tanto, hay que usar con precaución la asimilación de exploraciones a la hora de comparar exploraciones intervencionistas reales con proyecciones normalizadas de exploraciones radiológicas sencillas.

CONCLUSIONES

1.- Los valores de dosis medidos con dosímetros termoluminiscentes y los estimados a partir de la medida de los productos dosis-área para las exploraciones Drenaje Biliar, Varicocele y Dacriocistografía, son indicativos de un bajo riesgo de efectos estocásticos debidos a la radiación X usada. La incidencia negativa de la radiación como inductora de enfermedades malignas hereditarias graves es baja, incluso en la intervención de Varicocele masculino que, a priori, era susceptible de ocasionar mayor riesgo.

2.- No se alcanzan, en ningún caso, valores de dosis superiores a los umbrales de efectos determinísticos.

3.- La discordancia entre los valores de dosis estimados y medidos pueden ser debidos a la extrema variabilidad de los parámetros radiológicos usados en las exploraciones. Para intentar conocer la relación entre ambos conjuntos de valores se requiere incrementar el número de pacientes estudiados y asegurar la homogeneidad de características anatómicas entre ellos, al objeto de disminuir la incertidumbre en los resultados.

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PATIENT RADIATION DOSES FROM NEURORADIOLOGY PROCEDURES

García-Román, M.J.[1]; Prada-Martínez, E.[2]; Abreu-Luis, J.[1]; Hernández-Armas, J.[1]

[1]Servio de Física Médica. Hospital Universitario de Canarias; La Laguna, Tenerife (España).
Fax:34922319279. e-mail: chechegr@iname.com
[2] Servicio de Radiodiagnóstico. Hospital Universitario de Canarias. La Laguna, Tenerife (España)

ABSTRACT

Following the presentation of radiation-induced deterministic effects by some patients undergone neuroradiological procedures during successive sesions, like temporary epilation, in the 'Hospital Universitario de Canarias', measurements were made of dose to patients. The maximum dose-area product measured by ionization chamber during these procedures was 39617 cGy·cm^2 in a diagnostic of aneurysm and the maximun dose to the skin measured by thermoluminescent dosemeters (TLDs) was 462.53 mGy. This can to justify certain deterministic effects but it is unlikely that the patients will suffer serious effects from this skin dose. Also measurements were made of effective dose about two usual procedures, embolisation of tumour und embolisation of aneurysm. These procedures were reproduce with a anthropomorphic phantom Rando and doses were measure with TLDs. Effective doses obtained were 3.79 mSv and 4.11 mSv, respectivily. The effective dose valued by the program EFFDOSE was lesser than values measure with TLDs.

INTRODUCCIÓN

Las determinaciones de los niveles de dosis a pacientes en exploraciones de Neuro-radiología, constituyen un factor clave para el subsiguiente establecimiento de medidas de protección radiológica. Se han realizado algunas determinaciones de estas dosis [1-4] y puede concluirse que, en general, se suministran dosis relativamente altas en la cabeza de los pacientes, que pueden, incluso ocasionar efectos determinísticos tales como depilación temporal y eritemas. Los valores publicados de dosis a pacientes no son coincidentes incluso entre exploraciones similares, debido a las profundas diferencias que pueden darse entre los pacientes, a la diversa instrumentación utilizada y al grado variable de preparación y experiencia entre el personal que realiza estos procedimientos.

Para establecer los riesgos asociados con la exposición de los pacientes a radiaciones en neuro-radiología se ha recomendado la utilización de la magnitud dosis equivalente[5], aunque también se ha indicado la conveniencia de usar la magnitud dosis efectiva[6], cuya evaluación puede ser problemática[7]. En Europa está muy extendido el uso de la magnitud Producto Dosis Área (PDA) para la caracterización dosimétrica de procedimientos radiológicos.

El objetivo de este trabajo es determinar los valores de magnitudes dosimétricas características de 3 tipos de exploraciones neuro-radiológicas realizadas en el Hospital Universitario de Canarias (Tenerife - España) y estimar el nivel de riesgos estocásticos y determinísticos de los pacientes sometidos a las mismas.

MATERIAL Y MÉTODO

Se analizaron 25 casos en procedimientos de neuro-radiología diagnóstica o intervencionista realizados durante el año 2000. Todos los estudios fueron realizados por el mismo neuro-radiólogo utilizando un equipo de angiografía por substracción digital marca Philips modelo Integris 3000, con el generador e intensificador de imágenes propios del equipo y con capacidad para proporcionar campos circulares. El tubo de rayos X y el intensificador de imágenes está dispuesto en un arco tipo C. El haz de rayos X tiene una filtración equivalente a 3.5 mm de aluminio. El equipo ajusta automáticamente el potencial y la corriente del tubo, si bien puede conocerse el rango de kV usado, que varió entre 62 y 97.

La técnica angiográfica empleada en todos los procedimientos de neuro-radiología realizados en el Hospital Universitario de Canarias, implica la inyección automática de un agente de contraste yodado por arteria femoral.

Para la medida del PDA se utilizó, en todos los estudios, una cámara de ionización de transmisión marca PTW modelo Diamentor M2, que permite obtener directamente el valor del PDA en cGy·cm^2. La cámara se adosó al diafragma del tubo de rayos X, tras el filtro de aluminio y su sistema de registro se situó en la zona protegida. Los datos correspondientes a cada estudio se recogían mediante un seguimiento permanente del desarrollo del procedimiento que, en algunas ocasiones, podía prolongarse durante varias horas. Se obtuvieron, separadamente, los valores del PDA debidos al uso de rayos X en modo escopia y en modo grafía, así como las distintas proyecciones utilizadas en cada momento.

Adicionalmente, en 6 de los pacientes, se colocaron 4 dosímetros termoliminiscentes de LiF (TLD modelo 100 Harshaw Chemical), adosados a la piel del paciente en aquellas zonas donde se consideraba más probable que se alcanzaran los mayores valores de irradiación: huesos fronto-temporoparietales izquierdo y derecho, frontal a la altura de las cejas y sobre la región nasal. Siempre se midieron las dosis registradas por los dosímetros antes de que transcurrieran 24 horas después de su irradiación con un lector Harshaw 4000. Los resultados se muestran en la *Tabla II.*

La irradiación controlada de los dosímetros utilizados, realizada por un laboratorio oficial de calibración, puso de manifiesto que la respuesta de los mismos era lineal en las diversas energías de rayos X utilizadas.

Una vez finalizada la recogida de los datos en los pacientes reales, se llevó a cabo una medida de dosis en un maniquí antropomórfico tipo Rando con el que se reprodujeron, en el mismo equipo radiológico y por el mismo neuro-radiólogo, las exploraciones realizadas con los valores medios de los datos medidos sobre los pacientes. El proceso se llevó a cabo para dos de las exploraciones estudiadas, colocando un total de 59 dosímetros termoluminiscentes en el maniquí, situando en su superficie y en 'órganos' o 'tejidos' interiores de forma que proporcionaran datos que permitieran calcular la dosis efectiva.

RESULTADOS Y DISCUSIÓN

Tipo de estudio	Campo de radiación (cm)	FLUOROSCOPIA				GRAFÍA		PDA Total cGy·cm^2
		kV	mA	Tiempo (s)	PDA cGy.cm^2	Nº exposiciones	PDA cGy·cm^2	
1. D.A.	20	78 – 90	4.3 – 6	112	387	58	2887	3274
2. D.A.	17	74 – 91	4.6 – 6	205	662	132	7490	8152
3. D.A.	20	73 – 97	2.5 – 2.8	4904	20462	317	19155	39617
4. D.A.	17, 20	73 – 96	3.9 – 5.8	2835	8549	131	9956	18508
5. D.A.	17, 20	67 – 77	3.8 – 4.9	162	626	120	7315	7941
6. D.A.	17, 20	67 – 80	3.7 – 5.9	246	1279	138	11214	12493
7. D.A.	17, 20	67 – 84	3.1 – 5.8	264	900	136	7239	8139
1. E.A.	20	62 – 87	2.4 – 5.9	2717	13315	135	8717	22032
2. E.A.	20	67 – 73	3.9 – 5	2640	5588	374	22548	28136
3. E.A.	20	67 – 72	3.8 – 5.6	264	665	176	866	9325
4. E.A.	20	67 – 72	2.4 – 5.6	42	126	60	3259	3385
5. E.A.	20	71 – 83	3.8 – 4.8	1051	2755	180	8411	11166
6. E.A.	17, 20	73 – 76	3.8 – 4.9	143	544	58	3134	3678
7. E.A.	17, 20	71 – 78	3.1 – 5.3	1337	5514	143	8510	14024
8. E.A.	20, 25	67 – 74	2.4 – 4.2	2708	4767	358	8279	13046
9. E.A.	20	70 – 86	3.9 – 4.8	2766	987	268	11637	12624
10. E.A.	20	71 – 77	3.4 – 3.9	153	429	72	4086	4515
11. E.A.	20	75 – 92	4.4 – 5.9	3684	20837	249	15253	36090
12. E.A.	17	67 – 87	4.7 – 6.0	1500	11436	151	12286	23722
13. E.A.	17, 20	66 – 83	2.5 – 5.8	1686	11775	194	14021	25796

1. E.T.	20	73 – 82	3.5 – 5.9	232	828	140	8782	9610
2. E.T.	17, 20	70 – 87	3.2 – 6	247	803	98	5071	5874
3. E.T.	20	71 – 78	4.9 - 5.8	823	3627	177	10401	14028
4. E.T.	20	77 – 91	4.3 – 5.8	1854	5065	209	9601	14666
5. E.T.	17, 20	62 – 81	2.2 – 5.7	996	5664	243	20135	25799

D.A= Diagnóstico de Aneurisma; E.A.= Embolización de Aneurisma; E.T.= Embolización de Tumor.

Tabla I.- Producto dosis área medido en los distintos procedimientos

En la *Tabla I* se presentan datos de las exploraciones realizadas y los valores de PDA en cada una de ellas.

Destaca la gran variación de tiempos de escopia y valores del PDA, incluso tratándose del mismo estudio, debido, básicamente, al distinto grado de complejidad del caso de cada paciente.

En la *Tabla II* se muestran los resultados de las dosis medidas con dosímetros termoluminiscentes. Se observa que los dosímetros colocados en uno de los lados de la cabeza dan valores de dosis superiores debido a que la exploración se realizó con predominio de la irradiación de uno de los lados, según donde estuviera localizada la lesión.

Paciente	Tiempo escopia, s	Nº exposiciones	Posición	Dosis (mGy)
5. D.A.	162	120	Frontal	3.99
			Región nasal	3.84
			Temporoparietal dcho.	162.50
			Temporoparietal izdo.	107.55
6. D.A.	246	152	Frontal	9.02
			Región nasal	4.58
			Temporoparietal dcho.	63.37
			Temporoparietal izdo.	281.14
7. D.A.	264	136	Frontal	3.40
			Región nasal	3.05
			Temporoparietal dcho.	0.03
			Temporoparietal izdo.	90.86
12. E.A.	1500	151	Frontal	8.81
			Región nasal	6.31
			Temporoparietal dcho.	0.55
			Temporoparietal izdo.	16.89
13. E.A.	1686	194	Frontal	13.97
			Región nasal	7.65
			Temporoparietal dcho.	68.79
			Temporoparietal izdo.	15.24
5. E.T.	996	243	Frontal	7.09
			Región nasal	0.01
			Temporoparietal dcho.	86.49
			Temporoparietal izdo.	462.53

Dcho.= derecho, Izdo.=izquierdo

Tabla II .- Dosis en distintos puntos de la cabeza de los pacientes.

Órgano/Tejido	Nº _TLDs Colocados	Dosis en Procedimiento (mGy)	
		E.T.	E.A.
Ovarios	2	0.12	0.10
Testículos	1	0.13	0.05
Colon	8	0.17	0.19
Pulmón	16	0.78	1.26
Estómago	1	0.22	0.35

Vejiga	1	0.09	0.12
Mama	2	0.61	1.85
Hígado	5	0.18	5.16
Esófago	3	1.46	7.02
Tiroides	1	2.24	7.7
Superficie cabeza	13	206.35	36.37
Cristalino	2	11.83	396.61
Glándulas parótidas	2	14.28	13.61
Oído medio	2	202.77	206.12

Tabla III.- Dosis en piel y órganos en reproducción de procedimientos con fantoma Rando.

En la *Tabla III* se presentan los valores medios de dosis medidos en órganos del maniquí antropomórfico Rando, así como los resultados de las dosis medidas con dosímetros superficiales.

Aplicando los factores de ponderación propios de cada tejido u órgano propuestos en las Recomendaciones ICRP 60[8], puede calcularse la dosis efectiva recibida por el fantoma RANDO, ($E = \Sigma w_T H_T$). Obteniendo las contribuciones $H_{\text{médula ósea roja}}$ y $H_{\text{superficie ósea}}$ mediante simulación con el programa Effdose, se llegó a una dosis efectiva, con los órganos que se había medido, de 3.79 mSv para embolización de tumor y 4.11 mSv para embolización de aneurisma.

CONCLUSIÓN

Comparando con otros datos publicados[2], podemos ver como los valores de PDA con los que se trabaja en el Hospital Universitario de Canarias son del orden que los impartidos en otros lugares. Se pudo ver como cada proyección tiene una contribución diferente al DAP por lo que la dosis recibida por el paciente puede ser reducida minimizando el uso de aquellas proyecciones específicas. Otros factores para la reducción de la dosis pueden ser alternar la entrada del haz de radiación entre caras opuestas, reducir el campo a la región de interés o hacer uso de filtración adicional.

Los procedimientos de neuro-radiología pueden causar dosis de radiación relativamente altas en la región craneofacial, pero en los casos estudiados, la máxima dosis en piel (462.53 mGy en el caso 5 E.T.) está muy por debajo de la dosis conocida que causa depilación temporal (3 Gy) o eritema local (6 Gy). Asimismo, para el valor más alto de dosis efectiva, 4.11 mSv, y usando el coeficiente de cáncer mortal publicado por la International Commision on Radiological Protection[5], $5 \cdot 10^{-5}$ mSv^{-1}, con este valor de dosis se provocaría un cáncer mortal por cada 4886 estudios. Este riesgo es bastante menor que el asociado a la enfermedad por la cual el paciente se somete a un procedimiento de neuro-radiología.

Los valores de dosis efectiva medidos con la reproducción de los procedimientos con el fantoma supera en la mayoría de los órganos a la obtenida con el programa de simulación Effdose y esto se refleja en la dosis efectiva que para el último de los métodos fue 2.02 mSv (E.T.) y 1.77 mSv (E.A.)

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SOME EXPERIENCES FROM RADIATION PROTECTION OF PATIENTS UNDERGOING X-RAY EXAMINATIONS IN TANZANIA

Ngaile, J.E., Muhogora, W.E., Nyanda, A.M. National Radiation Commission
P.O.Box 743, Arusha, United Republic Of Tanzania, Fax no: +255 27 2548554 E-Mail: nrctz@habari.co.tz

Abstract- a study of patient entrance surface dose (ESD) received by adult patients was undertaken to five major diagnostic facilities in Tanzania. Five selected X-ray projections for chest, PA; Abdomen, AP; lumbar spine, AP; lumbar spine, LAT and pelvis, AP were done in the study. The mean entrance surface doses after introduction of dose reduction methods were 0.34 mGy, 5.41 mGy, 3.7 mGy, 4.8 mGy and 8.8 mGy for chest, PA; abdomen, AP; pelvis, AP; lumbar spine, AP and lumbar spine, LAT respectively. The variation of doses observed in the study were influenced by the diversity of diagnostic factors like the difference in patient size and weight, skills employed, technique used and the range of operational parameters that were used such as generating tube potential, filtration, focal spot position, source- image receptor distance, field size indication, tube current and time. The results show that increasing the tube voltage reduced the ESD by 35.5%, while lowering of mAs reduced ESD in the range from 15% to 60%. The reduction of ESD by increasing the filtration ranged from 11% to 58% while increasing of speed class of film-screen combination reduced the ESD in the range from 33% to 57%. From the results, it can be concluded that there is existing potential for dose reduction method in the diagnostic radiology facilities and the most important factor for improvement is to increase awareness, both from reality of harm from unnecessary radiation exposure and with relative ease doses can be reduced

1. INTRODUCTION

In diagnostic radiology, measurements of radiation doses to the patients provide means for setting and checking standards of good practices as an aid to the optimization of patient protection. It is difficult for an X-ray facility to be aware of its performance without some form of patient dose monitoring. In Tanzania, the medical use of X-rays for diagnosis of diseases and injury started as early as 1938 and as technology and health care improved there has been an increase in the usage of radiation. To date the country has more than 300 diagnostic X-ray units and it is estimated that about 1,000,000 X-ray examinations are carried out annually in the country [2]. Despite such extensive use, there was no radiation protection until the Protection from Radiation Act, 1983 came into force. The Act established the National Radiation Commission (NRC), as the Competent Authority responsible for all matters relating to radiation protection [1]. The increasing trend of the number of X-ray examinations in absence of guidance levels prompted the NRC, to carry out a pilot study to investigate the factors that influence patient dose from diagnostic radiology. The patient dose assessment based on such pilot study would be a precursor of establishing the National guidance levels of patient entrance surface dose for regular monitoring purposes. The range of doses associated with the same procedures that were found in the study which have shown huge potential for dose reduction were due to the diversity of diagnostic factors like, the difference in patient size and shape, the variety of available imaging systems, processing chemicals, skills employed and the range of technical parameters that were used, such as tube potential, current, exposure time, filtration, field size, and distance. The study revealed that different techniques and clinical factors that influenced the doses to patients from diagnostic radiology, might give added knowledge for use in the optimization of diagnostic radiology procedures. This paper presents and discusses some experiences from radiation protection of patients undergoing X-ray examinations from five major diagnostic radiology facilities in Tanzania.

2. MATERIALS AND METHOD

Where is image data?

The Entrance Surface Dose (ESD) study involved a total of ten X-ray rooms at four referral hospitals and one regional hospital. The hospitals were the Muhimbili Medical Centre (MMC), Kilimajaro Christian Medical Centre (KCMC), Bugando Medical Centre (BMC), Mbeya Consultant Hospital (MCH) and Arusha Regional Hospital (ARH) which collectively attend nearly 50% of patients undergoing X-ray examination in the country annually [2,7]. Five selected X-ray projections for chest, PA; abdomen, AP; lumbar spine, AP; lumbar spine, LAT and pelvis, AP were used in the study as recommended [3]. Ten adult patients whose individual weights and thickness were close to 70 kg and 20 cm respectively had their ESD measured. The ESD were determined using the LiF thermoluminescent dosemeter (TLD) chips, which were calibrated at the National Calibration Laboratory (NCL) for ionizing radiation, Arusha, Tanzania. A Harshaw TLD system model 4000B (No.3190) was used to evaluate the TLDs. Two calibrated TL chips enclosed in a labelled 30x30x0.01 mm^3 polythene sachet were used to determine the ESD by attaching the dosemeters at the middle of the light field on the patient for each radiographic exposure. The quality assurance program (QA) on x-ray equipment was undertaken before the introduction of the dose reduction methods. The quality control (QC) tests on the X-ray equipment were undertaken by using a non-invasive X-ray test device, Victoreen model 4000M+. The leakage measurements were measured using a calibrated Radiation Alert Monitor 4. The beam alignment and the beam perpendicularity were determined by using RMI test tools.

3. RESULTS AND DISCUSSION

3.1 Quality assurance program on X-ray equipment

The results of quality control (QC) checks done on X-ray equipment are given in table 1. By comparing these results with the recommended tolerances [3,6], it can be seen that all the X-ray machines under study, passed all QC tests done. However, in clinical situations where diagnostic conditions for which equipment and technique related factors are variable, the use of these X-ray machines may still lead to un –optimized diagnostic procedures. Therefore the QC results provide guidance on the choice of exposure techniques and hence suggest the need for optimized dose reduction methods. The lowering of mAs was found to be effective for X-ray equipment with higher timer reproducibility than lower timer reproducibility. The increasing of filtration was found to be effective for an X-ray machine of lower half value layer. Likewise, the increasing of tube potential reduced the patient dose [4] more efficiently for the X-ray machines that possessed better tube voltage consistency and higher accuracy.

Table 1: Results of QC checks on X-ray equipment at the five hospitals (maximum value of performance indicated)

Parameters	**KCMC**		**MMC**		**BMC**		**ARH**	**MCH**
	R1	**R4**	**R4A**	**R4B**	**R203**	**R207**	**R1**	**R1**
kV accuracy (10%)*	4.1	8.0	5.3	7.2	4.1	7.5	5.4	5.6
kV reproducibility(4%)*	1.0	0.5	0.5	0.5	1.1	0.5	1.0	0.3
kV consistency (10%)*	6.0	2.1	4.2	3.8	7.8	4.3	6.6	2.1
HVL,mmAL (at 80kVp)*	4.1	4.0**	3.4	3.1	3.7	2.8	3.7	2.1
Timer accuracy(10%)*	0.4	1.5	1.6	1.0	1.5	1.0	6.1	0.8
Timer reproducibility(5%)*	1.0	0.3	0.9	0.3	0.5	0.2	0.1	0.1
Output linearity mGy/mAs(5%)*	3.9	1.0	1.1	2.9	3.9	1.8	5.0	4.6
Leakage radiation at 1 m (1000 μSv/h)*	9.5	20.0	10.3	15.0	20.8	350	12.0	400
Light –radiation Beam alignment (Deviation at 1 m) (+2%)*	A	A	A	A	A	A	A	A
Beam perpendicularly(1.5°)*	A	A	A	A	A	A	A	A

*Tolerance ** at 120 kVp A; Acceptable R: Room

3.2 Entrance surface dose measurement on patient

The mean ESD per examination before the introduction of dose reduction methods was found to be in the range from 0.1 to 0.9 mGy for chest, 3.5 to 13.9 mGy for abdomen AP and 1.6 to 13.1 mGy for pelvis AP X-ray examinations. For Lumbar spine, AP and Lumbar spine, LAT the dose ranges were 3.6-12.7 mGy and 10.0-29.6 mGy respectively. It can be seen that about 70% of the mean doses are below the recommended ESD guidance levels [3,5]. Indeed, the dose results compare well with the results from similar studies [3]. Despite the fact that majority of ESD values are below the Internationally recommended ESD guidance levels, the corresponding ESD variations may not be fully justified.

Factors that influences ESD are comprehensively discussed elsewhere [3,4]. The choice of film-screen combination influences the patient entrance surface dose [4]. A sensitive screen-film combination requires much less exposure than a low sensitivity non-screen film system, although shows less detail. Two types of speed classes of film-screen combination such as 200 and 400 were employed although majority of hospitals use the '200' type, as they are relatively cheaper than the other class. The alternative use of high kV technique for chest X-ray examination reduced the patient dose, as high energy X-rays are more penetrating than low-energy X-rays [4]. The influence of filtration reduces the intensity of the beam. Filters selectively remove many more low-energy X-ray than high –energy X-rays [3,4]. The observed high mAs variation in a majority of X-ray examinations for patients of similar size, also suggested that the reduction of mAs could be effective in reducing patient dose.

Table 2:Summary of the measurements of patient entrance surface doses

Examination	dose range prior to QC (mGy)	dose range after QC (mGy)	dose reduction (%)	corrective measures
Chest, PA	0.2- 1.1	0.13-0.6	17-50	Lowering of mAs
Chest, PA	0.3- 0.72	0.20-0.31	33-57	Increase of speed class of film-screen combinations
Chest,PA	0.93	0.60	35.5	Increase of kVp
Chest, PA	0.15	0.10	33.0	Lowering mAs and increase filtration
Chest, PA	0.4-0.60	0.30-0.39	25-58	Increase of filtration
Abdomen, AP	3.5-12.6	2.8 -9.6	20-30	Lowering of mAs
Abdomen, AP	3.0	2.3	23	Lowering mAs and Increase filtration.
Abdomen, AP	9.8	5.53	44	Increase speed class of film-screen combination.
Abdomen, AP	9,8-10.0	4.8-7.54	25-51	Lowering of mAs, increase of speed class of film-screen combination.
Pelvis, AP	5.1-13.9	3.9-5.5	24-60	Lowering of mAs
Pelvis, AP	4.94-5.7	2.9-3.1	41-46	Increase of speed class film-screen
Pelvis, AP	4.03	3.07	24	Lowering of mAs, increase speed class film-screen combination
Pelvis, AP	5.7	3.0	47	Increase of filtration
L/spine, AP	4.0-9.7	3.3-7.1	27-48	Lowering of mAs
L/Spine, AP	7.3-9.47	4.4-5.78	39-40	Inc speed class film-screen combination.
L/spine, AP	3.5	3.1	11	Increase filtration
L/spine, AP	7.4	4.3	42	Lowering mAs and increase filtration
L/Spine, AP	7.3	3.6	51	Lowering mAs and Increase speed class of film screen combination
L/spine,LAT	8.4-18.3	5.9-12.50	15-49	Lowering of mAs
L/spine, LAT	20.4	11.8	42	Inc speed class film-screen combination.
L/spine, AT	8.51	4.5	47	Lowering of mAs and increase of speed film -screen combination
L/spine, LAT	6.7	4.4	34	Increase of filtration

Irrespective of the type of X-ray examination, the results show that increasing the tube voltage reduced ESD by 35.5% while lowering of mAs reduced ESD in the range from 15% to 60%. The reduction of ESD by increasing the filtration ranged from 11% to 58% while increasing of speed class of film –screen combination reduced ESD in the range from 33% to 57%. These include film –developing conditions, speed class of film combinations, filtration and exposure factors such as kVp and mAs. Large variation of distance from the x-ray tube has also been found to influence the ESD on patients [3].
After introduction of the dose reduction methods the change of the ESD median from second round ESD measurement was 0.41 mGy to 0.36 mGy for chest PA, 8.9 mGy to 6.4 mGy for abdomen AP and 5.21 mGy to 3.3 mGy for pelvis AP. For Lumbar spine AP, the ESD changed from 6.7 mGy to 4.94 while for lumbar spine LAT, it changed from 15.6 mGy to 6.2 mGy. The changes corresponded to about 12%, 28%. 37%, 26% and 60% for chest respectively. Table 2 gives the summary of ESD measurements before and after the undertaking of quality control checks. The mean ESD values for second round were 0.34 mGy, 5.41 mGy, and 3.7 mGy for chest, A, abdomen, AP and pelvis respectively. For lumber spine AP and lumbar spine LAT the mean ESD were 4.8 mGy and 8.8 mGy respectively. Assuming the mean ESD, it can be seen that about 56%, 50%, 75%, 43% and 57% of measurements respectively for chest PA, abdomen AP, pelvis AP, lumbar spine AP and lumber spine LAT X-ray projections, achieved the mean ESD level of dose reduction.
Other factors observed to influence patient doses were unnecessary exposure due to improper film development as previously presented [7]. Retaking of X-rays was also a common cause of unnecessary radiation and was done for several reasons such as unqualified X-ray operator and loss of the original films and chemicals. This leads to the conclusion that lack of necessary attention or awareness about the levels of doses and risk associated with particular procedures and particular techniques may also contribute to patient dose.
In a rapidly changing field of modern x-ray diagnostics, the referring physician and the radiologist/radiographer who are responsible for clinically directing the examination must build their decision upon a correct assessment of the indications for X-ray examination and the way the results are likely to influence diagnosis and subsequent patient dose. The above facts should take into consideration the physical properties and biological effects of ionizing radiation and the concepts of benefits and risks in radiological protection. Generally, the effectiveness of dose reduction was observed to be independent of the type of x-ray examination and X-ray equipment type. This suggests that the influence of the technique used and skill employed may be significant to the ESD reductions.

4. CONCLUSIONS

Some experiences from radiation protection of patients undergoing X-ray examinations in Tanzania have been presented. The results of the study provide evidence of the existing potential for dose reduction in the country's hospitals and the most important factor for improvement is to increase safety culture, both from reality of harm from unnecessary radiation exposure and of the relative ease with which doses can be reduced. This requires familiarity with the levels of doses connected with the various X-ray projections and with techniques of quality control. The study should therefore be implemented on the national scale as an approach to establish national guidance levels of patient entrance surface dose associated with particular procedures for good medical practice and regular monitoring purpose.

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DOSES FROM NUCLEAR MEDICINE EXAMINATIONS- A 25-YEAR FOLLOW-UP STUDY

K. J.A. Kairemo, H. Korpela.
Radiation and Nuclear Safety Authority (STUK), Radiation Practices Regulation, PO Box 14, FIN-00881 Helsinki, Finland

ABSTRACT

New radiopharmaceuticals have been introduced in nuclear medicine examinations, and on the other hand, the amount of many routine nuclear medicine procedures have been replaced with clinical methods utilising non-ionisating radiation (ultrasonography, MRI)
To clarify the situation in Finland, a country wide survey on the use of radiopharmaceuticals in diagnostics and therapy was made in 1975, 1982, 1989, 1994, 1997 and will be made in 2000. A questionnaire was sent to all hospitals and institutes using unsealed sources in both diagnostic and therapeutic nuclear medicine procedures. For each procedure, the pharmaceutical used, the number of procedures and the typical administered activities were recorded. The collective effective doses from nuclear medicine examinations were calculated according to the ICRP formulae similarly for each survey.
In Finland, in each of these years, more than 50 000 procedures in more than 30 different laboratories were performed. Dramatical changes in collective doses were observed: for example, the collective dose from I-131 was 350 manSv in 1975, and 20 manSv in 1997, respectively. This means, that in 1975 68% (n=23967) of collective dose originated from I-131, whereas in 1997 the percentage of I-131 in collective dose was 10 % (n=1118). In 1994 and 1997, the use of the three radionuclides (Tc-99m, I-131 and Tl-201) accounted for 96 % and 95 %, of the collective effective dose.
Our results indicate that the collective effective dose from nuclear medicine examinations has decreased in last 25 years. National surveys form the basis when setting reference levels for typical nuclear medicine examinations. By introducing reference levels based on national practice make it possible to even decrease the collective effective dose.

Correspondence:

K. J.A. Kairemo, MD, PhD, MSc(Eng),
Radiation and Nuclear Safety Authority (STUK),
Radiation Practices Regulation,
PO Box 14, FIN-00881 Helsinki, Finland

tel. +358-9-75988225
fax +358-9-75988248
e-mail kalevi.kairemo@stuk.fi

Introduction

Nowadays more than 50 000 clinical nuclear medicine examinations in more than 30 different laboratories will be performed in Finland. Exact data has to be reported regularly to the Radiation and Nuclear Safety Authority based on the implementation of MED-directive. Additionally, data on the frequency and collective effective dose of nuclear medicine examinations in Finland, were available in years 1994 [1] and 1997 [2]. Data was available in years 1975 [3] and 1982 [4] before that. However, the methods for evaluating collective effective dose have been changed. The aim of this study was to calculate collective effective doses from national surveys beginning 1975 in a similar manner, especially for iodine-131. Furthermore we wanted to find out how nuclear medicine procedures have been changed during 1975-2000.

Materials and methods

A country wide survey on the use of radiopharmaceuticals in diagnostics and therapy was made concerning the years 1975, 1982, 1989, 1994, 1997 and will be made concerning the year 2000. A questionnaire was sent to all hospitals and institutes using unsealed sources in both diagnostic and therapeutic nuclear medicine procedures. For each procedure, the pharmaceutical used, the number of procedures and the typical administered activitities were recorded. The collective effective doses were calculated according to the ICRP formulae similarly for each survey. The dose factors (mSv/MBq) given in ICRP 62 [5] were used.

Results

Information was obtained from all hospitals and institutes. The major component of the collective dose was I-131. Table 1 demonstrates how the collective dose from I-131 has developed between 1975 and 1997.

Year	Total number of nuclear medicine examinations	Collective effective dose from I-131 (manSv)	Collective effective dose from I-131 (%)
1975	59350	350	75,9
1982	85340	303	56,6
1989	55730	124	-
1994	50900	33,0	14,9
1997	51730	19,8	9,6

Table 1. *The collective effective doses from the use of I-131 between 1975 and 1997.*

The collective effective dose from I-131 was 350 manSv in 1975, and 20 manSv in 1997, respectively (Table 1). This means, that in 1975 68% (n=23967) of collective dose originated from I-131, whereas in 1997 the percentage of I-131 in collective dose was 10 % (n=1118). The following radionuclides in descending order, Tc-99m, Tl-201, Cr-51, I-131, In-111, I-123, F-18, O-15, C-11, Se-75, Xe-133, Co-57, were used in more than 100 different investigations in 1997. In 1997, the use of Tc-99m, I-131 and Tl-201 accounted for 95 %, of the effective collective dose.

Table 2 demonstrates how the use of bone scintigraphy using Tc-99m-labelled phosphates or diphosphonates has been changed between 1975 and 1997.

Year	Number of bone scintigraphies	Collective effective dose from Tc-99m (manSv)	Collective effective dose from Tc-99m (%)
1975	2761	8,7	1,8
1982	15266	44,6	8,3
1989	19689	62,2	-
1994	20912	62,6	28,5
1997	21845	71,0	34,3

Table 2. *The collective doses from the use of Tc-99m-phosphates between 1975 and 1997.*

The total amount of nuclear medicine procedures was higher in the 80's than in the 90's (Table 1). In 1975 there were 42 laboratories and also 42 different diagnostic procedures and a total of 59350 investigations were performed. Nuclear medicine procedures were carried out in 33 laboratories in 1997, and more than 150 different diagnostic procedures were carried out, eventhough the total number of investigations was 51730. The amount of bone scintigraphies has stabilized during the last 10 years. The amount of collective effective dose derived from Tc-99m in bone scintigraphy has increased gradually. Figure 1. demonstrates the current practice of bone scintigraphy in different laboratories.

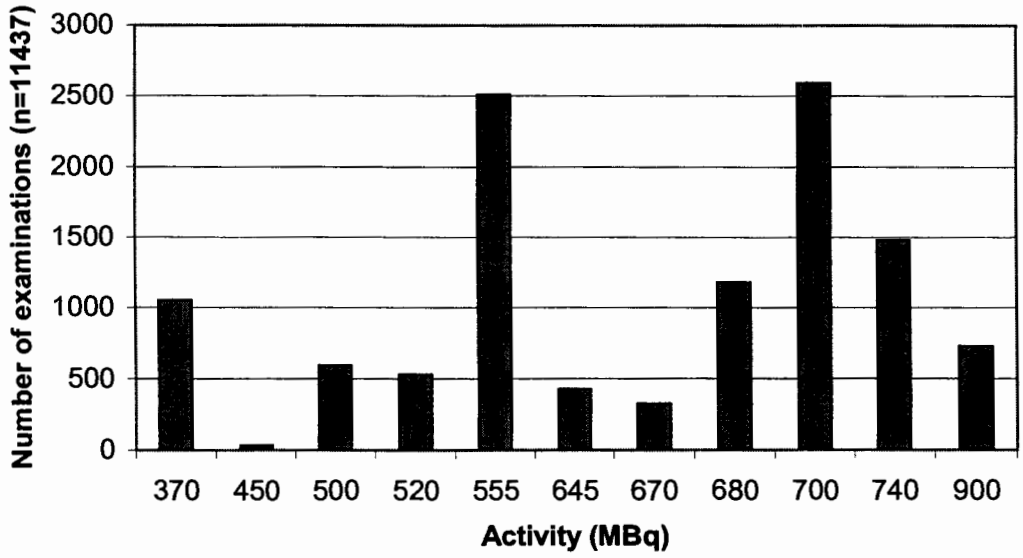

Figure 1. *Injected mean activities in bone scintigraphy in Finland in 1997.*

Discussion

Our results indicate that the collective effective dose from nuclear medicine examinations has decreased in last 25 years. Our results also demonstrate that the total amount of nuclear medicine procedures is nowadays lower than in the 80's. The major constituent of the collective dose has been I-131 (Table 1). Its use has been decreased in a greater extent than those of other radionuclides in diagnostic nuclear medicine.

The influence of Tc-99m on the collective dose derived from bone scintigraphy has increased (Table 2). There is still a great variability in the administered activities between laboratories (Figure 1). Therefore, reference levels are needed. National surveys form the basis for reference levels for administered activities in nuclear medicine examinations. By introducing reference levels based on national practice make it possible to even decrease the collective dose. The reference level planned for bone scintigraphy is 600 MBq and, if SPECT is performed 800 MBq. For comparison, in German national survey [6], in 1992, the mean effective dose from bone scintigraphy was 4.8 mSv per examination whereas our mean effective dose was 3.2 mSv in 1989 and 3.0 mSv in 1994, respectively. In Germany in 1992 [6], the bone scintigraphy was responsible for 38.8 % of the collective effective dose whereas the collective effective dose was in Finland in 1994 28.5%.

In general, the nuclear medicine has developed into right direction during the last 25 years in Finland, i.e. the collective effective dose has decreased and the diversity of nuclear medicine procedures has increased. Also, most of the collective dose originates nowadays from Tc-99m, which is an optimal solution from the radiation protection point of view.

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QUALITY SYSTEMS FOR RADIOTHERAPY –IMPACT BY A CENTRAL AUTHORITY FOR IMPROVED ACCURACY, SAFETY AND ACCIDENT PREVENTION

Hannu Järvinen, Petri Sipilä, Ritva Parkkinen, Antti Kosunen and Ilkka Jokelainen
Radiation and Nuclear Safety Authority (STUK), Helsinki, Finland
e-mail: hannu.jarvinen@stuk.fi

Abstract

High accuracy in radiotherapy is required for the good outcome of the treatments, which in turn implies the need to develop a comprehensive Quality Systems for the operation of the clinic. The legal requirements as well as the recommendation by professional societies support this modern approach for improved accuracy, safety and accident prevention. The actions of a national radiation protection authority can play an important role in this development. In this paper, the actions of the authority in Finland (STUK) for the control of the implementation of the new requirements are reviewed. It is concluded that the role of the authorities should not be limited to simple control actions, but comprehensive practical support for the development of the Quality Systems should be provided.

1. EC directives lay down the legislative basis for Quality Systems

The EC directive on medical exposure (MED) [1] and the directive on basic safety standards (BSS) [2] lay down the basis for the radiation safety of the patients and the staff and public, respectively. The number of detailed requirements in these directives implies in practice that the user of radiation must establish and maintain a well documented system of organizational and technical arrangements to ensure radiation safety of the operation. In terms of modern quality concepts this is considered equivalent to saying that the user must have a comprehensive Quality System [3] for the operation.

For radiotherapy, the requirements by the EC directives are supported by the recommendations issued by the European Society for Therapeutic Radiology and Oncology (ESTRO) [4,5]. The recommendations by ESTRO on the Quality Systems in radiotherapy combine the general principles of quality standards [3] with practical experiences on quality assurance in radiotherapy procedures [6]. The recommendations provide the general approach of the quality standards but tailored to the concepts and practical needs in the field of radiotherapy.

2. Regulatory actions at a national level

The radiation protection legislation in Finland has established the basis of radiation safety essentially in terms of licensing the use of radiation and setting up a number of requirements on the arrangements for radiation safety by the user. The implementation of the requirements is verified by regular inspections of the operation, including the inspection and acceptance of the local quality assurance programs, by a radiation protection authority (STUK). As a particular detail for radiotherapy, the inspections by the authority incorporate a thorough set of dosimetric measurements to verify the accuracy and correctness of the procedures applied by the user.

The new EC directives (BSS and MED) imposed a number of changes in the basic legislation for radiation protection, while a special degree by the Ministry of Health and Social Affairs was issued to cover the detailed requirements given in the MED directive. Based on the predictions of the practical impact of these changes, as well as on the recommendations published by the ESTRO, a national working group of radiotherapy experts (physicians, physicists and a nurse) was convened by STUK in order to prepare a national guide on Quality Systems in radiotherapy. The guide, finally issued in autumn 2000, is entirely based on the ESTRO guide [5] but is written in Finnish and supplemented by the national experiences of clinical work. A few meetings with key radiotherapy physicians, physicists and the heads of radiotherapy departments preceded this work in order to provide the necessary support and to direct the effort on the actual needs of the clinics.

Besides the changes of the basic legislation and the above practical guide on Quality Systems, a number of special guides (so called ST-guides) to supplement and detail the legal requirements have been issued by STUK. Some of these pertain to all applications of radiation (e.g, guide on personnel monitoring), but two of these are specific to the radiotherapy applications: "Quality Assurance for Radiotherapy" and "Radiation Safety of Radiotherapy Rooms and Equipment". The former one is the key guide, which details the basic principles and requirements for overall QA in radiotherapy.

3. Regulatory actions versus audits

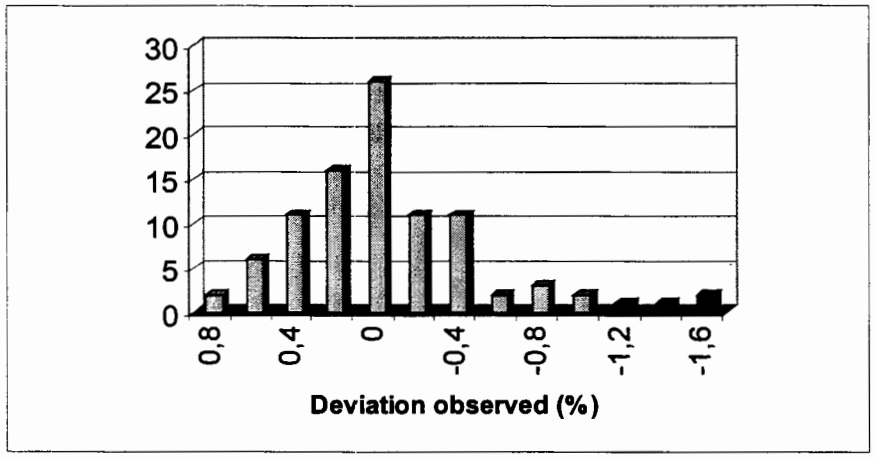
An important new concept in the requirements for overall QA in radiotherapy is the need for internal and external *audits* of the radiotherapy process. Here a clear distinction has to be made for the following types of audits:

(a) Quality Audits for *external certification* that the Quality System operated by the clinic conforms to a given standard.
(b) Dosimetry Audits or "Quality Audits" for the verification of the accuracy and correctness of the local dosimetry and quality control procedures.
(c) Clinical Audits as introduced in the MED directive, for a comprehensive evaluation of the quality of the clinical practice including the work done by all professionals of the clinic.

The last one is the most comprehensive evaluation aiming at comparing the existing clinical practices with "good" practices and introducing improvements when necessary. As such, it should inherently include an element for the verification of the correct dose to the patient; in other words, Dosimetry Audits should be a part of its implementation. For the full implementation of the Clinical Audits, no exact model nor detailed recommendations are available but the requirement in the MED directive calls for its implementation in accordance with the national arrangements. The objectives of the Clinical Audits are well specified in the new Finnish legislation, while the organization and practical implementation of the Clinical Audits are now under extensive discussion between authorities, professional societies and radiation users.

observed deviations are given in Fig.1.

The extensive comparative measurements by STUK, in connection with the regular inspections of radiotherapy equipment and practices, are considered as a practical means of control. These are aimed at verifying the accuracy and the correctness of methods of Quality Assurance applied by the user, the criteria being set by the action levels defined for the results of the comparative measurements. An example on the distribution of the



The system of regular comparative measurements provides STUK with the necessary follow-up and confirmation that the technical conditions for a high-quality radiotherapy are continuously maintained in all clinics. The system of on-site visits enables a much more effective and comprehensive evaluation than a mere postal control of certain parameters with the help of thermoluminescence dosimeters, as widely applied for audits [7]. During the on-site visits, the problems can be immediately identified and further investigations and the necessary remedial actions initialized.

Due to the established system of regular site-visits with comprehensive measurements, in Finland there is no need for postal TL-audits in the same sense as recommended e.g. by the ESTRO. However, an occasional participation of the clinics at other audit programs, such as the ESTRO-EQUAL program, is considered to provide a useful external audit of the whole national system of comparative measurements. Further, the TL-audits for the comparative measurements, carried out annually by the IAEA for the laboratories in the SSDL Network, provides another confirmation of the accuracy and quality of the methods applied in the national system.

4. Central register of abnormal incidences

One of the major objectives of the Quality Systems is to provide the organization, the radiotherapy department, with a framework which makes it possible to identify mistakes before they effect the treatment, i.e., to ensure effective methods of accident prevention. Information on such incidences are centrally collected by STUK in order to provide possibilities to learn from the incidences and effectively affect on minimizing their appearance. Whenever necessary, a through investigation of the cases are conducted, the

marketing organizations and manufacturers are contacted, and other users of similar equipment or techniques are alerted.

5. Education and Training actions

The MED directive imposed more attention to the need of continuous training of the all users of radiation. The authorities, which are responsible for the control of the implementation of these requirements and the acceptance of the training programs, are not expected to provide the training needed for the required competence. However, as the centres of expertness, radiation protection authorities can provide training for the training organizations, and also such practical training which improves the knowledge of the users on safety features. In Finland for radiotherapy, STUK organizes regular annual meetings with the radiotherapy physicists and targeted training for particular topics in radiation dosimetry and quality assurance. Also, national guides on dosimetry are prepared and issued by STUK, in collaboration with radiotherapy physicists.

6. Quality of radiotherapy metrology

For practical reasons, the maintenance of the national standards for ionizing radiations is also a responsibility of STUK. The standard dosimetry activities are developed to conform to the international requirements, in particular, to the requirements of the Mutual Recognition Arrangement (MRA) [8]. The Quality System of the laboratory has been developed in accordance with the new ISO standard [9], and the data on the calibration and measurement capabilities (cmc) have been prepared for EUROMET database. Research on calibration and measurement techniques are undertaken to maintain the expertness and to develop the methods to cope with the rapid development of radiotherapy techniques. A number of improvements of calibration techniques are being implemented. This includes, among other things, the implementation of the new international code of practice for absorbed dose to water calibrations [10], centralized calibrations of plane parallel ionization chambers in electron beams, new calibration techniques for brachytherapy sources, and new radiation qualities for the calibrations of dosimeters in diagnostic radiology.

7. Conclusions

The EC directives create the regulatory basis for the development of the Quality Systems in radiotherapy, the major efforts which are also recommended by the ESTRO. The radiation protection authorities evidently play an important role for the implementation of the legal requirements. The role of the authorities should not be limited to simple control actions, but the authorities should provide comprehensive practical support for the development of the Quality Systems. This could include preparation of appropriate guidance, arrangements or support of dosimetric comparisons, central collection of data on abnormal incidences, acceptance of training programs with targeted training of trainers and key professionals, maintenance of high quality in radiation metrology and high expert knowledge through appropriate research efforts.

8. References

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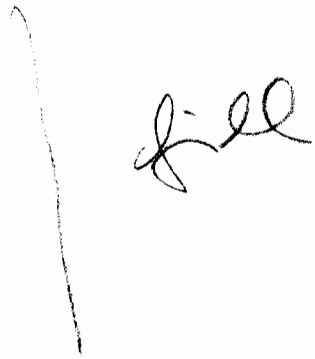
[2] (BSS directive)
[3] (ISO 9001)
[4] (ESTRO filosofia-julkaisu)
[5] (ESTRO practical guidelines)
[6] (WHO: QA in radiotherapy)
[7] (ESTRO-EQUAL ohjelmasta sopiva julkaisu)
[8] (MRA sopimukseen liittyvä julkaisu)
[9] (ISO 17….)



PATIENT DOSES FROM COMPUTED TOMOGRAPHY IN NORTH-EAST REGION OF UKRAINE

N.Pylypenko, V.Kornyeyeva, H.Gur
Grigorev Institute for Medical Radiology, Kharkov, Ukraine
Fax: 380 572 431 125/437 120
E-mail: imr@online.kharkiv.net

Abstract

Survey of CT-examinations, including the measurements of a computed tomography dose index (CTDI) and patient dose assessment was implemented in CT departments of north-east region of Ukraine. The value of CTDI differs by factor 1.3 – 2 for the different units of one type of CT scanner. Total number of CT examinations is gradually increased from 19,717 in 1997 to 68,377 in 1998. The number of CT examinations of children is about 7.6% of total number of examinations. The collective effective dose to the patients due to CT examinations was 276.8 man.-Sv in 1998. The comparison of number and collective effective doses for different kind of CT examinations shows that although only 16% of the CT examinations concern to abdomen, the contribution of this kind of CT examination to collective effective dose is the highest and makes about 50%. Whereas CT examinations of head represent 59% of the all examinations in 1998, its contribution to the collective dose is only 13%.

Introduction

In accordance with the state documents, accepted recently in Ukraine in the field of nuclear regulation, a problem of the population exposure control at medical use of ionising radiation sources is very actual now. A realisation of such monitoring is in need of the implementation of both organisational and practical measures.

Computed tomography takes the special position among other methods of receiving the diagnostic information and finds more and more broad use in practice of medical establishments. At the same time doses of patients undergoing the CT examinations are much higher, than ones from the conventional radiography. It caused an increase in the contribution of CT-examinations to a collective dose from a medical exposure.

The purpose of this study was to survey the state of computed tomography in the four regions of the north-east area of Ukraine and assess the collective dose from this X-ray diagnostic method.

Material and methods

Dosimetry measurements and patient dose assessment at the CT-examinations were carried out in 11 hospitals of the north-east area of Ukraine, including the Dnepropetrovsk, Donetsk, Poltava and Kharkov regions.

The quantity computed tomography dose index (CTDI) was measured free-in-air at each operating CT scanner by means of a specially designed dosimeter with thermoluminescent detectors (TLD). The dosimeter consists of the PMMA capsule with the outer and inner diameter equal 8 and 5 mm, accordingly. Inside the capsule the LiF:Mg,Ti thermoluminescent pellets with a diameter of 4,5 mm and thickness of 0,8 mm (type MTS-N, Krakow Institute of Nuclear Physics) are placed. Length of an accommodation area of the detectors was selected to be sufficient to enclose the full dose profile at free-in-air measurements. The dosimeters were placed along a rotation axis of the scanner so that a single slice scanning plane crosses the centre of the dosimeter. The exposure of the dosimeters were performed at the combinations of scan parameters, such as tube voltage,

current-time product and slice thickness that are most frequently used in routine practice of the CT department.

The measured CTDI were used for the calculation of effective doses apply to average sized adult patient for the routine CT-examination of head, chest, abdomen and pelvis. For an evaluation of doses from CT examinations of head, carried out on the scanner type CPT-1010 (Ukraine) the effective dose conversion factors were obtained using the heterogeneous anthropomorphic phantoms (Riga, Latvia) and thermoluminescent detectors based on LiF type MTS-N and MCP-N (Krakow Institute of Nuclear Physics). For the calculation of effective doses from CT-examinations performed on other types of CT scanners the effective dose conversion factors readily available in publications [1,3] were used.

The data about the number and the structure of CT-examinations carried out in 11 hospitals in 1997-1999 were obtained from the special questionnaires sent to every CT department. The information received has provided the age distribution of CT-examinations and taken into consideration a scanning of the following body sections: head, chest, abdomen and pelvis.

Results

The measurements of CTDI were performed on 6 types of CT scanners. The results have shown that the value of computed tomography dose index measured for the relevant combinations of scan parameters differs by factor 1.3 – 2 for the same type of CT scanner.

The age distribution of CT-examinations performed during 1997-1999 is presented on Figure 1. It can be seen that the number of child examinations is rather small, being about 7.6% of all patients.

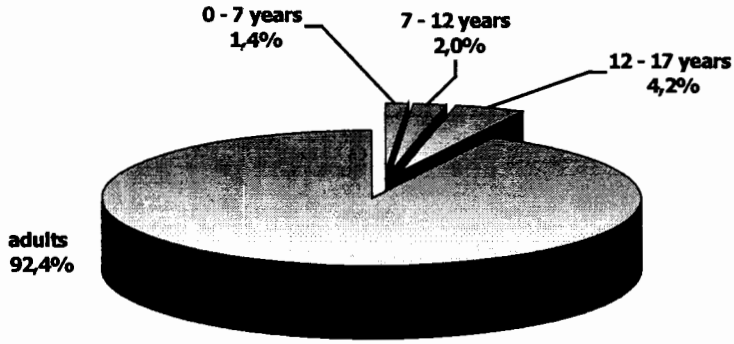


Figure 1. Age distribution of CT-examinations in north-east region of Ukraine in 1997-1999

Figure 2 shows the data about the number and structure of CT examinations of adults carried out in north-east region of Ukraine. As it follows from Figure 2, the total number of CT examinations is gradually increased from 19,717 in 1997 to 68,377 in 1998. The structure of the examinations in 1997-1998 was as follows: head - 60.3%, abdomen -15.8%, pelvis – 15.3%, chest – 8.6%. One of the reason the substantial contribution of the head examination is the relatively large number of CPT–1010 type scanners which are constructed specially for the head scanning.

The derived collective doses from CT examinations performed in 1998 for adult patients are show on Figure 3. In addition, the comparison of number and collective effective doses for different kind of CT examinations is given on this Figure. The conclusion may be done that although only 16% of the CT examinations concern to abdomen, the contribution of this kind of CT examination to collective effective dose is the highest and makes about 50%. Whereas CT examinations of head represent 59% of the all examinations in 1998, its contribution to the collective dose is only 13%.

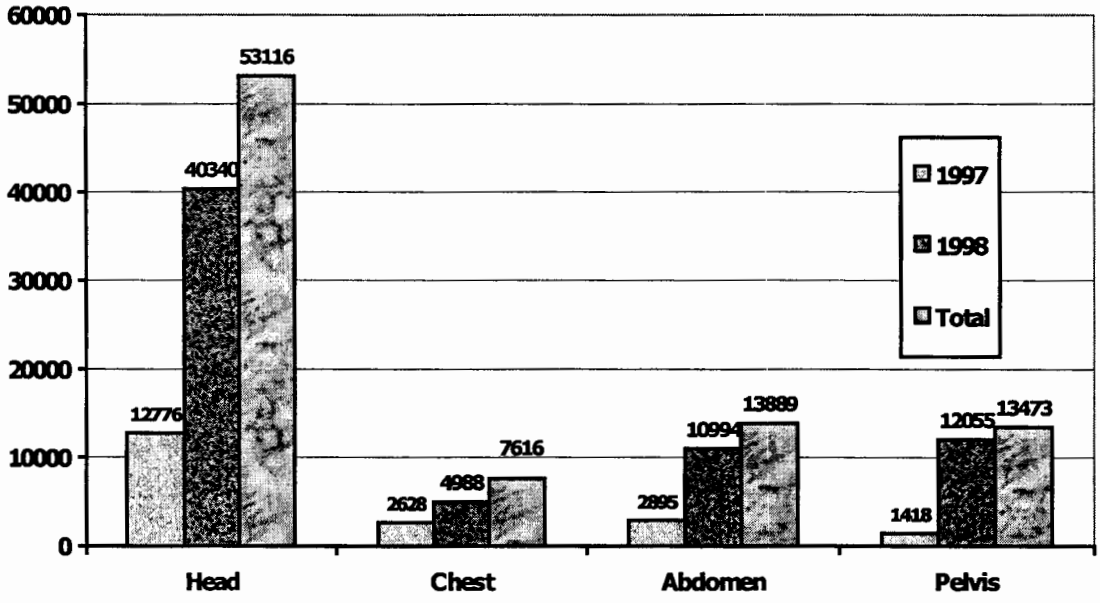


Figure 2. Number and structure of CT examinations in north-east region of Ukraine in 1997-1998

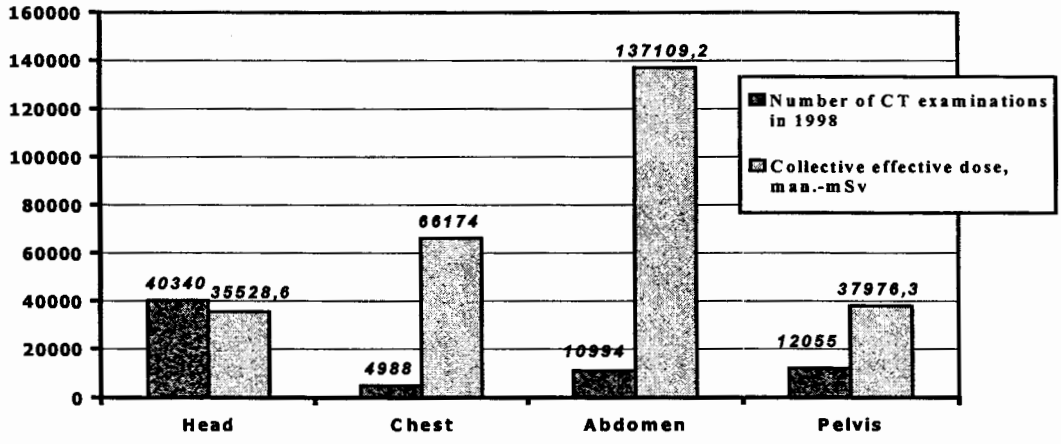


Figure 3. Number of CT examinations and collectlve effective dose (adults) in 1998

Conclusion

Realisation of regular CTDI measurements in CT departments is necessary for the evaluations of patient doses and for the estimations of the relative contribution of different kinds of CT examinations to collective effective dose.

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IMPLICACIONES Y PROBLEMÁTICA SURGIDAS DE LA APLICACIÓN DE LOS REALES DECRETOS QUE ESTABLECEN LOS CRITERIOS DE CALIDAD EN RADIODIAGN., MED. NUC. Y RADIOT., DESDE EL PUNTO DE VISTA DE LOS RADIOFÍSICOS

A. Hernández Vitoria, B. Fernández González, J. Martí Climent, J. Pérez Calatayud
Sociedad Española de Física Médica (SEFM)
Dirección electrónica: fpro@hcu-lblesa.es

Abstract
New laws about Quality Criteria in Radiodiagnostic, Nuclear medicine and Radiotherapy have been recently issued in Spain, concerning radiological protection to patients in each of those medical specialities. The present work deals briefly with the necessities, consequences and problems arose from their putting into effect, in those three fields, from the point of view of radiophysicists.
In the diagnostic area the main difficulties arise from organization aspects to carry out the Quality Control programme in a fluid way. In Nuclear Medicine, the most difficult task is related to the dose estimation in each patient treated with radiopharmaceuticals. In radiotherapy, difficulties are connected with the specified tests to establish the initial reference state of the equipments as well as those for the quality control programme. In particular, in brachytherapy the main problem comes from the compulsory calibration in Standard Laboratories of the detectors used to measure the air kerma rate free in air for all types of employed sources.
In this paper, these and other difficulties are discussed, as well as some actions taken in order to solve them.

Introducción

En los últimos años se han publicado en España los Reales Decretos por los que se establecen los criterios de calidad en Radiodiagnóstico[1], Medicina Nuclear[2] y Radioterapia[3], relacionados con la protección radiológica del paciente en cada uno de esos campos. En los tres decretos se abordan los criterios de calidad en todas las etapas de que consta el diagnóstico/tratamiento del paciente, y que competen a todos los profesionales que intervienen, no limitando el control de calidad al de los equipos que se utilizan. Respecto a este punto, la SEFM ha publicado unas recomendaciones, en colaboración con otras sociedades científicas, para los tres campos de aplicación [4 a 6].
En este trabajo se exponen brevemente las implicaciones, necesidades y problemáticas, emanadas de su aplicación, desde el punto de vista del radiofísico.

Criterios de calidad en Radiodiagnóstico (RD)

Las tareas a las que obliga el decreto[1] al radiofísico: control de calidad técnico del equipamiento, estimación de dosis, participación en la elaboración de especificaciones técnicas de compra de equipamiento, asesoramiento en temas de protección radiológica, etc.. no ofrecen en principio dificultades teóricas. Las que pueden surgir están relacionadas principalmente con cuestiones de organización que no dependen directamente de los radiofísicos pero que sí pueden verse afectados por ellas. Por ejemplo, no en todos los

hospitales está resultando fácil el funcionamiento de una Comisión de Garantía de Calidad de un modo operativo.
Así, pueden surgir problemas al tratar de llevar a cabo las tareas del radiofísico si fallan los procedimientos establecidos para ello o la cooperación necesaria entre Servicios. Por ejemplo, puede ocurrir que no se le comunique en el momento adecuado la sustitución de una unidad de RX o la instalación de una nueva, o que haya dificultades para establecer las dosis de referencia en exploraciones no comunes si no existe la necesaria colaboración entre los profesionales que intervienen, o que se incumpla el procedimiento fijado para solicitar un informe de dosis personalizado de un paciente.
En los últimos años se ha avanzado mucho en la optimización de las exploraciones pero tal vez no tanto en el aspecto de la justificación de las mismas.
Otro asunto que puede ofrecer dificultades está ligado con la formación en cuestiones de protección radiológica. Pueden surgir problemas para impartir dicha formación a algunos especialistas o a personas contratadas en sustituciones (vacaciones, bajas laborales). Esto último obliga a programar frecuentemente sesiones de formación a las que deben acudir las personas recién incorporadas pero plantea problemas de organización a veces irresolubles.

Criterios de calidad en Medicina Nuclear (MN)

El Real Decreto[2] establece que el programa de garantía de calidad en las unidades asistenciales de Medicina Nuclear debe incluir, entre otros, medidas de control de calidad de la instrumentación y de los sistemas de tratamiento de datos, la relación de dosis efectiva por unidad de actividad administrada de los radiofármacos más utilizados y los parámetros relacionados con la estimación de la dosis absorbida en pacientes. En cuanto al radiofísico, cabe destacar que participa en la estimación de la dosis absorbida por el paciente en una prueba diagnóstica, cuando se requiera, y tras la administración de radiofármacos con fines terapéuticos, en la realización de las pruebas de aceptación del equipamiento y en el control posterior del mismo.
Así pues, la participación del radiofísico en el programa de garantía de calidad en Medicina Nuclear es fundamental en la estimación de las dosis absorbidas por los pacientes y en el control de calidad del equipamiento, para lo cual es importante su integración en la dinámica de funcionamiento de la unidad asistencial de Medicina Nuclear.
En la administración de radiofármacos con fines diagnósticos, la dosis puede estimarse utilizando tablas en distintas publicaciones [7] o información aportada por el fabricante del radiofármaco. Pero en la administración de radiofármacos con fines terapéuticos, la dosis absorbida recibida por los órganos debe ser estimada para cada paciente, precisando de un estudio biocinético para conocer la cinética y biodistribución particular del radiofármaco en cada paciente. Las dificultades técnicas principales de esta evaluación son la no existencia de unos procedimientos consensuados para la estimación dosimétrica y el conocimiento de la cinética y biodistribución de cada paciente concreto. Así, en España se ha creado una comisión, en la que intervienen miembros de las sociedades científicas de Medicina Nuclear, Física Médica y Protección Radiológica, con el fin de redactar un protocolo de procedimientos dosimétricos en la utilización de radiofármacos en Medicina Nuclear.

Criterios de calidad en Radioterapia (RT)

A) Braquiterapia (BT)

Aparte de resaltar que el decreto [3] recoge la prohibición explícita de la utilización clínica de las fuentes de Ra-226, que ya estaban prácticamente abandonadas en España, la implicación más destacable de [3] es la obligatoriedad de la verificación de la Tasa de Kerma de Referencia en Aire (TKRA) de todas las fuentes empleadas y que los equipos de referencia para la medida deben estar calibrados en laboratorios de metrología reconocidos. Este hecho, que ya se viene cumpliendo extensamente en RT externa, en braquiterapia significará que para todas las fuentes de uso clínico deberá existir un calibrador con trazabilidad a un patrón. Por tanto se deberán adquirir en la totalidad de unidades de Radiofísica los calibradores adecuados, con factores de calibración del sistema para todos los modelos de fuentes operativos en el Servicio de RT.

Como se recoge tanto en el Informe del Grupo de BT de la SEFM [8] como extensamente en el Informe sobre necesidades metrológicas en BT[9] este aspecto obligatorio en el decreto es del que mayor problemática y necesidades se derivan para su cumplimiento.

Por diversas razones [8-10], el sistema de referencia para la medida de la TKRA es el detector pozo con los insertos apropiados; la calibración de estos sistemas se debe realizar con un modelo de fuente exacto al que posteriormente se va a utilizar para la medida de su TKRA. El problema es que no existen patrones disponibles en los laboratorios de calibración que cubran la amplia variedad de fuentes en uso en España. Para el caso de fuentes de Tasa Alta (HDR) y Tasa Pulsada (PDR) existe la alternativa del uso de las cámaras cilíndricas típicas para RT Externa[8,9], calibradas para una determinada calidad de RX junto con Cs-137 y/o Co-60.

En el caso de fuentes de Baja Tasa de Cs-137 (LDR) para los que no exista patrón, la solución más viable y práctica [9] para la verificación de su TKRA es mediante el uso de cámaras de gran volumen ($\geq$ 1 litro) calibradas en la energía del Cs-137. Esto requiere la adquisición de la instrumentación adecuada, el desarrollo de procedimientos y metodología de medida y la disponibilidad en los laboratorios para calibrar estas cámaras [9].

Problemas de difícil solución son el caso de fuentes que no se pueden extraer de los aplicadores en sistemas de carga diferida de LDR, caso del Selectron y el caso de conjuntos de fuentes que el fabricante proporciona selladas en sus aplicadores [8]. Es necesario que se desarrollen recomendaciones y procedimientos de verificación dosimétrica para estos casos, de los que hay un buen número operativos en España, para que las unidades de Radiofísica pueda cumplir lo especificado en [3].

B) Radioterapia externa

En radioterapia externa, la publicación del decreto [3], no ha modificado de forma relevante la actuación del radiofísico ya que este campo ha sido tradicionalmente el de su mayor dedicación. Principalmente, las obligaciones que impone respecto a la calibración de equipos no ofrecen problemas particulares a diferencia de lo que ocurre con la braquiterapia.

Sin embargo, tras su publicación, han podido surgir algunos cambios en la organización o modo de actuación de los Servicios implicados. Por ejemplo, el decreto impone unas normas de actuación respecto a las averías que se producen en las unidades de terapia, que ha podido alterar las existentes previamente en los Servicios de Radiofísica/Radioterapia.

Según el decreto, debe ser el radiofísico el nexo de unión entre el técnico que repara la unidad y el radioterapeuta. El radiofísico debe autorizar al técnico la reparación de la unidad y recibir el informe de la misma. Si la jornada de trabajo del radiofísico no coincide en su totalidad con la de funcionamiento de las unidades de terapia o con el de horario de trabajo de los técnicos, este hecho obliga a tomar decisiones que pueden diferir en cada centro de trabajo (parar tratamientos en caso de avería, prolongación de jornada o guardias de radiofísico, etc..). Hay que resaltar como algo muy positivo que el decreto obligue a que en el parte de reparación el técnico haga constar si, como consecuencia de su reparación, se ha podido alterar alguna característica de los haces.
Es posible que, como consecuencia de la publicación del decreto [3], en muchos Servicios de RT se haya tenido que incluir de modo obligatorio un control semanal de la ficha de tratamiento, tanto por parte del radioterapeuta como del radiofísico.
La única dificultad que conllevan estas actuaciones es el tiempo que hay que dedicarles, pero son actuaciones que ayudan a mejorar la calidad de los tratamientos.

Dificultades comunes en radioterapia externa y BT.

Respecto al contenido y periodicidades de las pruebas para el establecimiento del estado de referencia inicial y del programa de control de calidad en radioterapia externa, braquiterapia y en los equipos de planificación y cálculo, cabe destacar que se entienden sometidas a la flexibilidad que se deriva del artículo 15 en el que se señala que dichas pruebas, tolerancias y periodicidades podrán ajustarse a protocolos de reconocida solvencia pudiendo modificarse además con criterios justificados que tengan en cuenta los objetivos de los tratamientos y tecnología disponible. Esta interpretación parece ser la de más amplia aceptación en la SEFM pero resulta dudosa según lo que literalmente expresa el artículo 12 respecto a las pruebas para fijar el estado de referencia inicial. Si hubiera que hacer rigurosamente lo que figura en el anexo II de [3] se necesitaría una explicación adicional detallada e inclusive una eventual modificación del decreto.
La publicación del decreto [3], pese a implicar un aumento de tiempo de dedicación del radiofísico a tareas como las mencionadas anteriormente, no ha venido emparejada con un aumento de plantilla de los Servicios de Radiofísica, y éstos tienen en general, un déficit de personal [11]. También son necesarios unos medios mínimos instrumentales.

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THE VALUE OF HEPATOBILIARY SCINTIGRAPHY IN THE EVALUATION OF PATIENTS AFTER THE RECONSTRUCTIVE SURGERY ON HEPATOBILIARY TREE

Marcela Volneanschi, Victoria Coretchi, Department of nuclear medicine and MRI, Republican Clinical Hospital
Alexandru Ferdohleb, Vadim Hotineanu, Department of gastrosurgery, Republican Clinical Hospital.

INTRODUCTION

The pathology of the biliary tree take an important part in gastrosurgery. The most frequent risks of biliary surgery are systemic and regional consequences of biliary obstruction. The long-term folow-up after surgery function of anastomosis depends on correctness of indication and of surgical technique. The absence of function in this cases is bound up with persistent or appearance of organic or functional obstacle at any levels of anastomosis complex. The new methods of investigations and new surgical techniques in treatment of biliary obstruction establish the continue decrease of morbidity and mortality ratio in postoperative period.

The imaging investigations in this context are complementary with unequal efficiency. Most of this modalities of investigations have as result the morphological description of investigated structures, few of them can associate and description of function. For example, ultrasound ans scintigraphy are complementary, both modalities can be associated for more precise diagnosis. The hepatobiliary scintigraphy studies in nuclear medicine are easy to perform, efficient, fast and inexpensive. No special patient preparation is required.

The biliary passage can be examined using 99mTc-labelled hepatobiliary agents, typically 99mTc-imidodiacetic acid (HIDA) or Desofenin (DISIDA). Following intravenous injection, technetium (99mTc) etifenin is bound to plasma proteins and carried to the liver. It is cleared rapidly from plasma, less than 1% of administrated activity remaining 1 hour after injection.

Technetium (99mTc) etifenin is taken up by the active transport into hepatocytes in a manner similar to bilirubin, reaching peak activity in the liver in 12 minutes. The liver T1/2 is 25-30 minutes in health but this may be influenced by plasma albumin concentration, hepatic blood flow and hepatocyte function. Tracer can be excreted unchanged into bile or bound to bile salts either within the hepatocyte or immediately after excretion. Small amounts only are excreted in the urine unless there is a significant biliary obstruction. In healthy subjects, the biliary tree is visualized within 5-20 minutes of injection and the gall bladder within 10-40 minutes.

Hepatobiliary scintigraphy is useful in diagnosis of biliary obstruction, detain of radiofarmaceutical in duodenum and can demonstrate the site of obstruction. May be used for evaluation of biliary passage through biliary-enteric

anastomosis. In cases of obstruction radiotracer is absent in extrahepatic biliary tract and in intestinal area. The advantage of method is: can be performed in patients with high level of cholestasis (real 10-15 mg%) till the biliary secretion through glucuronide is present.

We investigated the effectiveness of hepatobiliary scintigraphy for the evaluation of the recovery of biliary passage in postoperative period in patients after reconstructive surgery on biliary tree.

MATERIALS AND METHODS

We studied a group of 12 patients, including 7 female and 5 male, the mean patient age was 29-73 years. Hepatobiliary scintigraphy was carried out before surgery and within the first, third and six months after re-constructive surgery on biliary tree.All patients underwent ultrasound examination and 7 patients underwent radiography.

The surgical indications was:

Megacholedoc associate with choledocholitiasis - 2 cases;
Iatrogenic stricture of main biliary tract :
· at common hepatic duct level - 3 cases;
· distal part of choledoc - 1 case;
Benign biliary strictures - 4 cases;
Residual giant choledocholitiasis - 1 case.
In 9 cases clinically evoluated with acute purulent angiocolitis and in 4 cases - acute liver insufficiency.

The surgical procedures included: choledocojejunoanastomosis using a Roux limb - 2 cases, choledocholitotomy pr. Kher - 1 case; choledoc exerez with implantation of choledoc using a Roux limb - 6 cases, hepaticojejunostomy using a Roux limb - 2 cases.

The results of hepatobiliary scintigraphy was compared with ultrasound results, other X-ray investigations: retrograde cholangiopancreatography, fistulography, laboratory tests in order to confirm (or exclude) the suspicion of obstruction by demonstrating of biliary tree dilatation, identification of site and excluding of other causes of biliary obstacles (hepaticococanalar or pancreatocanalar postoperator benign stenosis, secondary distal stenosis in chronic pancreatitis etc.).

Hepatobiliary scintigraphy was performed after intravenous injection of 120 MBq of technitium-99m HIDA. All patients fasted for at least 4 hours before the scan.

Hepatobiliary scintigraphy was performed on a "DIACAM SIEMENS" gamma camera. LEAP colimator was used. Data was acquired every 60 seconds for 90 minutes in the anterior projection, matrix 64#64. Additional images were obtained at 4 hours when intestinal activity was not visualized at 120 minutes.

Results of hepatobiliary scintigraphy was analyzed quantitatively. The quantitative parameters used were time to maximum activity (Tmax), time to half of maximum (T1/2), the intestinal passage.

RESULTS

Hepatobiliary results was analyzed for evaluation of morpho functional integrity of biliary tree and was classified as: complete biliary obstruction or partial biliary obstruction. Radiopharmmaceutical appear in small intestine one hour after intravenous administration in normal condition. In cases of complete biliary obstruction radiopharmaceutical doesn't penetrate in small intestine in decay images. The scintigraphyc visualization of cholecist and biliary tree without penetration of radiotracer at intestinal level are a sign of extrahepatic biliary obstruction. In cases of intrahepatic cholestasis elimination of radiotracer began one hour after administration, but less as in normal condition. In partial obstruction the excretion of radiopharmaceutical in small intestine is late, but is present.

In 6 of 12 investigated patients we found complete biliary obstruction and in 5 cases - partial biliary obstruction.

Hepatobiliary scintigraphy examination suggested the diagnosis which was confirmed toultrasound and radiofraphy. In 5 patients with ultrasonographyc signs of choledocholitiasis the finding on hepatobiliary scintigraphy suggested complete bloc without intestinal visualization in decay images (3 cases) and partial bloc (2 cases). In 2 patients with sign of dereglation of biliary passage confirmed on ultrasound, scintigraphy showed complete bloc and in one case - extrahepatic biliary obstruction. The dynamic studies in postoprsative period (1,3 and 6 months after surgery) showed gradual improvement of radiotracer passage.

DISCUSSION

Radionuclide imaging studies of the gastrointestinal tract are generally far less invasive than the alternative X-ray contrast procedure. They do not involve the use of dense and often unpalatable contrast agents and use a range of more physiological tracers which add to the clinical value in both diagnosis and research. In general radionuclide procedures are more readily tolerated by patients and have the important consideration of reduced exposure to radiation than X-ray alternative. For the same reasons it is possible to establish important data in dynamic studies on patients. The superiority of hepatobiliary scintigraphy was in estimate the functional aspects, while ultrasound reveals anatomic aspects of the biliary tree.

Hepatobiliary scintigraphy can be performed dynamic in order to evaluate the functional recovery of biliary tree in patients after reconstructive surgery. In our study after re-constructive surgery on biliary tree the biliary passage re-established through biliary-eneric anastomosis in 80% cases and retained in 20% . This is very important for clinicians in order to estimate the tactics of treatment.

CONCLUSION

Our study confirm, than hepatobiliary scintigraphy is a noninvasive, rapid, easy to perform and is helpful in evoluation of functional recovery of biliary passage inpatients in short-term and long-term postoperative period.

The radiation exposure and risk of allergic reaction are minimal. The method is indicated for all patients with suspicion of dereglation of biliary transit.

Hepatobiliary scintigraphy is a complementary method in combination with other diagnostically procedures and offer information for appreciation of function, anatomy and topography of liver, intra and extrahepatic biliary tree.

THE STATE OF RADIATION PROTECTION OF MEDICAL STAFF IN UKRAINE FROM DATA OF CENTRALIZED PERSONAL DOSE MONITORING

L. Stadnyk, I. Yavon, I. Panchenko
Grigorev Institute for Medical Radiology, Kharkov, Ukraine
Fax: +038 (0572) 431-125 or 437-120
e-mail: imr@ online.kharkiv.net

Abstract. . The experience of centralized personal dose monitoring of more than 5000 medical radiologists and medical staff in diagnostic radiology of Ukraine during 1981-1999 is described. The dynamics of collective, mean annual doses and another radiation-hygienic parameters which characterize the state of radiation protection for different professional groups of medical staff are analyzed. The determination of critical groups of medical staff, development of the ways for optimization of radiation protection and safety are considered.

Close control over the doses of staff exposure and performing unjustified exposure limitation measures are important constituents of radiation safety assurance during radiological diagnostics and radiation therapy.

Radiation monitoring of workers using personal dosimeters is carried out for medical staff of whole Ukraine by centralized service in Grigorev Institute for Medical Radiology from 1979.

The main stages of centralized personal monitoring consist following:

- the central laboratory receive the lists of persons undergoing individual dosimetry from the all hospitals of different regions;
- the personal dosimeters and documentation needed are prepared in the central - laboratory and sent to each hospital by mail;
- every 3 mouths exposed dosimeters are returned to central laboratory by mail;
- the staff of central laboratory measure the readings of dosimeters and enter these into the database of automatic information system;
- the central laboratory send the results of dose measurements to each hospitals;
- the radiation-hygienic analysis of annual occupational exposure is performed by central laboratory for each professional group, hospital, region and for whole Ukraine;
- the central Laboratory send the results of this analysis to Ministry of Health and to hospitals.

At present laboratory check the dose levels more than 5000 persons from about 300 hospitals of all regions of Ukraine. In Ukraine the personal monitoring encompass practically all persons working in radiation therapy and nuclear medicine and only about 20 % of medical staff dealing with X-ray diagnostics.

The measurements of dose are performed using manual TL-readers DTU-01 (Latvia) and TL-detectors DTG-04 (Russia).

The results of individual dosimetric control were treated by special computed program. This program allows to collect, accumulate, save the individual doses data and analyse them. The system provides also the opportunity to create different documents intended for sending from central laboratory to medical establishments and returning back.

A considerable amount of information on collective and mean annual doses of medical staff exposure, on dose dynamics during observation years, on personal annual dose

distribution for different types of work with radiation souses in medicine and among different occupational groups has been accumulated . The summary results concerning irradiation doses of medical staff of Ukraine are shown on Fig.1 and Fig.2.

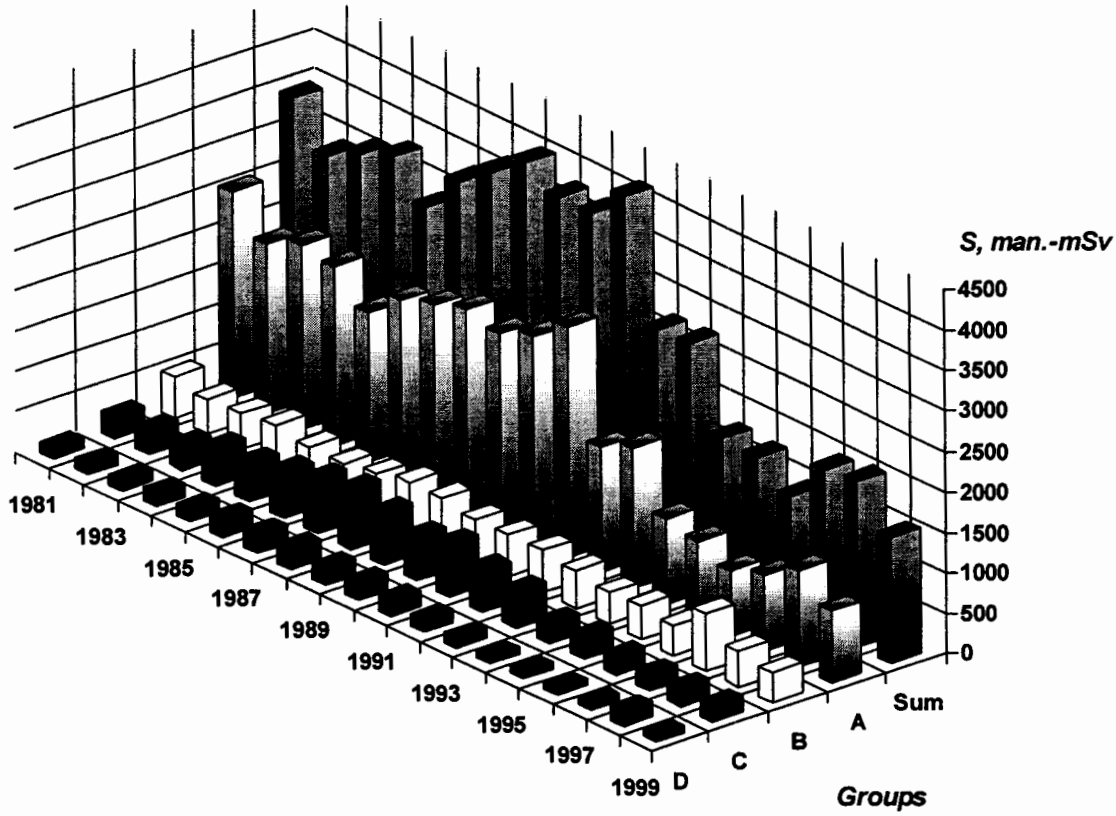

Fig.1 Dynamics of collective doses of medical radiologists of Ukraine in1981-1999

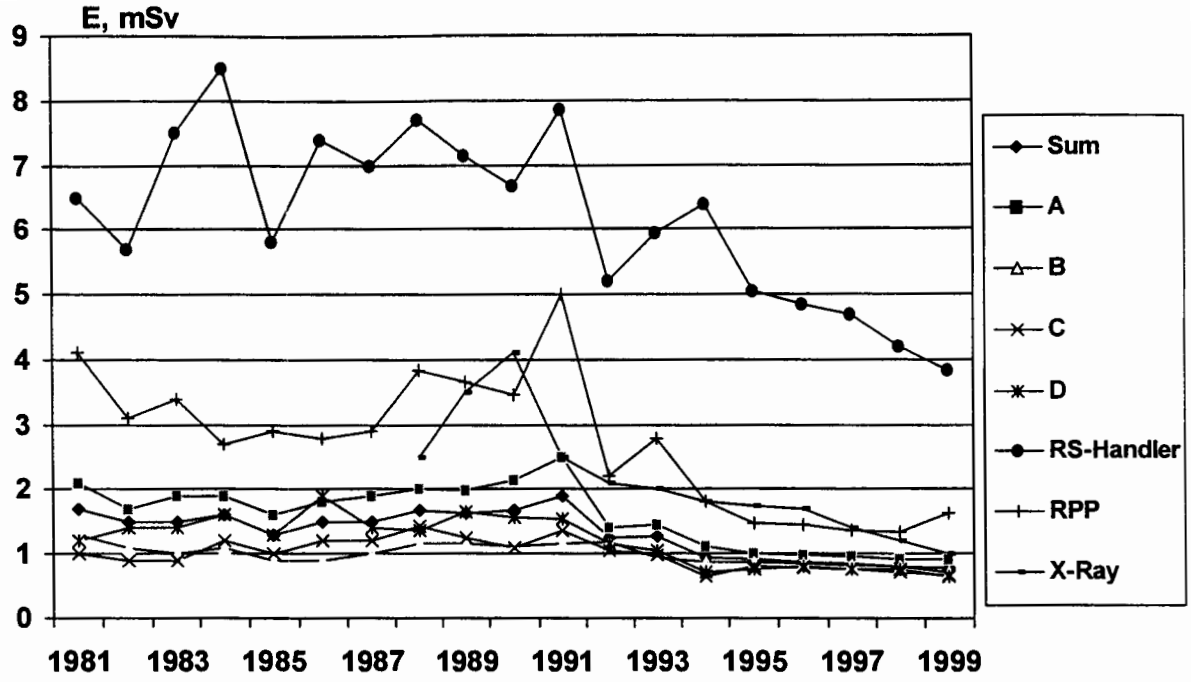

Fig.2 Dynamics of mean annual doses of Medical Staff in 1981-1999

The group **Sum** – the all medical staff working with gamma-radiation sources – medical radiologists;

- the group **A** – the medical staff performed the intracavitary gamma-therapy;
- the group **B** - the medical staff performed the telegamma therapy;
- the group **C** – the medical staff of nuclear medicine;
- the group **D** - the medical physics and technologists;
- the group **RS-handler** – the medical personal worked as nurses-handler of radioactive substances;
- the group **RPP** – the radiomanipulation paramedical personnel;
- the group **X-ray** – the medical staff in diagnostic radiology.

In Ukraine the Dose Limits for occupational exposure correspond to International Basic Safety Standards: an effective dose – 20 mSv per year averaged over 5 consecutive years, but the maximal dose limit (MDL) equal to 50 mSv in any single year [1,2].

The majority of Ukrainian medical workers (up to 98 %) whose connected with radiation sources have been shown to obtain annual doses of 0.1 maximal dose limit – 5mSv per year.

Mean annual doses of some groups of medical staff working in radiotherapy were 1.3-2.5 mSv/year, working in diagnostic radiology were 1.0-4.1 mSv/year.

According to the mean annual dose level and to the fraction of persons obtaining doses more than 0.3 MDL the critical groups were separated from medical staff performing radiotherapy with enclosed gamma radiation sources.

Mean annual doses of handlers of radioactive substances and radiomanipulation paramedical personnel exceed or approach 0.1 MLD (5.2-8.5 and 2.2-5.0 mSv) and a fraction of persons who has obtained doses more than 0.3 MLD is about 20 % and 5 % respectively.

Among the staff working in diagnostic radiology the most high mean annual doses are obtained by physicians - non radiologists (surgeons, anaesthetistes) and junior nurses, performing complicated X-ray diagnostics procedures in intervention radiology (up to 4.5mSv per year). But according to National Safety Standards the Dose Limit for non radiologists participated in diagnostic radiology equal to 5 mSv per year [2]. The fraction of non radiologists who has obtained doses more than 0.3 MLD may be as much as about 4 %.

The further optimization of radiation protection system during the work with medical radiation sources should be aimed at the reduction of dose loads in the professional groups with higher doses and risk.

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PROCEDIMIENTO NORMALIZADO DE OPERACIÓN PARA LA REALIZACIÓN DE AUDITORIAS DE CALIDAD EN INSTALACIONES DE TELETERAPIA CON UNIDADES ISOTÓPICAS DE CO^{60}

Eduardo Francisco Larrinaga Cortina[1], Lourdes Domínguez Hung[1], Raudel Campa Menéndez[2]

1. Centro de Control Estatal de Equipos Médicos. Calle 4 e/19 y 21 No.455 altos Vedado Ciudad Habana, Cuba. CP10400.
   Tel: (537) 32 5072-32 7217
   E.mail: larri@cceem.sld.cu
2. Centro de Protección e Higiene de las Radiaciones.

ABSTRACT

The use of the radiotherapy implies the necessity of rigorous quality standards in its different components, aimed to provide the best possible treatment and avoid potential patient's risks, that could even causing him the death. Projects of technical cooperation had been developed in Cuba support by the International Atomic Energy Agency addresses to the implementation of Programs of Quality Assurance (PGC) in radiotherapy services. The establishment of the National Quality Audit Program (PNAC) is a superior stage. The National Control Center for Medical Devices as the national regulator entity for the control and supervision of medical devices in the National Health System is the responsible for the making and execution of the PNAC. The audit modality selected was the inspection visit *in situ* due to its intrinsic advantages, our geographical extension and the number of radiotherapy services. This paper presents the methodology for the execution of the PNAC, in form of a Normalized Procedure of Operation (PNO) that defines the objectives, scope, terms and definitions, responsibilities, composition and selection of the auditor team, security's conditions, materials and equipment, steps of the audit execution, results calculation and interpretation, records, etc.

1. INTRODUCCIÓN

El cáncer constituye la segunda causa de muerte en nuestro país, representando este indicador el 20.6% de las defunciones ocurridas en 1999 [1]. El empleo de la radioterapia como una de las principales alternativas en la cura y paliación de esta enfermedad, implica el cumplimiento de rigurosos estándares de calidad en las diferentes componentes de su desempeño, con el fin de proporcionar el mejor tratamiento posible y evitar riesgos potenciales al paciente, que incluso pudieran llegar a causarle la muerte. En los últimos años en Cuba se han desarrollado proyectos internacionales de cooperación técnica con el Organismo Internacional de Energía Atómica (OIEA) dirigidos a la implementación de Programas de Garantía de Calidad (PGC) en los servicios de radioterapia y en la elaboración y adecuación a nuestra realidad actual, de protocolos internacionales de garantía de calidad en los aspectos físicos de la radioterapia.

El establecimiento del Programa Nacional de Auditoria de Calidad (PNAC) es una etapa superior en los PGC en los servicios de radioterapia. El Centro de Control Estatal de Equipos Médicos es la entidad reguladora nacional para el control y supervisión de los equipos médicos del Sistema Nacional de Salud (SNS) y el responsable de la confección y ejecución del PNAC; para ello se apoya en un grupo tripartita integrado por el Instituto Nacional de Oncología y Radiobiología-Grupo Nacional de Oncología, responsable del fomento y supervisión de los PGC en los servicios de radioterapia y el Laboratorio Secundario de Calibraciones Dosimétricas del Centro de Protección e Higiene de las Radiaciones (LSCD-CPHR), encargado de garantizar las calibraciones de la instrumentación radiométrica y su traceabilidad como parte integrante de la red internacional de laboratorios patrón secundario OIEA.

Debido a la extensión geográfica de Cuba y al número de servicios de radioterapia (9), se seleccionó como modalidad principal de auditoria la visita de inspección *in situ*, además por las ventajas intrínsecas que esta opción representa, puesto que permite una revisión general de un gran número de aspectos del

PGC, de manera directa y en presencia del físico responsable de su ejecución en el servicio. En el presente trabajo se expone la metodología para la ejecución del PNAC.

2. DESARROLLO.

La política de calidad del CCEEM define como objetivo principal el cumplimiento de los requisitos de seguridad y de efectividad de todos los equipos médicos, previo a su introducción en el SNS y durante su utilización en el mismo, mediante el desarrollo de los procesos de evaluación de mercado, control regulatorio y vigilancia sanitaria, acorde a las normas nacionales e internacionales vigentes [2,3]. Dentro de dicha política se integra la confección del Procedimiento Normalizado de Operación (PNO) [4] como documento metodológico y normativo de la actividad de auditoria de calidad a estos servicios de radioterapia del PNAC implementado por el CCEEM. Además las instalaciones de radioterapia, como equipos emisores de radiación ionizantes de categoría relevante están sometidos a control regulatorio por el Centro Nacional de Seguridad Radiológica y Nuclear (CNSN), así como las actividades relacionadas con dichas instalaciones [5], auditorias de calidad incluidas, constituyendo este PNO parte de la documentación necesaria para la acreditación de la actividad de auditoria de calidad ante el CNSN.

El PNO describe detalladamente la forma de realizar las operaciones de rutina para garantizar la calidad y uniformidad organizativa del proceso de auditoria de calidad. En su parte inicial se define su objetivo, alcance, términos y definiciones empleadas y las responsabilidades. Como segunda parte se establece la composición del equipo auditor, condiciones de seguridad durante la realización de las visitas y los materiales y equipamiento necesarios a utilizar. Su tercera parte se refiere a las etapas de preparación y ejecución de la auditoria, el cálculo e interpretación de los resultados y la confección de los informes. Por último se definen lo registros de las visitas de auditorias. Además se anexan el protocolo para la recolección de evidencias objetivas y los modelos de recolección de datos. A continuación se explica de manera concisa la estructura antes mencionada.

2.1. Objetivo: su objetivo es establecer la metodología a seguir para la realización de las auditorias de calidad en instalaciones de teleterapia con unidades isotópica de ^{60}Co pertenecientes al SNS. Como objetivo específico documenta y garantiza el cumplimiento de los requisitos regulatorios establecidos por la autoridad competente.

2.2. Alcance: aplicable en el CCEEM, Departamento de Radiofísica, para la ejecución de las auditorias de calidad anuales a las instalaciones de teleterapia con unidades de teleterapia isotópica de ^{60}Co, de las instituciones asistenciales del SNS.

2.3. Términos y definiciones: se especifican conceptos pertenecientes al tema.

2.4. Responsabilidades: se definen las responsabilidades en la planificación, ejecución y control del procedimiento de auditoria de calidad en sí y de las garantía de las condiciones necesarias para lograr los objetivos de la auditoria, así como del entrenamiento y capacitación de los miembros del equipo auditor.

2.5. Condiciones de seguridad: se definen las garantías de la vigilancia radiológica individual del equipo auditor, se aclara la responsabilidad del equipo auditor de informarse acerca del manual de seguridad y el plan de emergencias radiológicas de la institución visitada y seguir las instrucciones y procedimientos en ellos establecidos para la operación normal o en casos de accidentes radiológicos, además se aclara que la manipulación de la unidad de tratamiento y sus accesorios durante la toma de datos y comprobación del desempeño de los programas de garantía de calidad de radioterapia se harán solamente por el personal de la institución directamente encargado de dichas operaciones. Por último se especifica que los resultados de la auditoria son confidenciales.

2.6. Materiales y equipamiento: se detalla el tipo y estado requerido para el equipo radiométrico, accesorios y materiales necesarios para la recolección de evidencias objetivas.

2.7. Preparación de la visita de auditoria: para cada etapa se definen la responsabilidad de cada integrante del equipo auditor.

a. Selección del equipo auditor: Selección de los especialistas que conformarán el equipo auditor de acuerdo a la experiencia teórica-práctica de los mismos, capacitación en el tema de auditorias de calidad y competencia institucional. Designación del auditor principal.
b. Coordinación de la visita: Coordinación con el responsable del PGC del servicio a auditar de la fecha de visita. Envío de la comunicación oficial de la auditoria al responsable del servicio de radioterapia especificando: Objetivos, Composición del equipo auditor, Tipos de datos que se requerirán, Medidas a tomar, Tiempo requerido por las visitas, Número de secciones de trabajo, Tiempo por especialistas (físico médicos, oncólogo radioterapeuta, técnico radioterapeuta), Medidas y cálculos que se necesita sean realizados en la institución. Se envía además un modelo de información preliminar que se requiere al servicio sobre el PGC, datos utilizados en la práctica clínica, etc; de manera que se cuente con esa información antes de partir hacia la auditoria.
c. Notificación de la visita: Notificación al responsable del servicio de radioterapia la fecha en que se realizará la auditoria, como mínimo una semana antes de la fecha fijada.
d. Revisión preliminar: Revisión del modelo de información preliminar y análisis del mismo con vistas a orientar la ejecución de la auditoria a algún punto de interés.
e. Asignación del equipo auditor: Asignación de las responsabilidades de cada miembro del equipo auditor en cuanto a las componentes del PGC a auditar.
f. Equipos y accesorios: Preparación, gestión y verificación del estado (funcionamiento y aptitud: certificado de calibración, etc) de todo el equipo radiométrico, accesorios y materiales.
g. Documentos de trabajo: Preparación de los documentos de trabajo pertinentes (modelos de recolección de datos, formularios, hojas de cálculo, tablas de datos, etc) para facilitar al equipo auditor las investigaciones, documentación e informe de los resultados

2.8. Ejecución de la visita de auditoria: para cada etapa las responsabilidades se delimitan según la asignación realizada a cada miembro del equipo auditor durante la preparación de la visita.

a. Reunión de apertura: Presentación de los miembros del equipo auditor al responsable del servicio de radioterapia. Planteamiento del alcance y los objetivos de la auditoria, explicación de los métodos y procedimientos que serán utilizados en la auditoria, designación de un el eslabón de comunicación oficial entre el responsable y el equipo auditor. Se confirma que el equipo auditor tendrá acceso a los recursos y las áreas necesarias; así como la fecha y hora de la reunión de clausura y de cualquier otra reunión conjuntamente con el responsable. Esclarecimiento de cualquier detalle del programa de la auditoria
b. Verificación de la información preliminar: Verificación de la información preliminar requerida a la institución en la comunicación oficial de la auditoria, concordancia con los registros presentes en el servicio, disponibilidad y utilización rutinaria de la misma por personal capacitado (físico médico y técnico radioterapeuta). Se verifican además detalles administrativos del PGC en lo referido a: manual de garantía de calidad y de seguridad, registros de los controles periódicos de calidad, plan de emergencias radiológicas, cadena de mando para reporte de problemas, etc.
c. Recolección de evidencias objetivas: Realización de la recolección de evidencias objetivas de los aspectos a auditar en lo referente a: Seguridad de la instalación y la unidad de tratamiento, Aspectos mecánicos de la unidad de tratamiento, Aspectos dosimétricos de la unidad de tratamiento y Aspectos clínicos del tratamiento; según la metodología empleada en la puesta en servicio para cada prueba en específico y el protocolo anexado al PNO. Se completan los modelo de recogida de datos correspondientes a cada una de los aspectos por los miembros responsables del equipo auditor, constituyendo esto un registro para su documentación.
d. Cálculos e interpretación de los resultados: El protocolo de recolección de evidencias objetivas detalla y explica cada una de las pruebas en específico a realizar para cada aspecto a auditar, el procesamiento de los datos adquiridos y la interpretación de sus resultados, definiendo además sus tolerancias.
e. Reunión de clausura: Realización de la reunión de clausura de la auditoria en presencia del responsable del servicio de radioterapia, una vez concluida la recolección de evidencias objetivas y el esclarecimiento de las posibles no conformidades halladas. Se comentará el cumplimiento de los objetivos de la visita y se expondrán de manera preliminar los resultados hallados en la misma así

como de las recomendaciones que el equipo auditor considere pertinentes; destaque que las mismas pueden estar sujetas a cambios debido a análisis *a posteriori*. Se confirma la fecha de entrega del informe final de la auditoria

f. Informe de la auditoria: Se especifica el formato del informe conteniendo en lo general: Datos de la institución auditada (incluyendo marca y modelo de la unidad de tratamiento), Fecha, Documentos de referencia utilizados (de la institución y del equipo auditor), Resultados de la recolección de evidencias objetivas, Posibles acciones correctivas tomadas en el curso de la visita, Recomendaciones y conclusiones. Se instruye además los medios y plazos para el envío del informe al servicio de radioterapia, las reglas de confidenciabilidad para su distribución y su registro.

2.9. Registros: se definen los registros necesarios para la organización del PNAC, sus procedimientos de archivo y compartimentación pertinentes dentro del Dpto. Radiofísica CCEEM.

2.10. Verificación: se define el responsable de la revisión y conformidad del PNO elaborado, dentro de la política de calidad del CCEEM. Además se aclara que el informe de la auditoria debe ser revisado por una tercera parte independiente del equipo auditor que cumpla con los requisitos exigidos para este.

2.11. Referencias/Documentos aplicables: bibliografía utilizada para la elaboración y ejecución del PNO.

2.12. Anexos: se adjuntan los Registros, Modelos de recogida de datos y el Protocolo para la recolección de evidencias objetivas. En lo referido al protocolo, está basado en lo fundamental, en las recomendaciones de un panel de expertos organizado por el OIEA dentro de las actividades del Programa Regional ARCAL XXX "Mejoramiento de la Garantía de Calidad en Radioterapia" [6].

3. CONCLUSIONES Y RECOMENDACIONES

El PNO aquí abordado constituye un paso inicial en la conformación del PNAC, como una etapa superior en la ejecución de los PGC en servicios de radioterapia; por resultar novedoso en nuestro contexto necesita de un período de puesta a punto y mejoramiento continuo. El PNO garantiza uniformidad en la estructura organizativa del PNAC, los criterios en cuanto a las tomas de medidas, la interpretación de los resultados y sus tolerancias. El PNO está dirigido únicamente a las instalaciones de teleterapia con unidades de isotópica de ^{60}Co. En lo referente al protocolo para la recolección de evidencias objetivas en los aspectos a auditar, se hace hincapié en los aspectos físicos del PGC, tratándose la parte clínica del tratamiento de manera menos profunda, aunque se comprueban casos típicos en la planificación de los tratamientos y la dosis de tratamiento impartida o unidades monitor (tiempo).

El PNO constituye una parte de la información necesaria para la certificación del PNAC ante las entidades reguladoras competentes en materia de seguridad nuclear.

Se recomienda complementar el PNAC mediante la modalidad de auditoria postal a través de las facilidades que brinda el LSCD-CPHR para mediciones con TLD, validando estos resultados con los registros de las auditorias postales realizadas por el OIEA a distintos servicios de radioterapia del país. Se debe completar y profundizar los aspectos clínicos del tratamiento como son los procedimientos clínicos utilizados, selección de las técnicas de tratamiento, sistemas computarizados de planificación de tratamiento, etc. Por último, el PNAC debe ampliarse a las instalaciones de braquiterapia y unidades de teleterapia de ortovoltaje, elaborándose la documentación metodológica y normativa para estas modalidades de la radioterapia

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FORM B
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INTERNATIONAL CONFERENCE ON THE RADIOLOGICAL PROTECTION OF PATIENTS

in

- **Diagnostic and Interventional Radiology**
- **Nuclear Medicine and**
- **Radiotherapy**

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AUTHOR(S) INITIAL(S) AND FAMILY NAME(S)	SCIENTIFIC ESTABLISHMENT(S) IN WHICH THE WORK HAS BEEN CARRIED OUT	TOWN/COUNTRY
1. Shakirov Eduard	Republican Oncology Center	Tashkent, Uzbekistan
2.		
3.		
4.		
5.		

AUTHOR WHO WILL PRESENT THE PAPER	Mailing Address:
(Mr)/Ms.	700174, Tashkent, Uzbekistan
Initial(s): SE	Farobi str. 383
Family Name: Shakirov	Telefax No E-Mail : Telex No

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CRITICAL LOOK AT IONIZATION CHAMBER TECHNIQUES

Tomas Unfors, Unfors Instruments AB, Uggledalsv. 27, SE 427 40 Billdal, Sweden, Fax: +46 31 910 950, tomas@unfors.se,

CRITICAL LOOK AT IONIZATION CHAMBER TECHNIQUES

Abstract:
Ionization chambers have a long tradition for measurements of ionizing radiation. DAP measurements using ionizing chambers have been adopted as standard. Silicon sensors have lately been significantly improved and have several advantages for dose measurements and should be considered as parallels to, or replacing, ionization chambers.

For many years ionization chambers (ICs) have been standard for various measurements of ionizing radiation, inclusive DAP-meters. ICs are traditionally used for measurements according to national and international standards. Silicon sensors (SSs) may be superior alternatives to ICs. In general, ICs have lower energy dependence than SSs, especially for lower energies (< 50 keV). For spectras generated with 50-150 kVp at a specific tube filter, the energy dependence can be lower than some ICs.

However, ICs have other disadvantages:
1. Size; the required active volume to generate a specified current at a specific dose rate is 100-1000 times smaller for an SS compared to an IC. The global trend is to generate and measure lower dose rates, which sometimes requires an inconvenient size of an IC.
2. Back scatter dependence.
3. Mechanically sensible.
4. Needs bias voltage (about 150-300 V).
5. Expensive construction.
6. Pressure and temperature dependence.

DAP measurements are generally accepted as standards for assessing ionizing radiation. The advantages with ICs are:
1. Radiation transparency, no disturbance of images.
2. Integration of the total dose produced from an X-ray tube.

There are disadvantages:
1. The total integrated dose may not reach the patient.
2. The dose is measured in the collimator and is thus not the skin dose. To calculate the skin dose, correction has to be made for the distances focus-DAP and focus-skin.
3. No measurements of point doses; organ dose cannot be calculated. The heel effect gives a larger dose in the cathode end of the radiation field than in the anode one.

The main SSs advantages are:
1. Correct organ dose measurements possible.

2. No corrections necessary for the distances focus-DAP and focus-skin.
3. The sensor needs not be visible on images (no metal in sensor or connection).

IC measurements have become tradition as nothing more suitable has been available. However, silicon sensors should be discussed as parallels or even replacement of ICs when measuring radiation doses to patients because of their advantages that outweigh possible disadvantages.

ALARM DEVICE FOR SELF PROTECTION AND DOSIMETRY FOR PATIENTS

Jan H. Göthlin, Dept. of Radiology, Sahlgrenska University Hospital, SE 413 45 Göteborg, Sweden, Fax 46 346 972 27, jan.gothlin@zeta.telenordia.se

ALARM DEVICE FOR SELF PROTECTION AND DOSIMETRY FOR PATIENTS

Jan H. Göthlin, Göteborg, Sweden

Abstract
A main hazard in radiation protection is lacking knowledge of and slack attitudes to how to avoid harmful effects. Immediate feed back when operators or patients receive non-acceptable doses of ionizing radiation should most likely correct behavior. A small silicon sensor that can be fitted under a glove or anywhere else on a fluoroscopist or a patient and connected to a radio transmitter can visibly or audibly warn at unacceptable dose rates. An immediate correction of false fluoroscopy behavior is thus possible. In patients, especially at head CT of children, warnings may prevent unnecessary radiation doses to e.g. eye lenses.

The sensor may be constructed without metal parts and connected to a transmitter to avoid image artifacts.

X-rays do not smell and cannot be directly seen, heard or felt.

Part 1

The hazards of ionizing radiation are known since about 100 years. Until the 1950ties lesions of patients and radiologists were common. The older among us remember even older radiologists with missing fingers due to excessive fluoroscopy and I still remember treatment of hemangiomas with radiation and its subsequent sequelae.

Today we see interventional radiologists with cataracts and bone marrow depression. Among interventional radiologists the story is told that of 12 known interventional radiologists´ kidney carcinomas all are on the left side - closest to the fluoroscopy tube.

The awareness of the hazards of ionizing radiation, be it for radiologist and radiographers, surgeons and cardiologists with co-workers, patients and victims of nuclear catastrophes has increased considerably. Laws and regulations are requiring higher security but are not always sufficient to protect those working with ionizing radiation. One reason is that with most of current radiation measuring systems the accumulated dose over time is measured. It is difficult to afterwards know which moves during a procedure were false. Without real-time measurements it is also impossible to know when somebody around the patient should be replaced because of too much radiation.

Despite improved shielding the risks of receiving harmful doses of ionizing radiation have increased because of the changed panorama of patients and procedures: patients are often very old, the procedures more complex and thus fluoroscopy times often long.

The ideal dosimeter should
be convenient to use - that is small;
not jeopardize sterility;
give dose rates in real time;
give warning when pre-set dose rate is exceeded;
give warning when accumulated radiation dose exceeds pre-set dose.

The dose rate should continuously be displayed and warnings should be given visibly and/or audibly. Where should dose rates be registered? Eye, thyroid, feet and fingers are known to be the most actual targets. Clinical tests have to decide whether several sensors should be carried or whether one sensor should be placed at different sites at different occasions. The main thing is to learn the sensor-carrier to correct false behavior thus to perform the procedure without unnecessary exposition to ionizing radiation.

Ideally a very small sensor on the individual should transmit information to a receiver out of the immediate working zone as the necessary battery would increase the sensor size unacceptably. The second best solution is to have a wire connection to a transmitter located on the body. Sterility is only a problem for the fingers but a small enough sensor under the glove on the back of a finger or back of the hand would not unacceptably impair the working procedure.

The most important feature of the dosimeter would be to teach cardiologists, surgeons (especially orthopedic surgeons) and radiologists to avoid harmful ionizing radiation doses, to change their working pattern and their attitudes towards handling ionizing radiation.

Part 2

Diagnostic procedures giving harmful doses to patients are well known. Repeated CT examinations of children's hypophysis may be harmful to the eyes. Cardiac radiology especially in children and diagnostic/therapeutic procedures in elderly may cause lesions. It is feasible that the dose to the eye for a CT examination may be calculated from one slice and the subsequent examination optimally planned also for the amount of ionizing radiation. A sensor placed in eye level but localized so that it and its cable do not give artifacts may give the necessary information. A sensor without metal and a connection to a transmitter is possible to produce. The maximal accumulated dose may be preset and the examination stopped when the dose is reached. At cardiology, or other examinations, with high doses not only for fluoroscopy and exposure, the immediate registration of both patient dose rate and accumulated dose in real time should be essential. This is to change

both fluoroscopy and exposure behavior and initiate equipment control. It is, of course, most important in children who have a long life expectancy.

Monitoring of radiation therapy is difficult. The dose leaving the ionizing radiation source is well defined but the target dose is deducted from the entrance dose with correction from measurements in phantoms or patients. The target definition is often made with CT and controls during therapy with radiographic films. The doses are high and small aberrations may not be too important. However, lesions in e.g. the spine should be avoided not to handicap the patient. Radiation to the bowel and urinary bladder may cause real discomforts. A small sensor with thin cables may easily be introduced into cavities in the gastro-intestinal, reproductive and urinary systems for correct dose measurements. Small sensors may even by introduced percutaneously or intravasally for adequate dose control.

STRATEGIC MANAGEMENT OF RADIATION PROTECTION PROGRAMME IN THE MINISTRY OF HEALTH MALAYSIA

– AN APPROACH BASED ON MS ISO 9000 QUALITY MANAGEMENT SYSTEM

Wang Hwee Beng

Radiation Health and Safety Unit

Ministry of Health Malaysia

Summary

The MS ISO 9000 Quality Management System launched in 1996 was one of the quality improvement efforts introduced by the Ministry of Health Malaysia. The main objective of implementing MS ISO 9000 in the Ministry of Health was to lay the foundation and provide a suitable framework for internalising and institutionalising quality in the health system. This Quality Management System enabled the institutions to systematically document the appropriate work processes in tandem with the requirements of the functional system of the organisation. The Quality Management System allowed the essential activities of the health care delivery to be consistently managed and continually improved upon. This paper discusses the rationale, applicability and approach taken by the Ministry of Health in its efforts to introduce and implement MS ISO 9000 Quality Management System in all its institutions. This paper describe the strategic approach taken by the Radiation Health and Safety Unit, Ministry of Health Malaysia to develop and implement radiation protection activities for the application of radiation in medicine based on the MS ISO 9000 Quality Management System and the achievements of the unit in obtaining the certification.

INTRODUCTION

The Ministry of Health (MOH) has introduced various quality improvement activities in the delivery of health services. Among these quality initiatives, the Quality Assurance Programme was initiated in 1985, while the Federal Government launched the quality programme for the public services in 1991. These quality initiatives are aimed at enhancing and improving the technical and service quality of health care delivery and various enforcement functions in the MOH.

In the MOH, quality programmes were developed and implemented in parallel, by way of Government of Malaysia Development & Administration Circular (GMDAC) for the administration section, and the Quality Assurance Programme for the technical and professional sections.

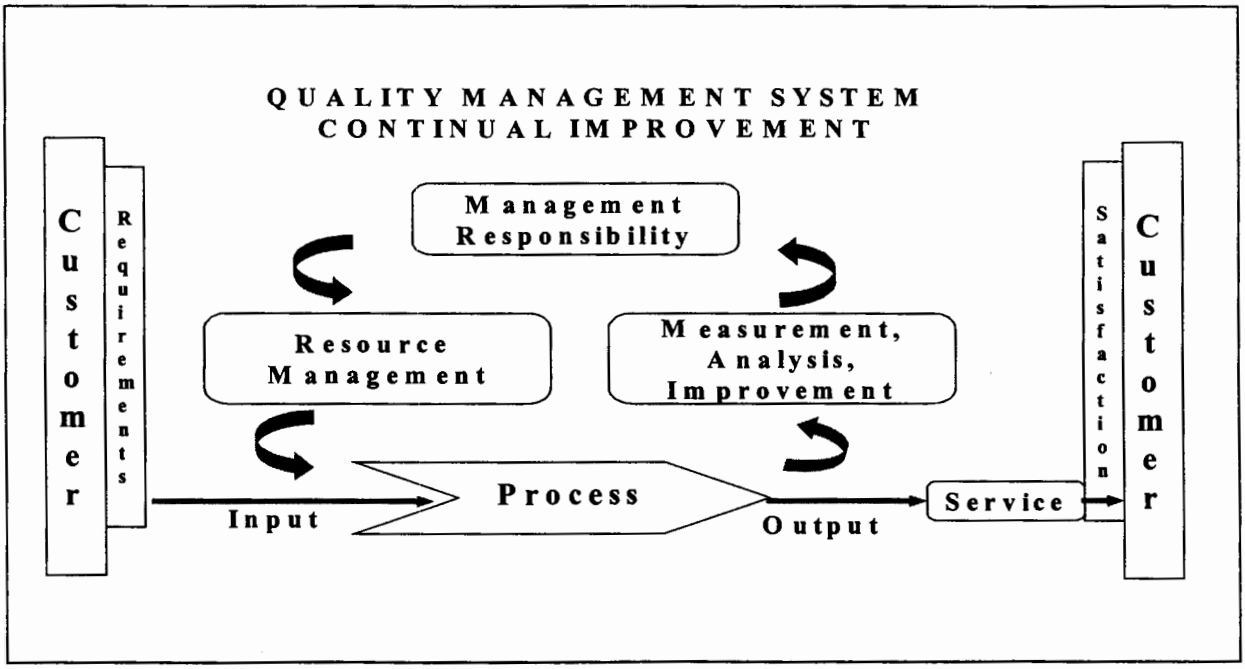
In 1996, the Federal Government felt that there was still room for improvement in its service delivery and decided that it was timely for all its agencies to implement a quality management system which was universally and internationally recognised. In this regard, the Government

of Malaysia Development & Administration Circular (GMDAC) No. 2/96 for the implementation of MS ISO 9000 in the Malaysian Civil Service was issued. The MOH during the 1996 Directors' Conference had resolved to implement MS ISO 9000 in all its institutions. It was envisaged that the adoption of this standard would complement and further strengthen the various quality improvement activities already existing in the Ministry.

APPLICABILITY OF MS ISO 9000 QUALITY MANAGEMENT SYSTEM

For decades, most healthcare service delivery and enforcement functions have structured its organisation according to functions. The functional hierarchy is closely observed with the staff at the bottom of the hierarchy reporting to the immediate superior of the functional area. In the day-to-day tasks, work processes cut across functions. Experience has shown that, in achieving organisational goals, numerous and complex cross-functional work processes are required. Radiation protection activities involve work processes, which encompass input components, value-added activities and output delivery. Every process is an input and output chain. The strength and applicability of MS ISO 9000 lies in its ability to harmonise the traditional functional system of the organisation with the various interrelated work processes, which are required for the effective and efficient running of the day-to-day tasks. Figure 1 illustrates a conceptual presentation of a generic ISO quality management system demonstrating the interaction between functional system of the organisation and the work processes.

Figure 1: Quality Management Process Model



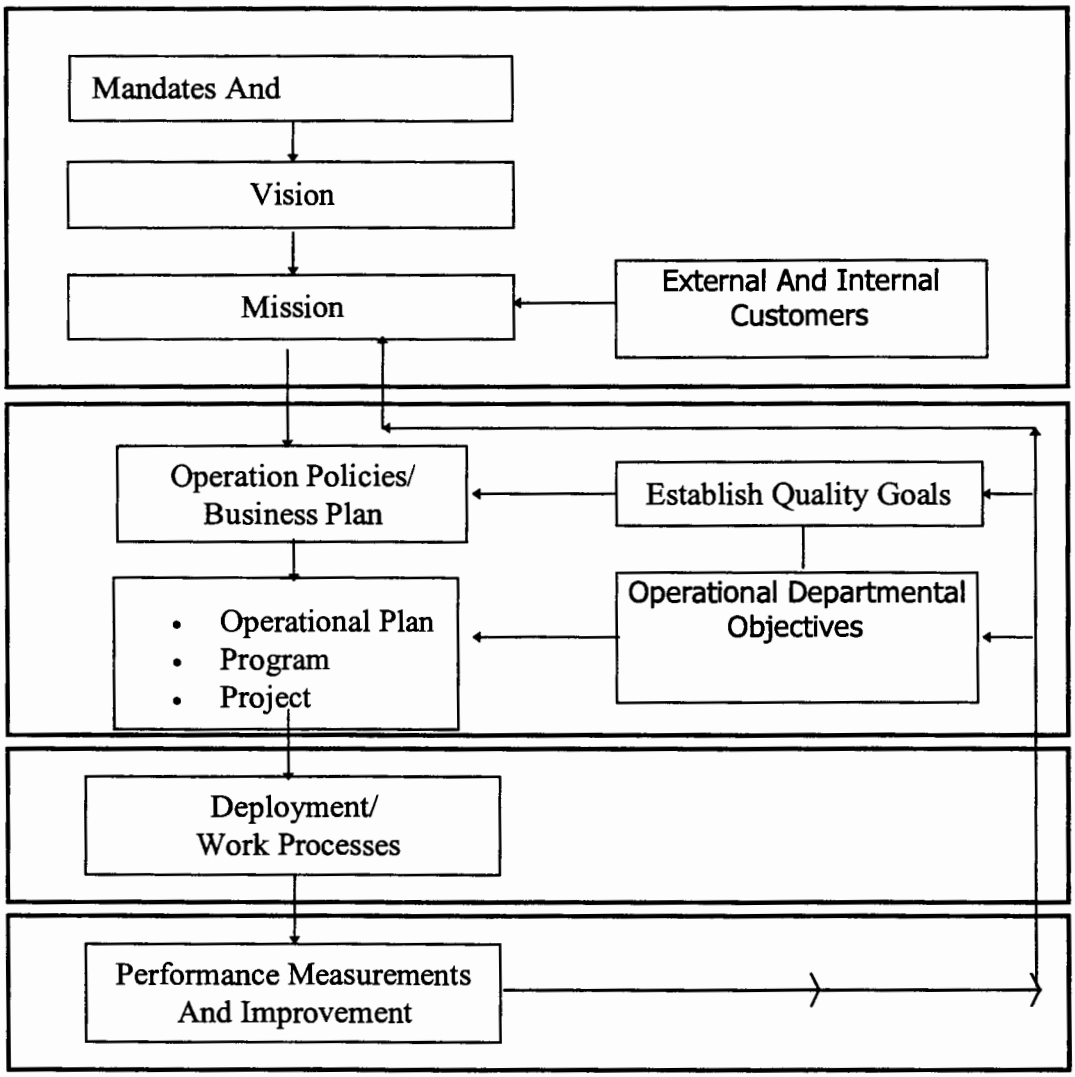
THE MINISTRY OF HEALTH APPROACH

The Ministry of Health has established a technical committee to coordinate the overall strategic planning process, scheduling and implementation of MS ISO 9000 Quality Management System. Meanwhile, the Programme Directors are required to facilitate and coordinate the identification of core business processes in their respective programs. They are also required to assist in re-examining selected core business to improve work processes and to possibly effect re-engineering before commencing the documentation process, taking into account international standards where possible and appropriate.

METHODOLOGY

The methodology for establishing MS ISO 9000 Quality Management System (QMS) consists of steps as illustrated in Figure 2.

Figure 2: Schematic Approach for Establishing QMS



The first step involves defining and clarifying organisational mandates and responsibilities. The purpose of this step is to clarify the formal and informal mandate placed on the organisation. Mandates prescribe the right functions to be done by the organisation. It ensures that management responsibilities are clearly identified and defined. In tandem with the mandate and defined management responsibilities, vision describes the organisation's aspiration for the future and mission provides the *raison d'être*. Vision and mission help to identify common goals and direction for the organisation.

With this foundation, together with a careful analysis of the customers/patients requirements, quality goals are established. For attaining this goal, necessary strategies, operational plans such as programmes and projects are developed. The purpose of this systematic approach for setting and meeting goals is to integrate quality improvement into the management system thereby attaining the desired quality. In this context, this step enables business plans, hospital and departmental operational policies to be prepared accordingly.

The next step involves deploying and mapping the goals into the operational plans, which are broken down into programmes, or projects of the various functional units, project team or permanent work processes and procedures. For each programme or project, the quality objective, which is specific and achievable within a given time frame, and which is relevant and measurable, is established. The Clients' Charter and the National Indicators of the QAP are good examples of the quality objective. The quality objective lays the foundation for selecting and developing key/core work processes that are essential to produce the necessary output.

These interlinked work processes are defined, designed and documented so that they can be managed and improved upon. The work processes are categorised into:

i) Core process for delivering the services

ii) Support processes

iii) Quality improvement processes

From these work processes, quality management procedures are prepared. These include:

i) Procedures that describe the activities

ii) Procedures that describe the sequential and interactive nature of the process

iii) Instructions that describe the operating practice and control of activities

The procedures are finally consolidated into a procedure manual of the quality management system.

The last step involves instituting an effective performance measurement system to ensure that service outputs meet both the functional and process objectives and that all patient requirements are satisfied. Objective performance data about important governance, management, clinical and support systems generated through the applications of performance measures or indicators can be used to identify performance variations. Analysis of these variations will consequently lead to identifying opportunities for improvements.

ACHIEVEMENTS

According to the road map format of the Government of Malaysia Development & Administration Circular (GMDAC) 1/99, the stages for implementing MS 9000 are :

i) Awareness training

ii) Formation of project team

iii) Preparation of action plan

iv) Identification of business core processes

v) Documentation

vi) Implementation

vii) Certification

Since 1996, the Radiation Health and Safety Unit has embarked on an extensive awareness training program for its staff. This has resulted in a high level of awareness amongst the staff regarding MS ISO 9000. Identification and documentation of business core processes for radiation protection activities was completed in mid-1996. In the implementation phase, activities were carried out according to documented procedures. By March 1997, SIRIM the Malaysian certification body for MS ISO 9000 audited the Unit for compliance. The Radiation Health and Safety Unit was subsequently awarded the coveted MS ISO 9002 certificate for the scope; the management of the provision of radiation protection programme for application of radiation in medicine. This makes the Radiation Health and Safety Unit, MOH the first department to be certified in the Malaysian Public Services. For the consecutive years 1998, 1999 and 2000, the Unit was recertified.

CONCLUSION

The standards of the MS ISO 9000 Quality Management System are generic in nature, thus, allowing their use in diverse sectors. It is important to note that these standards apply to an organisation and its operational structure, not the nature of the service, and that the organisation is self-defined. The standards identify requirements relating to the management of processes considered necessary to assure quality. The Quality Management System, while requiring the right and appropriate work processes and activities to be defined, documented and proven, does not necessarily prescribe norms, performance criteria and professional standards. Such standards, including statutory requirements are normally mapped into the system through the establishment of operational policies and business plan. The contention of the Ministry of Health's quality policy is such that all performance standards relating to the profession, industrial norms and statutory requirements need to be established.

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ARE WE ALWAYS SURE ON OUTPUT FACTOR OF ELECTRONS BEAM?

Antanas Vaitkus, Oncology Clinic, Kaunas Medical University Hospital,
Kaunas, Lithuania, vaitkus@bigfoot.com

Abstract

The additional systematic error about 10% could be received if formal approach is used for electron beam radiotherapy absolute dosimetry. On example of GE linear accelerator "Saturne" it was demonstrated that the algorithm of output factor calculation, transference to SSD, different from 100 cm, and unjust air gap correction factor algorithm could harm significantly the treatment dose prescribed for radiotherapy patient.

Introduction

The output factor is defined as the ratio of the dose on the central axis at a reference depth for a field size to the dose at the same depth for a reference field of (10 x 10) cm^2 and the reference source surface distance (SSD). The treatment planning systems are adopted usually for relative absorbed dose calculations in the tissues, and monitor unit calculations are based on the correction factors measured during the commissioning of equipment [1]. The scattered radiation from the collimators, cones or trimmers influences significantly on output factor as well as on the air gap correction. Air gap correction factor is used in some clinical situation then the SSD, different from reference is required. There are the algorithms for electron output factor calculation [2-4] and methods for SSD correction [5-6] described in literature. However, the corrections are related with the geometry of individual equipment, collimator system, cones and trimmers. The full range of measurements should be done during the commissioning of equipment due to prevent the systematic errors. As criteria for good clinical practice the SD of absorbed dose at the dose specification point should be less than 3,5% [7].

Materials and methods

The output factor of electron beam was measured for GE linear accelerator "Saturne". The measurements were performed in polystyrene phantom 30x30x40 cm^3 at the depth of maximum dose. Plane parallel NACP2 type ionisation chamber, PTW electrometer and PMMA build up plates were used for air gap correction and output factor measurements.

The output of linear accelerator and stability of ionisation chamber – electrometer system was good enough for relative measurements. SD of measurements was 0,022%.

The use of polystyrene phantom instead of water is acceptable, because of good agreement between the output factor measurements, obtained in water during the commissioning of accelerator and the measurements in polystyrene phantom. The maximum deviation was 0,76%.

Results and conclusions

The maximum disagreements between the widely known algorithm described by Mills and al. for output factor calculation and the data measured in polystyrene phantom were from 0,7% for 21 MeV energy till 4,9% for 4,5 MeV energy electron beam.

Output factor at SSD, different from 100 cm, was not constant. The deviations for 12 MeV energy electron beam were up to 1,0%, -0,9% for SSD 95 cm and up to 1,8%, -3,8% for SSD 115 cm.

The deviation of air gap correction factor from the inverse square law for small field sizes were –1,5% at SSD 95 cm and +2,3% at SSD 110 cm.

The additional systematic errors about 10% could be possible on monitor unit calculations for electron beam radiotherapy if formal approach to output factor calculation, to air gap correction, and to transfer output factor for SSD, different from 100 cm is applied into practice. It exceeds the tolerance levels [7] and should be reduced.

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POSTER PRESENTATION

TS 3
IAEA-CN-85/126

Radiation Management in Fluoroscopy

Benjamin R. Archer, Ph.D. DABR, FACMP, FAAPM, Department of Radiology, Baylor College of Medicine, Houston TX 77030
Louis K. Wagner, Ph.D. DABR, FACR, FAAPM, Department of Radiology, The University of Texas-Houston Medical School, Houston, TX 77030

Abstract

During the past fifteen years, developments in x-ray technologies have substantially improved the ability of practitioners to treat patients using fluoroscopically guided interventional techniques. Many of these procedures require a greater use of fluoroscopy and serial imaging (cine). This has increased the potential for radiation-induced dermatitis, epilation and severe radiation-induced burns to patients. It has also increased the potential for radiation injury and radiation-induced cancer in personnel. In response, the Center for Devices and Radiological Health of the United States Food and Drug Administration issued an advisory (1) warning healthcare facilities of the potential for radiation-induced burns to patients from fluoroscopic procedures. A separate article cited the growing number of cases of severe injury (2). To date, the FDA has documented some 50 cases of radiation-induced burns, many involving cardiologists. European investigations have confirmed at least 15 cases of radiation dermatitis that resulted from cardiologic procedures (3-7). Additional case histories of injuries to both patients and physicians (8-11) have appeared in the literature. Some of the radiation-induced wounds discussed in these studies have required skin grafts resulting in permanent disfigurement. Cataracts and serious radiation injuries to hands have also been observed in physicians who have recently (as late as 1994) started using fluoroscopy in their practice (12,13).

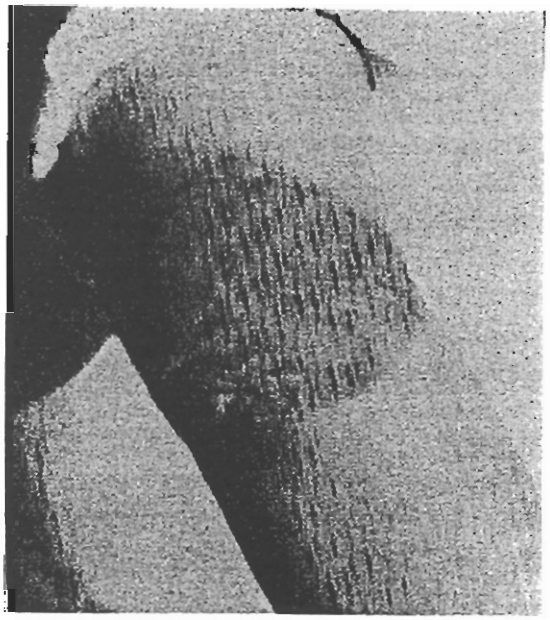
The FDA Advisory alerted facilities to assure proper training of fluoroscopy personnel in light of "occasional but severe" radiation injuries from invasive procedures. We stress that training must include pertinent aspects of radiation management in the clinical setting in order that physicians know how to maintain risks to patients and personnel at acceptable levels. Training for interventional work should be procedure specific while incorporating general principles of safe practice. Requiring generalized physics training alone is insufficient (and often irrelevant) to assure appropriate radiation management. This is apparent from the numerous cases of burns from transjugular intrahepatic portosystemic shunt (TIPS) procedures, only some of which are reported in the literature [5] (we know of others). These injuries are frequently associated with difficult, protracted procedures in large patients. Although radiologists frequently have physics training, they are not necessarily trained in effective radiation dose management in these long and difficult procedures.

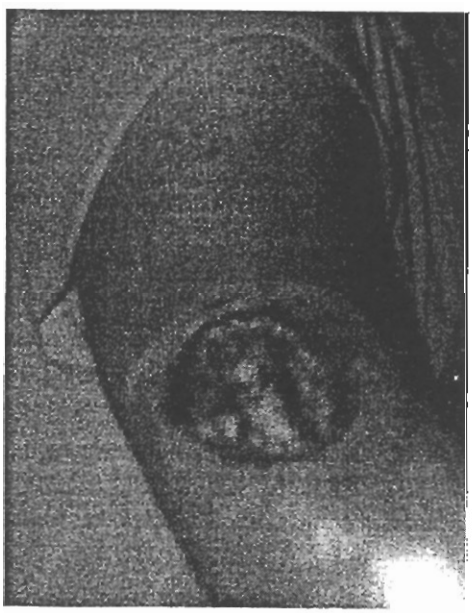
The exigent need for training to reduce radiation dose to patients is illustrated in the following case report from 1997.

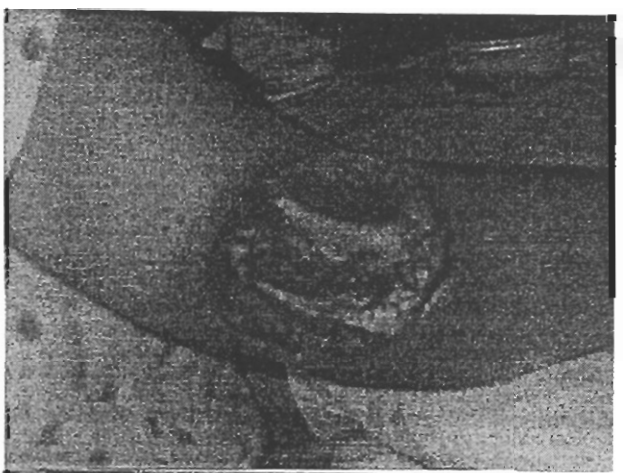
A middle-aged woman had a history of progressively worsening episodes of arrhythmia. A radiofrequency electrophysiological cardiac catheter ablation was scheduled to treat the condition. The procedure employed twenty minutes of beam-on time for each plane of a bi-plane fluoroscope.

Prior to the procedure the separator cones were removed so that the fluoroscopic c-arms could be easily rotated around the patient. The separator cone is a spacer attached to the tube housing designed to keep the patient at a reasonable distance from the x-ray source. This is done specifically to avoid the high skin-dose rates that can be encountered near the tube port. The right-side fluoroscope was in a left-anterior-oblique orientation. The patient's arms were originally placed at the patient's side but the right arm later fell into a lower position directly in front of this x-ray tube. The right humerus was directly in the beam at the port (see Fig. 1a). Because the separator cones were removed, the arm was only about 20 cm from the focal spot. With the soft tissue and bone of the arm directly in the beam, the automatic brightness control drove the output to high levels at the surface of the arm. The machine was a high-dose-rate unit. In the normal mode of operation the output at the skin of the arm would have exceeded 500 mGy per minute due to the inverse-square law and the close proximity of the skin to the source. In the high-dose-rate mode, the skin dose rate could have exceeded 1.5 Gy per minute. The cumulative dose probably exceeded 25 Gy.

The patient was released from the hospital the day after the procedure. At the time there were no complaints regarding her arm and no indication of erythema. About three weeks after the procedure, a bright erythema was demonstrated (Fig. 1b). The condition worsened and at five months a large ulcer the size of the collimated x-ray port developed (Fig. 1c). At eight months a debridement was performed and a surgical flap was put in place (Figs. 1d and 1e).







Several radiation management issues are of note:

1) the separator cone was removed;
2) the arm was directly in the field;
3) the port of the x-ray collimators was nearly in contact with the arm.

The x-ray source should always be moved as far away as possible from the patient's skin, especially when the separator cone is removed. Body parts that need not be in the beam should be moved out of the field to avoid their unnecessary irradiation and to maximize the penetration of x-rays through the anatomy of interest. This lowers the radiation output, resulting in lower dose to the patient and lower dose to personnel in the room. We would like to emphasize that using good collimation, using dose-reducing pulsed fluoroscopy and only using magnification when necessary are beneficial for the patient and personnel alike. Our experience is that physicians often focus on their own radiation safety. However, the important lesson is that exercising radiation management for the patient is crucial for both themselves and their patients. Training on fundamental points such as these is essential to avoid such injuries.

It is likely that many of the injuries to patients and staff cited in this commentary could have been avoided or reduced in severity if physicians were appropriately trained in radiation management. Training in radiation management and testing of every physician resident and/or fellow whose practice involves the use of fluoroscopy should be required. A template for some change has already been established. In 1999, the American Board of Internal Medicine will conduct the inaugural certification examination in Interventional Cardiology. Ten percent of this examination will cover imaging, which includes radiation physics and safety topics. This is an important first step for cardiology. Radiology can improve their training by focussing on radiation management in specific areas and making procedure-specific training a part of every program. Pain management programs should begin the process of incorporating formal training for all physicians involved in these procedures.

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FIGURE CAPTIONS

Figure 1.

a) Fluorographic image illustrating arm in the beam; b) erythema about 3 weeks after procedure; c) ulcer at 5 months after procedure; d) debridement at 6.5 months after the procedure; e) surgical flap 10 months after procedure. [Reproduced with permission from reference 14.]

RADIATION RISK FROM INTRACORONARY BRACHYTHERAPY

C Kirisits*, A Hefner†, D Georg*, R Pötter*
*Department of Radiotherapy and Radiobiology, Medical School, University of Vienna
†Austrian Research Centers Seibersdorf, Austria

Corresponding author:
ALFRED HEFNER
Austrian Research Centers Seibersdorf
Radiation Protection Division
A-2444 Seibersdorf, AUSTRIA
phone: ++43 2254 780 2509
E-mail: Alfred.Hefner@arcs.ac.at

ABSTRACT:
During the last years coronary endovascular brachytherapy has been extensively explored as a new treatment to prevent restenosis after percutaneous coronary interventions. While clinical and physical aspects of such treatments are addressed in literature, there is little information available on radiation protection and radiation safety aspects. In this paper we estimate the radiation risk for the patient using analytical methods and Monte Carlo calculations for three delivering systems currently used in clinics. Additionally, radiation risk to personnel involved in such treatments is investigated. For gamma emitting sources the radiation exposure to patients is in the order of magnitude of the exposure due to diagnostic angiography. Doses to organs at risk when applying beta emitting sources are significantly lower. Measured doses for the intervention personnel are consistent with the estimated whole body dose. They are smaller than 7,5 μSv per intervention, which is a dose much less than 0,1% of the annual radiation worker`s Maximum Permissible Dose (MPD) recommended by EC regulations, and less than 1% of the general public`s MPD.

1. INTRODUCTION

Ischemic heart disease due to narrowing is a significant cause of morbidity and mortality in the Western world. Restenosis is severely limiting the clinical outcome of percutaneous vascular interventions. Clinical studies have shown the possibility to apply endovascular irradiation for the prevention of restenosis [1-5]. Depending on trial protocol and source design, respectively, prescribed doses are between 7 and 20 Gy. The dose specification point, however, differs. For example, a point at 2 mm distance from the source axis has been used in some studies while others used a specified depths (e.g. 1 mm) into the vessel wall.

Detailed knowledge about the dose-distribution around endovascular brachytherapy sources is essential for retrospective analysis of dose-response relationship, to perform accurate treatment planning and to estimate the possible impact on radiation protection for the treated patients. However, since endovascular brachytherapy is a new field in brachytherapy, little information is available on dose distributions for treatment planning and estimations of the dose to organs at risk.

Additionally, detailed knowledge about the magnitude of the whole body dose received by the interventional staff (radiation oncologist, physicist, interventionalist) involved in coronary endovascular brachytherapy is needed in order to limit the dose to staff members according to the ALARA principle.

2. METHODS

We studied three different sources designs currently applied for intracoronary brachytherapy treatments: (1) a seed ribbon consisting of six ^{192}Ir seed sources, each 3 mm length, (2) a ^{32}P wire source of 40 mm length, and (3) a ^{90}Sr/^{90}Y seed train of 40 mm total length.

Precision dosimetric studies have been performed for these different source geometries and nuclides using Monte Carlo calculations with EGSnrc [6] code. Beta and gamma emitting sources were simulated in a plane-cylinder geometry model, using accurate energy emission spectra. We calculated the relative dose at various radial distances from the source center.

For distances beyond 1 cm from a ^{192}Ir source center line it is also possible to calculate the dose following the formalism described in the AAPM TG43 protocol [7]. Using the air kerma rate constant for a Ir-192 seed (0.109 μGy m^2 / MBq / h) and the dose rate constant (1.12 cGy / h / U) the dose rate at 1 cm from the source center can be calculated based on a given activity.

The quantity *Total Reference Air Kerma* can be used to specify brachytherapy applications [8]. It is the sum of the products of the *Reference Air Kerma Rate* and the irradiation time for each source, expressed in Gy (or convenient multiples). The TRAK is fast and easy to calculate and should be used in endovascular brachytherapy for the following reasons, (i) doses to all organs and thus to the integral dose to the patient are directly proportional to the TRAK, and (ii) the TRAK provides an estimation of the kerma (dose) rate at one meter from the source which can be useful for radiation protection purposes, and (iii) the inverse square law allows to estimate the dose delivered during the treatment to the organs at a distance from the source(s) down to 10-20cm.

The dose rate distribution in the standard cardiac catheterization laboratory is measured using suitable dosimeters and survey meters. In order to obtain the dose to individuals the measured dose rate is multiplied by the treatment time, for each relevant location in the catheterization laboratory. The doses to individuals are estimated by applying the inverse square law and taking into account shielding by the human body. Additionally, area monitoring inside and outside the cardiac catheterization laboratory is performed using dosimeters and survey meters [9]

3. RESULTS

Figure 1 presents Relative dose variation in radial direction from the source axis for the three different source design investigated.

In order to further compare the different nuclides concerning radiation exposure a dose prescription of 20Gy is presumed at 2 mm distance from to source axis. Table 1 summarizes the respective dose values at 1cm distance.

Based on a calculation using the TG 43 calculation formalism the dose rate at 1 cm distance from the source is 11.28 Gy/h for a 9250 MBq (250 mCi) ^{192}Ir source. For a typical treatment time of 18 min the resulting dose is 338 cGy at 1cm distance. This value confirms the Monte Carlo result presented in table 1.

Relevant organs, such as bones, lung tissue, spinal cord, thyroid, breast (women) are located at in distances from the source of 10cm and more. Therefore, the doses to these organs at risk can be estimated using the inverse square law and neglecting absorption or scatter. Following this theory, for beta emitting sources the dose to relevant organs at risk at 10cm distance is lower than 0.01cGy, for gamma sources it is lower than 4cGy, respectively.

Figure 1: Relative dose variation in radial direction from the source axis for the three different source design investigated.

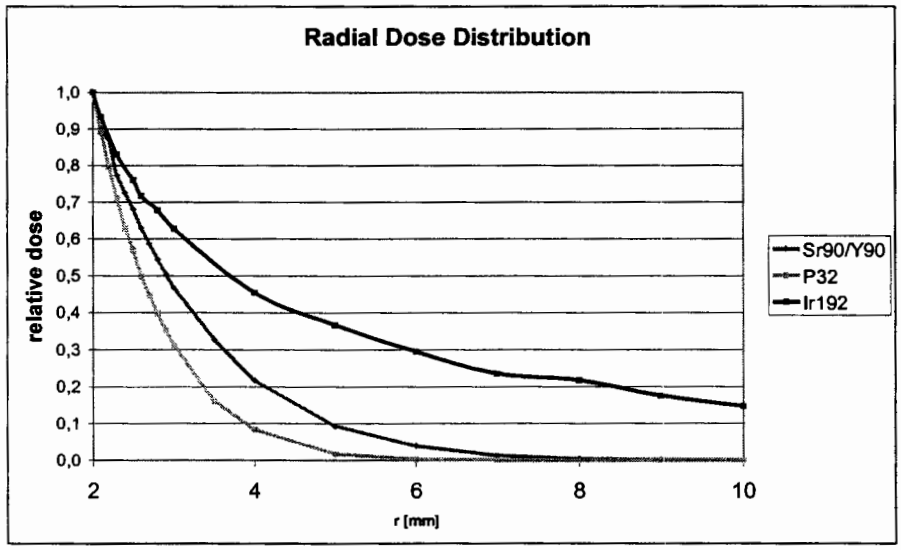

Table 1: Dose at 1 cm distance from the source axis (dose of 20 Gy at 2 mm) for the three sources types.

	Factor	Dose
Ir-192	0,16	320 cGy
Sr-90/Y-90	0,0003	0.6 cGy
P-32	0,0001	0.2 cGy

The Total Reference Air Kerma (TRAK) for the Ir-192 source specified above is 302μGy. Air Kerma Rate for beta sources are only due to Bremsstrahlung and cannot be defined precisely.

The doses measured for the intervention personnel are less than 7,5 μSv per treatment which is a dose less than 0,1% of the annual radiation worker's Maximum Permissible Dose (MPD) recommended in EC regulations. The measured dose for a single individual of the general public outside is the cardiac catheterization laboratory is less than 1‰ of the general public's MPD.

4. DISCUSSION AND CONCLUSION

Pattee et al. [9] estimated the organ dose during an 'average' coronary angioplasty procedure, which are 2.29 cGy for Bone, 9.35 cGy for lung, 0.99 cGy for thyroid and 4.89 cGy for breast (women). According to the results presented above the additional organ doses resulting from endovascular brachytherapy applications are far below this values when using beta emitting sources and in the same order of magnitude for for gamma emitting sources.

The dose at larger distance resulting from a beta emitting nuclei is due to Bremsstrahlung production. Therefore doses to organs at risk are much lower when applying beta emitting sources as compared to gamma sources.

The TRAK value presented for the Ir-192 source applied in intravascular brachytherapy is about one order of magnitude lower than the values reported for 'conventional' brachytherapy applications.

It has been shown in several clinical trials that restenosis can be avoided by intracoronary brachytherapy. The possible re-narrowing without brachytherapy have to be treated by another coronary intervention including further angiography exposure. Although there is an additional radiation exposure to patients and personnel by this single treatment the values are much smaller than those caused by a second angiography (ALARA principle).

The personal dose measurements and calculations showed that all principles of ALARA are fulfilled within the clinical trials. Safety and effectiveness is demonstrated for localized radiation therapy with endovascular brachytherapy sources during cardiovascular interventions for the treatment of patients with in-stent restenotic lesions.

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MAMMOGRAPHY QUALITY ASSURANCE IN MOROCCO

F. ZAOUI, K. TALSMAT and K. LALAOUI

Departement des Applications Medicales et Biologiques . Centre National de l'Energie des Sciences et des Techiniques Nucléaires . 65, Rue TANSIFT . AGDAL. RABAT. Morocco.
Fax number : 212 37 71 18 46 E-mail : zaoui@cnesten.org.ma

Abstract: The "Centre National de l'Energie, des Sciences et des Techniques Nucléaires" (CNESTEN) realised, from February 1999 to March 2000, a quality control of 41 mammography facilities in Morocco. The protocol and standards adopted for achieving the control of elements constituting the mammography chain are those elaborated by GIM and Qualix association. Statistics and conformities results are presented. The program was performed in order to demonstrate to the practitioners in mammography field, the utility and necessity to have a national quality assurance policy. The main objective of CNESTEN is to be accredited by the Moroccan government as a reference laboratory in quality control and dose evaluation in medical imaging and radiotherapy. To achieve this goal the CNESTEN has set up Medical Physic Unit well trained and equipped with the necessary instruments .

Introduction

The mammography is considered as an important tool for the early detection of the breast cancer. However the value and the diagnostic performance depend closely on the performance of elements constituting the mammography chain.

The institution of procedures of quality control and assurance quality program, specific to the mammography, is considered as factor permitting to get the maximum diagnostic information with minimizing the dose delivered to the patient and the medical personal. The cost of the exam is also reduced. Several procedures of quality control, aiming to improve and to assure quality of the images, have been developed and adopted in several countries : USA, Canada, European Union etc...

In Morocco, the quality assurance in medical imaging is an activity no even regulated, and is therefore not adopted and performed by the different centres of medical imaging. Rare are practitioners who judge useful to adopt procedures of quality control for monitoring the performance of theirs facilities

The CNESTEN , national institute, is considered as the main promoter of the use of nuclear techniques in the different socio-economic sectors in Morocco. The Department of the Medical and Biological Applications of CNESTEN via the Medical Physics Unit has start work in order to institute a national mammography assurance quality program . With the collaboration of the National Federation of Radiologists (FNR) and the Moroccan Society of Radiology(SMR), the CNESTEN undertook the realisation, free of charge, of quality control of mammography facilities. The goal is to demonstrate the interest to adopt a quality assurance program for improving the quality of images and reducing the cost exams .

Technical procedures

The number of mammography facilities in Morocco is 80 distributed mainly between cities of Casablanca and Rabat. For reasons of logistical order we were not able to achieve the control of all facilities. Only 41 facilities had benefited of this program : Casablanca : 20, Rabat : 12 , Fez : 4 and Tangier: 5 facilities. A detailed information letter concerning the progress and the

objective of the program has been sent to responsible of all facilities before the realisation of installation check.
The achieved tests have been done according with the French protocol, elaborated by the interdisciplinary grouping of mammography (GIM)[1] and the European committee [2]. Several parameters are concerned [3] : Storage film local, Dark room, Processor film, Screens–films systems, Mammography unit and the viewing conditions, as well as a global evaluation of the image quality with MTM 100 French phantom breast in the usual clinical conditions exposition.
After control, the results have been analysed [4-5] and have been interpreted [6-7] in accordance with French Standard Qualix Association [8]. A final report regrouping the results, noted irregularities as well as recommendations have been sent to the responsible of the installation concerned under confidential letter.

Statistics and conformities results

1) Storage film local and dark room

In the storage local, The visual inspection of films storage conditions revealed that : The storage was vertical in 22 facilities (53%) while it was horizontal in 6 facilities (15%). 13 facilities (32%) have not storage local . The temperature measured inside the local was in accordance with French standards (21°C). However the temperature inside the dark room was higher than the standards in 25 facilities (61%), while it was from 17°c to 21 °C in 18 facilities (39%).
For the darkroom fog check, a film was half covered in the room for two minutes and then processed. The difference of optical density between the two areas (covered and not covered) should be inferior to 0.20 OD according to the French standards. In 31 facilities (75%) the darkroom fog was correct. In 2 facilities (5%) the power lamp was superior to 25 KW . The others facilities (20%) were not equipped with lamp.

2) Processing film.

It is demonstrated that conditions of processing film have a big influence on the contrast and level of dose irradiation. The timing processing and developer temperature should be adjusted to obtain high quality mammography images. Only 4 facilities (9.7%) are equipped with the processing film machine dedicated only to the mammography exams.

2.1) Sensitometric film

The parameters measured are : base fog density and film's speed and contrast . The methodology consisted of sensitising a strip film by the sensitometer , running it through the processor, and measuring, by the densitometer the optical density in different steps.

✓ **Base fog density:** In 34 facilities (83%) the base fog density was lower than 0.2 OD while it was higher than 0.2 OD in the others facilities (17%).

✓ **Sensitivity screen-film** In almost facilities visited we noted that the reference conditions processor were not respected. In 15 facilities (37 %) the sensitivity film-screen was inside the range : from steps 10 to 11, and in 26 facilities (63%) the sensitivity was from steps 12 to 14.

✓ **Film Contrast :** this parameter is considered as the difference value of the optical densities between the interest and surrounded regions . In 24 facilities (58%), the contrast values was from 0.40 to 1. In 13 facilities (32%) , the contrast value was within 1.1 and 1.40 and in 4 facilities (10%) it was within 1.41 to 1.60.

2-2) The processing time

The processing time was measured by the chronometer. It's the time taking by the film from his entrance and exit through the processor. In 10 facilities (24%) the time processing was

from 75 to 90 s. In 20 facilities (49%) , it was from 100 to 120 s, in 8 facilities (20%) from 130 to 150 s and finally, it was from 160 to 180 s in 3 facilities (7 %).

2-3. cassettes - screen – film contact

In all facilities visited we noted only one contact screens- film problem .Two cassettes had a bad closing in 2 facilities but tracks of dust were present on the screens in 38 facilities.

3) Mammography units statement

The mammography unit mechanical state was controlled by checking the: rotator and translator movements, compression breast (force, thickness) , paddle, grid etc…

3.1 X-ray field congruence

According to the Qualix standards , we fixed the acceptability margin at ± 5 mm between the X-ray limit and the external board of the breast table . In 35 facilities (85%) the difference was within the margin fixed. In 6 facilities (15%) the difference was superior to ± 5 mm.

3.2 KVp accuracy and reproducibility

This test consist of checking out the accuracy and the reproducibility of KVp. We compared the KVp delivered by the X-ray generator and those measured by the KVp Divider. The range of KVp checked was from 25 to 30 KVp and the difference acceptability was fixed to ± 1.5 KVp. In 22 facilities(54%), the difference was ≤ 1.5 KVp wile it was ≥ 1.5 KVp in 9 facilities (22%). In 10 facilities (24%) equipped with the SIEMENS Mammomat B mammography unit, the test was not achieved because of the no compatibility of the KVp Divider's operative mode with the specified mammography unit.

3.3 Automatic Exposure Control AEC

To check out the AEC set-up and performance, we selected several cassettes which had very close speed. when it was not possible we used only one cassette. We realized several expositions, from 25 to 31 KVp, using a Plexiglas phantom of 4 cm thickness. The KVp were increased by step of one KVp. Then we varied progressively the thickness of the Plexiglas phantom : 2, 3, 4, 5 and 6 cm while keeping the same KVp .

The optical density was measured in all films .The optical density should be between 1.45 to 1.60 OD and the variation densities should be from 1.20 to 1.30. In 17 facilities (41%), the automatic exposure was efficient when in 20 facilities (49%) failures or problems in AEC density tracking or density calibration were noted. The test was not performed in 4 facilities because they are not equipped with an automatic exposure.

3.4 Image Quality Evaluation

For image quality evaluation, we used the MTM 100 French phantom breast. Its semicircular shape, 4 cm thickness, made with PMMA material and contained some inclusions like aspects of human equivalence (fibber, masses, microcalcifications). The phantom was positioned on the breast table with its longest edge centrally with the chest wall edge of the table. We exposed the phantom in the same conditions as used clinically for a standard sized breast . The film density in the reference zone should be inside the range of 1.30 to 1.6 OD. If The film density is outside the range we made an other exposure in order to have the density in the specified range : 1.3 to 1.6 OD.

A score number was calculated , it's relating to the visualisation (partially or totally) of inclusions. A total score which is the summary of score's number inclusions, was attributed for each facility. A minimum score of 24 points is required for accrediting the facility. In 14 facilities (34%) the score was lower than 24. In 16 facilities (34%) the score number was from 24 to 38 and in 11 facilities (27%) it was from 40 to 56.

Some artifacts were observed on the phantom image. This was attributed to the dust and the mod processing (roller, developer was mixed with the fixer, concentration of the developer, chemistry replenishment..) . In one facility we noted a grid artifact.

4) Viewing conditions

We tested the luminance of the monitors brightness using a photometer. Five measurements in the coins and in the middle for each monitor were performed. The luminance should be superior to 1700 Candela/m2. In 15 facilities (37%), the luminance was superior to the standard fixed. In 18 facilities (43%), the brightness was insufficient and in the others facilities (20%), the test was not performed because the photometer was not available at that time.

We point out that others tests like; the humidity, focal spot performance, breast exposure entrance and dose and beam quality (half-value layer) were also not performed because of the late purchase of the materiel.

Conclusion

This study which concerned 41 facilities of mammography permitted to reach a certain number of main objectives. Although the majority of mammography facilities are recent, some abnormalities degrading the quality of the images and therefore decreasing the diagnostic value of the exam were discovered. The detailed reports sent to practitioners convinced them of the necessity and the utility to institute a quality assurance program of their installation. Some radiologists follow our suggestions and recommendations and corrected the abnormalities noted. A final report including all results of this study will be presented to the Ministry of Health, Moroccan Federation of Radiologists and the Moroccan Society of Radiology, during special seminar dedicated to the quality assurance in mammography. To shortcoming this work, we hope to arrive with the authorised organism concerned to regulate the quality assurance in medical imagery.

Annex materiel: - Sensitometer X- Rite 334* Densitometer X –Rite 331X* Phantom breast (Plexiglas of 1cm thickness) * Contact test tool - Mammographic Screen –Film * Phantom breast – MTM100 Model * Photometer- LX- Digital Lux meter * KVp divider model 35080A– * Thermometer digital * Chronometer.

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DOSES TO PATIENTS AND STAFF FROM ENDOVASCULAR TREATMENT OF ABDOMINAL AORTIC ANEURYSMS – PRELIMINARY RESULTS

E. G. Bjørklund[1], A. Widmark[1], T. Gjølberg[2], D. Bay[2], J. J. Jørgensen[3] and L. E. Staxrud[3]
[1]Norwegian Radiation Protection Authority, [2]Department of radiology and [3]Oslo Vascular Centre, Aker Hospital, University of Oslo, Norway.
Correspondance: E. G. Bjørklund, [1]Norwegian Radiation Protection Authority, P.O. Box 55, N-1332 Østerås, Norway,
fax: +4767147407, e-mail: Eva.Bjorklund@nrpa.no

Abstract
Patient radiation doses received during endovascular treatment of abdominal aortic aneurysms (AAA) can be significant and give rise to both deterministic and stochastic effects. Recording of dose-area product (DAP), fluoroscopy time and number of exposures together with calculations of effective dose were performed for 8 patients. In addition, the entrance surface dose was measured for 3 of the patients. Typically, DAPs of 340 Gycm^2, fluoroscopy times of 30 minutes and 310 exposures were obtained together with maximum entrance surface doses of 1,8 Gy and effective doses of 50 mSv. Finger doses to the staff performing the procedure were in the order of a few hundred μSv. Conversion factors (effective dose/DAP) and (maximum entrance surface does/DAP) of 0,61·10^{-2} Gy/Gycm^2 and 0,15 mSv/Gycm^2, were obtained respectively.

1. Introduction

Endovascular treatment of abdominal aortic aneurysms (AAA) has been carried out since the early 90ies, but is still experimentally. The aim is to increase the survival rate and improve the quality of life for the patients. The procedure reduces the surgical stress and there is minimal need for intensive care. The patient is early mobilised and is discharged from hospital the third day postoperatively. About 30-50% of the patients fulfil the physiological and anatomical criteria necessary to be considered as candidates for this new, minimally invasive treatment modality.

This endovascular procedure may give rise to significant patient doses, due to potentially long fluoroscopy times, frequently use of different magnification modes together with a large number of exposures, and are therefore associated with both deterministic and stochastic risks. High skin doses may result in deterministic effects such as erythema, epilation, desquamation, tissue necrosis or ulceration [1, 2]. Such radiation induced skin injuries have already been reported in the literature following percutaneous transluminal coronary angioplasty (PTCA) [2-4]. The severity of these effects can be quantified by the entrance surface dose (ESD), which can be estimated using, for example, thermoluminescent dosimeters (TLDs) [5]. The stochastic risks of carcinogenesis and genetic effects are quantified by the effective dose (ED), which may be obtained by Monte Carlo simulations on phantoms [6].

The vascular surgeons and interventional radiologists performing the procedure may receive large occupational doses, for instance to their hands, since they are working close to the patient not only during fluoroscopy but also during the exposures.

Because of potential high patient doses associated with endovascular treatment of AAA, dose monitoring is of great importance. The most common way of dose monitoring is the dose-area product (DAP). In this procedure, DAP may be difficult to relate to the maximum entrance surface dose (MESD) and in some extent also to ED, because the irradiated skin area is varying during the procedure. Relationships between the easily measured DAP to both MESD and ED would therefore be of great help in estimating the risks of both deterministic and stochastic effects associated with this treatment.

In the present study, doses to the patients and staff associated with endovascular treatment of AAA were examined as well as conversion factors between DAP to both MESD and ED were carried out.

2. Material and methods

Eight patients (seven men, one woman) having a mean age of 66 years (range 56-79) were treated for AAA (mean 55 mm, range 51-60 mm) with bifurcated stent-grafts (AneuRx, Medtronics, Inc,

USA). In some of the cases, stent-graft extensions were used to seal a distal leakage or to secure the limbs near the origin of the internal iliac artery. All patients were included and evaluated according to the Eurostar Protocol[1].

All the stent-graft procedures were performed in a newly designed vascular and endovascular operating theatre having a special designed operating table (Koordinat O.R.) [7]. Beyond that, the theatre was fitted with all the facilities found in an ordinary angio-lab. The X-ray equipment used in this study was a Siemens Multistar Plus equipped with a ceiling mounted C-arm with a four-field (14/20/28/40 cm) image intensifier (Sirecon 40-4 HDR). The X-ray generator used was a Polydoros IS-A.

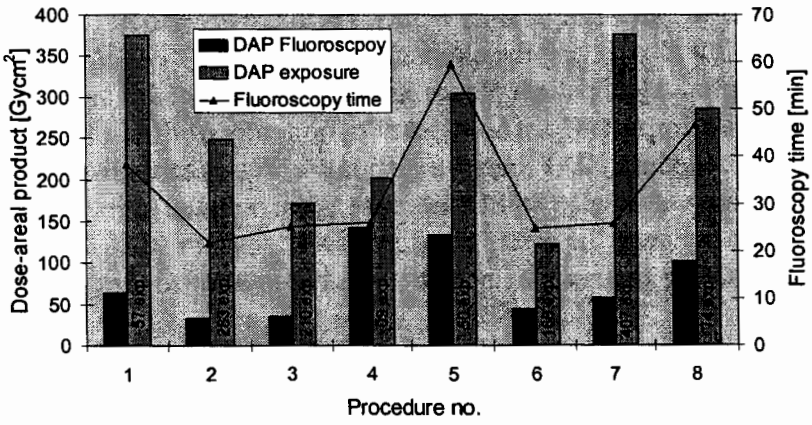
DAP was measured with a transmission ionisation chamber (DAP meter) (Diamentor, PTW, Freiburg, Germany) permanently attached to the collimator. For each patient the total DAP was separated into contributions from fluoroscopy and exposure. At present time, no information is available of the calibration procedure or the uncertainty in the DAP measurements.

TLDs (LiF:Mg,Ti, Harshaw TLD-100 chips) were used to measure ESD. The TLDs were calibrated free in air using the radiation quality ISO N-60 traceable to the measuring institute in Utrecht, the Netherlands[2] [8]. Background radiation was corrected for by means of 4 non-irradiated TLD controls. Overall uncertainty associated with TLD readings were estimated to be within ± 10%. Patient skin doses were obtained by placing 14 TLDs in the median plane at the patients back. The TLDs were placed with 2 cm spacing and centered at the level of crista. Finger doses to the staff performing the procedure were obtained by placing a sterilised TLD ring dosimeter on the middle phalanx of the middle finger bilaterally under the surgical gloves. All TLDs were read within one day after irradiation.

Rough estimates of the effective dose to the patients were obtained from the total DAP using the NRPB-R186 software [9]. This program uses an average adult patient of 70 kg mass and 174 cm height for its calculations. The abdominal PA projection with field size of 35 x 47 cm^2 were chosen for the effective dose calculations. The use of this projection will introduce an error to the estimated effective dose, since the field size usually used are smaller and the irradiated area of the skin varies during the procedure. The overall error is estimated to be within ± 25%.

3. Results

The endovascular procedure was completed for all patients and the second limb was attached without any problems. There was no 30-days mortality and no serious complications were observed. The use of one extension in patient 2, 5 and 8 and two extensions in the case of patient 1 and 7, matches the variations observed in DAPs, fluoroscopy times and number of exposures taken (Figure 1). Even though the fluoroscopy times were relatively long, typically 30 minutes, the exposures contributed mainly to the total DAP. A mean total DAP of 340 $Gycm^2$ and an average number of 310 exposures were obtained for these eight patients.



[1] Data registry center for stent-grafting in Europe. European Society for Vascular Surgery.

[2] TLD ring dosimeters used for measuring finger doses were calibrated free in air on a rod PMMA phantom, 1,9 cm in diameter.

Figure 1. The contributions from fluoroscopy and exposure to the total DAP together with the fluoroscopy time and the number of exposures taken during endovascular treatment of AAA. At the present time, total uncertainty in DAP measurements are unknown.

Skin dose distributions measured along the patients' back in the median plane are shown in Figure 2. Maximum skin doses in the range 1,3-2,3 Gy were obtained, matching the threshold dose for transient erythema for one of the patients. Maximum skin dose was generally localised somewhere between 6 cm cranialt and 10 cm caudalt from crista.

ED and MESD together with DAP to ED conversion factor (ED/DAP) and DAP to MESD conversion factor (MESD/DAP) for the procedure are given in Table I. Relatively high effective doses around 50 mSv were obtained. A mean ED/DAP conversion factor of 0,15 mSv/Gycm^2 and a mean MESD/DAP conversion factor of $0{,}61 \cdot 10^{-2}$ Gy/Gycm^2 were obtained for this procedure.

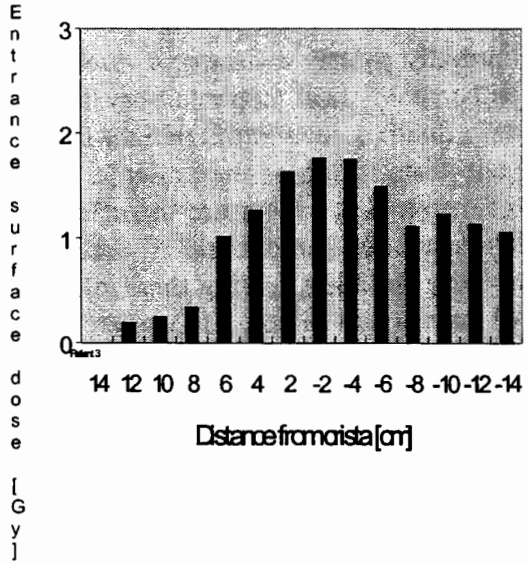


Figure 2. Skin dose distributions along the median plane of the patients back. Distances given in positive numbers and negative numbers are in the cranial and caudal direction from crista, respectively. The mean weight of the 3 patients was 83 kg, varying between 78-92 kg. Total uncertainty in the TLD readings was estimated to be within ± 10%.

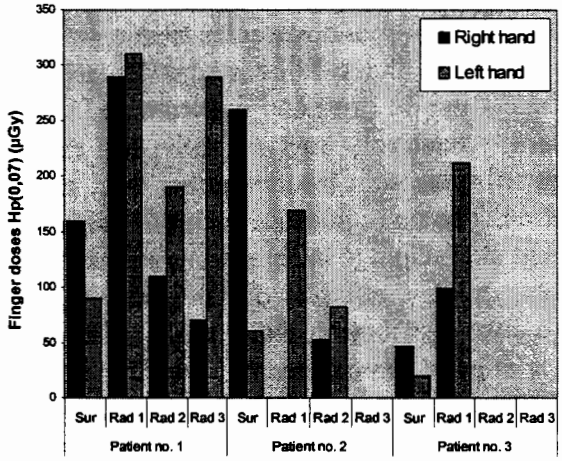


Figure 3. Finger doses received by the staff performing the endovascular treatment of AAA. Sur = surgeon, Rad = radiologist. Total uncertainty in the TLD readings is estimated to be within ± 10%.

Table I. Mean values of total DAP, maximum entrance surface dose (MESD) and effective dose (ED) together with DAP to maximum entrance surface dose conversion factor (MESD/DAP) and DAP to effective dose conversion factor (ED/DAP) for the endovascular treatment procedure of AAA. Range is given in brackets.

DAP [$Gycm^2$]	MESD [Gy]	ED [mSv]	MESD/DAP [$Gy/Gycm^2$]	ED/DAP [$mSv/Gycm^2$]
338 ± 32% (167-439)	1,79 ± 26% (1,35-2,27)	50 ± 34% (22-64)	$0,61 \cdot 10^{-2}$ ± 33% $(0,48\text{-}0,85) \cdot 10^{-2}$	0,15 ± 7% (0,13-0,17)

The finger doses to the surgeon and radiologists performing the endovascular procedure are shown in figure 3. The received finger doses, given a normal workload, were below the occupational dose limits of 500 mSv/year proposed by the ICRP [10], indicating a good working practice.

4. Discussion

Patients undergoing endovascular treatment of AAA are normally elderly and have as well, often, severe pulmonal and cardiovascular diseases. Total survival rate of these patients vary from 63-74%, depending on different publications [11]. Although the effective dose to the patient from this procedure is relatively high, 50 mSv, life expectancy and age distribution of the patients, indicate that deterministic skin injuries rather than stochastic risk of developing cancer are the effect to be considered. The main purpose with this study was therefore to establish a maximum advisable DAP to prevent skin damage such as transient erythema and temporary epilation, having threshold values of 2 Gy and 3 Gy, respectively. In obtaining a MESD/DAP conversion factor, TLDs were used to map the dose distribution along the patients back (Figure 2). To avoid missing the maximum skin dose it is of great importance to use many TLDs, especially in this procedure where magnification is used in combination with a moving primary beam irradiating different skin areas. Such use may result in an overlapping of exposed skin areas, which again can give high doses to small separated skin areas. By using the MESD/DAP conversion factor of $0,61 \cdot 10^{-2}$ $Gy/Gycm^2$ (Table I), maximum advisable DAPs to avoid transient erythema and temporary epilation of 330 $Gycm^2$ and 490 $Gycm^2$ were obtained, respectively. By having a DAP meter available during the procedure, the operator can prevent skin injuries by not letting the total DAP exceed the limits for skin injuries. If additional exposure is required to finish the procedure, the operator may avoid the appearance of skin damage by changing the projection in such a way that the irradiation is spread over different skin areas. Of the eight patients studied in this work, five of them exceeded the DAP limit for transient erythema. Unfortunately, no follow-ups of these patients were performed to determine if transient erythema really did occur. No complications were associated with these eight procedures, but potentially much higher skin doses are believed to occur if complications had appeared. Therefore, the monitored DAP should always be registered in the patients case records and used in evaluating the need of individual patient follow-ups with respect to skin injuries.

Patients selected for endovascular treatment of AAA will receive additional doses from preoperative evaluations and frequently postoperative follow-up controls. CT-scan and angiography are performed preoperatively. At the ambulatory evaluation, CT-scan and plain X-ray of the stent-graft are performed 1, 3, 6 and 12 months postoperatively and each six months thereafter. In addition, 12 months postoperatively one angiography is performed. The total accumulated skin dose related to endovascular treatment of AAA, although not given as a single exposure, may have the potential for increasing the risk of developing skin injuries. The Norwegian Radiation Protection Authority has, in collaboration with Aker Hospital, University of Oslo, initiated a work where the total accumulated doses to the patiens undergoing this treatment are collected. The work will also include a close follow-up study of patients received doses above 3 Gy, with respect to induced skin injuries.

No dose measurements from endovascular treatment of AAA could be found in the literature, for comparison. It is believed that the variation in DAP values and skin doses are

significant from hospital to hospital, since the results are depending on the practice of the persons whom performing the procedure and also of the weight of the treated patients. At this time, only limited data exists and more data should be collected before reference values and conclusions are drawn.

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DRUG INTERACTION WITH RADIOPHARMACEUTICALS AND THE IMPORTANCE FOR THE RADIATION DOSE TO THE PATIENT.

Deise Mara M Mattos[1], Maria Luisa Gomes[1], Rosimeire S. Freitas[1] and Mario Bernardo-Filho[1,2*].

1- Universidade do Estado do Rio de Janeiro, Instituto de Biologia Roberto Alcantara Gomes, Departamento de Biofísica e Biometria, Av. 28 de setembro, 87, Rio de Janeiro, RJ, Brasil, 20551-030.

2- Ministério da Saúde, Instituto Nacional do Câncer, Centro de Pesquisa Básica – Rio de Janeiro-RJ.(E. mail: bernardo@ uerj.br)

ABSTRACT

A central aspect of the profession of health physics is to establish practical scientifically based radiation protection standards with the worthy aim of minimizing the detriment while at the same time enhancing the benefits derived from sources of ionizing radiation. The biodistribution or pharmacokinetics of radiopharmaceuticals may be altered by drugs and it can lead to misdiagnosis or the necessity to repeat the examination, increasing the dose to the patient. Vincristine (0.03mg/ml) was administered into female mice. One hour after the last dose, ^{99m}Tc-GHA (7.4 MBq) was administered and the animals (n=15) were sacrificed. The organs were isolated and the percentages of radioactivity (%ATI/g) in the organs were calculated. We calculated the Drug Interaction Factor (DIF) and the Effect Mass Factor (EMF). The results were statiscally significant (Wilcoxon test, $p<0.05$) and have shown that the DIF to ^{99m}Tc-GHA was to thymus 1.70, to pancreas 1.68, to uterus 0.42, to spleen 0.78, to lymph node inguinal 0.55, to kidney 0.45, to heart 0.59. The EMF was to ovary 0.28, to uterus 0.64, to thymus 0.17, to spleen 0.45, to lymph node inguinal 0.24, to kidney 0.80, to liver 0.77, to pancreas 0.61. The effects could be explained by the metabolization and/or therapeutic action of these drug.

INTRODUCTION

The earliest considerations of radiation effects and protection were built on the principles that a certain specific level of radiation can be incurred by various tissues without apparent ill effect. This in turn logically led to concept of a tolerance dose. More completely and precisely, the tolerance dose was considered to be that level of radiation to which an individual could be continuously exposed without demonstrable ill effect [1].

Hence, drug-radiopharmaceutical interaction will be defined as altered biologic behavior due to tissue response of administered drug. When the modified biologic behavior is desired, the alteration is used for diagnostic intervention or drug therapy monitoring; when it is undesired; it may be due to toxicity or direct interaction. If unknown, the drug interaction with radiopharmaceuticals can lead to misdiagnosis or the necessity to repeat the examination, increasing the dose to the patient [2, 3, 4].

More than 80% of all imaging studies (mostly anatomic) currently use technetium-99m (^{99m}Tc), because it has turned out to be the ideal isotope from various considerations[2, 3, 5, 6]. The biological activities of vincristine can be explained by its ability to bind specifically to tubulin and to block the capability of the protein to polymerize into microtubules [7]. The radiopharmaceutical 99mTc-GHA (glucoheptonic acid) is used to renal study [8].

In this paper we are evaluated the effect of vincristine on the biodistribution of the radiopharmaceutical 99mTc-GHA.

MATERIAL AND METHODS

Vincristine (Oncovin, Eli Lilly, Brazil LTDA) (0.03 mg, 0.3ml) was administered by ocular plexus via into female isogenic Balb/c mice (n=15), in three doses with a total interval of 96 hours. After 96 hours, the animals were sacrificed, the various organs pancreas, lymph nodes (inguinal and mesentheric), thyroid, brain, thymus, ovary, uterus, spleen, kidney, heart, stomach, lung, liver and bone were isolated and their mass determined in an analytical balance. The mass of the organs of

these animals were compared with the control group, without vincristine. The statistical analysis of the results were performed with Wilcoxon test, $p< 0.05$. To study the vincristine effect in the biodistribution of the radiopharmaceutical, one hour after the last dose, 0.3 ml of ^{99m}Tc-GHA (7.4 MBq) was injected by the same via. In the control group (n=15), vincristine was not administered. To prepare the GHA, ^{99m}Tc, as sodium pertechnetate, recently milked from a ^{99}Mo/^{99m}Tc generator (Instituto de Pesquisas Energéticas e Nucleares, Brazil) was added to a kit of DMSA (Laboratório de Radiofarmácia, INCa, Brazil). The radiochemical control was performed by ascendent chromatography, using paper Whatman n° 1 and 0.9% NaCl solution and acetone as mobile phases. The labeling efficiency was > 95% and the percentage of free pertechnetate was < 5%. After 0.5 hour the animals were rapidly sacrificed. The various organs were isolated pancreas, thyroid, brain, thymus, ovary, uterus, spleen, kidney, heart, stomach, lung, liver, bone and lymph nodes (inguinal and mesentheric) and the radioactivity of the ^{99m}Tc-DMSA and ^{99m}Tc-GHA were counted in a well counter NaI(Tl) (Automatic Gamma Counter, 1272 Clinigamma, LKB, Wallac, Finland). The percentages of radioactivity per gram of tissue (% ATI/g) in the organs were calculated dividing the total activity in each organ by the mass of each organ. The percentage of radioactivity in each organ was compared with the control group. Statistical analysis were performed by Wilcoxon test ($p<0.05$). After that, we have calculated the a Drug Interaction Factor (DIF), dividing the %ATI/g in the organs of the treated animals by the %ATI/g in the organs of the control animals and the and the Effect Mass Factor (EMF), dividing the mass of the organs of the treated animals by the mass of the organs of the control animals.

RESULTS

Table 1 shows the relationship between the mass of the isolated organs of the group of mice that was treated with vincristine and the control group (no treated) and the values of the EMF. The analysis of the results in table 1 shows no significant alteration of the mass of lung, stomach, heart, bone, thyroid and brain and reveals significant ($p<0.05$) decreasing of the mass of spleen, thymus, kidneys, liver, ovary, pancreas, lymph nodes (inguinal and mesentheric) and uterus.

Table 1 - Effect of vincristine on the mass of different organs from female mice

	mass (g)		EMF
Tissue	control	treated	
Lung	0.1446 ± 0.0131	0.1482 ± 0.0167	1.02
Stomach	0.1187 ± 0.0131	0.1223 ± 0.0101	1.03
Heart	0.0858 ± 0.0093	0.0855 ± 0.0119	0.99
Thyroid	0.0135 ± 0.0035	0.0121 ± 0.0035	0.89
Bone	0.0387 ± 0.0082	0.0421 ± 0.0065	1.08
Brain	0.3831± 0.0293	0.3799 ± 0.0162	0.99
Spleen	0.0662 ± 0.0088	0.0300 ± 0.0059	0.45
Thymus	0.0280 ± 0.0055	0.0050 ± 0.0014	0.17
Kidneys	0.1207 ± 0.0122	0.0974 ± 0.0116	0.80
Liver	0.9734 ± 0.0597	0.7545 ± 0.0933	0.77
Ovary	0.0330 ± 0.0087	0.0095 ± 0.0027	0.28
Pancreas	0.0152 ± 0.0022	0.0094 ± 0.0019	0.61
Uterus	0.0453 ± 0.0097	0.0292 ± 0.0069	0.64
Lymph node inguinal	0.0328 ± 0.0062	0.0081 ± 0.0020	0.24
Lymph node mesentheric	0.0312 ± 0.0077	0.0079 ± 0.0023	0.25

Vincristine was administered into female mice Balb/c (n=15). The animals were sacrificed, the organs isolated and their mass determined. The results were compared with the control group, without vincristine, and statistical analysis were performed (Wilcoxon test, $p< 0.05$). EMF is the effect mass factor.

Table 2 shows the uptake (%ATI/g) of ^{99m}Tc-GHA in the group of the mice that was treated with vincristine and in the control group. The analysis of the results reveals an increase of the uptake in thymus and pancreas, and decreased the uptake in uterus, spleen, lymph nodes (inguinal and mesentheric), kidney and heart. The analysis of the results reveals no significant reduction of the uptake in lung, liver, ovary, stomach, thyroid, brain and bone and shows results of the DIF.

Table 2 - Effect of vincristine on the biodistribution of ^{99m}Tc-GHA in mice.

Organs	%ATI/g Control	Treated	DIF
Uterus	2.0455 ± 0.1065	0.8692 ± 0.1387	0.42
Ovary	0.9120 ± 0.0802	1.1052 ± 0.1456	1.21
Spleen	0.9999 ± 0.1749	0.7838 ± 0.0815	0.78
Thymus	1.3154 ± 0.3192	2.2366 ± 0.3924	1.70
Lymph node inguinal	6.2145 ± 0.3363	3.4240 ± 0.7052	0.55
Lymph node mesentheric	2.6655 ± 0.1809	1.3971 ± 0.0799	0.52
Kidney	28.4313 ± 2.5731	12.9191 ± 2.6499	0.45
Lung	2.5168 ± 0.0976	2.3914 ± 0.1338	0.95
Liver	0.5023 ± 0.0376	0.6280 ± 0.0712	1.25
Pancreas	1.1370 ± 0.1535	1.9138 ± 0.3079	1.68
Heart	1.2822 ± 0.0827	0.7666 ± 0.1609	0.59
Thyroid	3.8910 ± 0.7460	4.0743 ± 0.7240	1.04
Brain	0.1261 ± 0.0347	0.1169 ± 0.0101	0.92
Bone	0.8991 ± 0.0860	0.8079 ± 0.0689	0.89
Stomach	3.6938 ± 0.4021	3.5615 ± 0.4080	0.96

Vincristine was administered into mice and after 96h ^{99m}Tc-GHA was injected. The animals, the were sacrificed organs isolated and the activities (%ATI/g) determined. The values are averages (n=15), Wilcoxon test, $p<0.05$. DIF is the drug interaction factor.

DISCUSSION

There is considerable evidence that the pharmacokinetics of radiopharmaceuticals may be altered by a variety of drugs, disease states and surgical procedures. If unknown, such factor may lead to poor organ visualization, a requirement to repeat the procedure resulting in unnecessary irradiation of organs of even misdiagnosis [2, 3, 5, 6]. The capability of determined protocols with vincristine to induce long term toxicities, as infertility in males of all ages [7, 9, 10], could also associated with the effect in uterus in our studies to the radiopharmaceutical. As vincristine is a immunosupressive drug [7], this effect could explain the alteration of the mass of the thymus, spleen and lymph nodes (inguinal and mesentheric), and could explain the alterations in these organs to %ATI/g of the ^{99m}Tc-GHA. This drug can produce hyponatraemia with abnormal water retention due to the non-osmotic rellease of anti-diuretic hormone [7]. This could explain the alterations in uptake in the kidney to the ^{99m}Tc-GHA. Mattos 1999, related the alteration in uptake of ^{99m}Tc-MDP in this organ.

In conclusion, in general, the results could be explained by a direct toxic effect in specific organs, the metabolization and/or therapeutic and immunosupressive action of vincristine. As vincristine is capable to alter, in mice, the mass of many organs, studies are now in progress to evaluate the anatomical characteristics of organs of patients that will be submitted to a protocol with vincristine. Moreover, the fact of the drug interaction can alter the uptake of the radiopharmaceutical in a specific target (organ), unexpected radiation dose in non-target organs is undesired. This is more relevant when this unexpected uptake is in a reproductive organ. Then, we suggest to consider, with special attention, the phenomenon of the drug interaction with the radiopoharmaceutical in the calculation of the radiation dose in organs.

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